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地上に出た「もぐら」

The "Moles" Come to the Surface

社　長　秦　孝之
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タブレット型携帯端末，と書きながら，なんと判りづらい表現だろう，iPad（※1）という一言だけで聞いた人の頭の中にその商品のイメージが瞬時に浮かぶのに，と思う．勿論，アップルが先鞭をつけたこの商品は，その後多くの競合が参入し，すでにiPadは単なる一商品にすぎないのだが，他社の製品の名前が頭に浮かぶ前に，つい「○○社のiPad」と口にしてしまう程，その知名度は圧倒的である．そう，かつてソニーのウォークマン（※2）がそうであったように．

なんとグローバルな商品であろうか．言語とか，国境を軽々と越え，手に取った瞬間に誰でも操作を始めることができる．一見，無愛想なほどシンプルな外観で，色や模様といったデザインや操作に必要な情報をスクリーンに映るソフトにきっぱりと委ねている．多分，スペックや，使い込んだときの利便性だとか，細かい部分は後から参入した商品によりよいものがある筈だが，その実，多くのユーザーはこの割り切りを支持している．

さて，ジヤトコの作るオートマチックトランスミッション（2ペダルトランスミッション）であるが，公平な一ユーザーの立場で考えてみよう．

While writing "portable tablet terminal," I thought what a hard expression it is to understand. Someone who hears the simple expression iPad(1) can instantly form a mental image of the product. After Apple pioneered this product, the subsequent entry of many competitors into the market has naturally made the iPad just one of many similar products now available. But the iPad has such overwhelming public recognition that one unintentionally says company X's iPad before the name of that maker's product comes to mind. The same was once true of Sony's Walkman.(2)

What an incredibly global product the iPad is. It readily transcends languages and national borders, and anyone who obtains an iPad can begin operating it instantly. At a glance, its simple appearance is almost unfriendly-looking in color and pattern design. All the information needed to operate the device is entrusted entirely to the screen displays. Some of the rival products subsequently put on the market may perhaps be better in terms of specifications, the convenience that comes with mastery of the device or other small details. But the fact is that many users have supported Apple's product development stance regarding the iPad.

Turning now to the automatic transmissions (ATs)

ジヤトコの製品にも真のグローバルな訴求力がある．快適を商品という形にして，燃費性能で地球環境に貢献している．一度2ペダルトランスミッションの車に乗りなれた人は，もう二度とマニュアル･トランスミッションには戻らない．新興国で初めて車を買う人，スクーターから4輪に乗り換える人は，そもそもそれが差別化商品であるという意識さえない．車ははじめから2ペダルトランスミッションなのだ．魅力のある商品に説明は不要である点で，iPadとの共通性がある．

自動車産業の歴史の中で，車体設計やエンジンといった目立つ派手な分野と比較して，トランスミッションは長い間自動車部品の中でも地味な存在だった．担当の技術者は自らを「もぐら」，すなわち，目立たずに地中に潜んで静かにしているもの，と己の仕事に大きな誇りを持ちながらも，若干の揶揄と卑下を交えて例えていた．しかし，時代の要請はその価値を変えている．今世紀に入って，原油の高騰に端を発した燃費競争と環境問題が，2ペダル･トランスミッションを自動車の差別化の主役に押し上げている．

燃費効率の向上の余地が徐々に限界に近づきつつある内燃機関に比べて，2ペダル･トランスミッションの性能向上は，まだまだ進歩の余地がある．ステップATからCVTへの移行は，まだその端緒にすぎない．次世代の2ペダル･トランスミッションは何かが，車の形と商品性を決定する．そして，その形を決めていくのは，世界でも類のないトランスミッション専業メーカーのジヤトコである．ついに「もぐら」は地下から地上に出たのである．

さらに昨今，2ペダル･トランスミッションの方式や，どこの製品か，が最終ユーザーの自動車購入の決定の要因の一つになってきた．それが，燃費だけでなく，出足や，加速性といった車の性能と魅力を演出する主役であることが広く認知されるにつれ，ジヤトコの立場にも変化が出てきた．ジヤトコ製のCVTは日本だけでなく，例えば自動車の最大の市場である中国においても確立したブランドとなってきた．これからのジヤトコには，自動車のブランドと同じように最終ユーザーに直接訴求するブランド力が求められる．表に出る，主役となることは，それだけにより多くの

that JATCO makes, let us consider our two-pedal transmissions from the perspective of impartial users.

JATCO products also have true global appeal. As products that provide driving comfort, they also contribute to the global environment in terms of fuel economy. Once people become accustomed to a two-pedal transmission vehicle, they never go back to a manual transmission. First-time car buyers in emerging economies or people who switch from scooters to four-wheel vehicles are not even initially aware that two-pedal transmissions are products that differentiate vehicles. From the outset, they think that vehicles come with a two-pedal transmission. The fact that it is not necessary to explain the attractiveness of two-pedal transmissions is an attribute they share with the iPad.

In the history of the automotive industry, the transmission has long been an auto part with a modest existence compared with its conspicuous, flashy counterparts like the body design or engine. The engineers responsible for transmissions have likened themselves to moles that live quietly underground in obscurity. Though transmission engineers are justly proud of their work, this metaphor also has a tinge of mockery and humility. However, the demands of the times today have changed the value of transmission engineers. Since the advent of this century, two-pedal transmissions have been pushed into the role of differentiating vehicles with respect to environmental issues and fuel economy competition triggered by soaring crude oil prices.

Two-pedal transmissions still have room for much further improvement in performance compared with internal combustion engines that are steadily approaching the limit of their capacity for additional improvement of fuel economy. The transition from stepped ATs to continuously variable transmissions (CVTs) has only just begun. How the next generation of two-pedal transmissions evolves will determine the form and marketability of future vehicles. And JATCO, with its unparalleled global presence as a specialist transmission manufacturer, will be a key player in determining that future form. In short, the "moles" have come out of the ground to the surface at last.

より厳しい目にさらされることであり，ジヤトコに働く我々は誇らしく思いながらも，その心構えがあらためて問われている．注目には責任を伴うものである．

我々はモノづくりを通して世界を変えている．今，目の前にないものが忽然と姿を現す．そして，ユーザーはそれを使い始めるとその便利さ，快適さゆえにそれ以前の状況を瞬時にして忘れる．それがあることが当たり前の世界に，人はすぐに慣れる．我々が長い時間をかけて，多くの苦労をしながら生み出したものが市場に受け入れられたとき，その定着はあっけないほど速い．次の時代の2ペダル･トランスミッションを世に出すことは，次の時代の車の形を決めることであり，それは，車をめぐる市場と，それにかかわる人々の生活を形作ることと同義である．我々の手の中にある未来を，一日も早く形にして，その到来を告げる，それがジヤトコの社会的責務であり，我々ひとりひとりの取り組みで必ず実現できるものと確信している．

※1“iPad”は米国および他国のApple Inc.の登録商標です．
※2“ウォークマン”はソニー株式会社の登録商標です．

In recent years, the type and brand of two-pedal transmission have become decisive factors in end users' decision of which vehicle to purchase. It has become widely recognized that the transmission plays a principal role in bringing out a vehicle's performance and attractiveness in terms of launch smoothness and acceleration, not to mention fuel economy. As this recognition has spread, it has also changed JATCO's position. Today, JATCO's CVTs are an established brand not only in Japan, but also, for example, in China, which is now the world's largest automobile market. In the coming years, JATCO must have the brand strength to appeal directly to end users in the same way that vehicle brands do. Coming to the forefront and playing a leading role means that our products will be exposed to the more critical eye of many more consumers. While we who work at JATCO feel rightly proud of our products, we must once again question whether we are mentally prepared for this role. With public attention comes responsibility.

We are changing the world through our monozukuri activities. Things that do not presently exist suddenly take shape before our eyes. When people begin to use a new product, its convenience and comfort make them instantly forget the previous situation. And people soon become accustomed to a world in which such things are taken for granted. Once the marketplace accepts a product that we have created through much struggle over a long period of time, it can take root unexpectedly quickly. Our efforts to bring out the next generation of two-pedal transmissions will determine the form that vehicles take in the future. That is synonymous with giving form to the vehicle marketplace of the future and to the lives of the people involved. As quickly as possible we must give concrete form to the future we hold in our hands and announce its coming. That is JATCO's responsibility to society. And I firmly believe that we will definitely accomplish this mission through the concerted efforts made by each one of us.

(1) Ipad is a registered trademark of Apple Inc. in the United States and other countries.
(2) Walkman is a registered trademark of Sony Corporation.

Jatco CVT7とモノづくり

The Jatco CVT7 and Monozukuri

副社長 本田 聖二
Exective Vice President Seiji HONDA

テクニカルレビューNo.11の特集テーマは「Jatco CVT7」です．この商品はジヤトコのCVTラインナップの中でも，現在及び中期的視点においても大変重要な位置付けを果たす商品であるとともに，顧客であるカーメーカーからも，その性能，エネルギー効率（燃費）面で高い評価をいただいています．このことは即ち最終消費者のお客様からも高い評価をいただいているということに他ならないであろうと考えます．

この素晴らしい商品を世に提供し，貢献できていることに大きな喜びと誇りを感じます．そしてこれからもジヤトコがグローバルに成長を続けていくために，「Jatco CVT7」に代表される魅力的な商品，即ち，「実はこういう商品が欲しかったのだ!」と感じていただけるような商品を世界のマーケット自身の“気づき”に先んじる形で提供し続けることが求められています．マーケティングに裏付けられた商品開発と世界各所での生産を実現するための弛まぬ努力を実践することがジヤトコにはこれまで以上に求められることでしょう．

また，世界各国々の情況は時々刻々と変化を続けています．特に新興国においてはその変化のスピードは想像を超えるものがあります．テレビ等の報道映像からのみ判断して，新興国においてはエネルギー

JATCO Technical Review No. 11 presents a special feature focusing on the Jatco CVT7. This product occupies a crucial position in JATCO's current product lineup and will continue to do so over the medium term. What is more, it has received high acclaim from our automaker customers for its performance and energy efficiency (vehicle fuel economy). This undoubtedly signifies that the Jatco CVT7 is also being highly praised by vehicle owners who are the end consumers.

At JATCO, we are immensely pleased and proud to be able to supply and contribute this remarkable product to the global marketplace. To support JATCO's further global growth in the years ahead, we must continue to provide attractive products like the Jatco CVT7. This means continuing to anticipate and provide products before consumers in the global marketplace realize that is what they want, so that car buyers will say: "actually, this is exactly the product I wanted." We will need to exert more persistent efforts than ever before if JATCO is to accomplish product development backed by solid marketing and carry out production operations at various locations around the globe.

Today, circumstances in countries worldwide are constantly changing. The speed of change in

変換効率が低くてもよいのではないか，環境への配慮が低い生産の仕方や，旧型の環境対応施設を採用してもよいのではないか，といった発想からスタートして商品の投入や生産工場を建設した場合，近い将来においてさえ良い結果に結びつかないと考えるべきでしょう．

中国はいまや世界第一位の自動車生産及び消費国に成長しました．ほんの10年前は生産台数140万台そしてその中でのAT比率は6%しかありませんでしたが，2010年には1,470万台，32%にまで一気に成長と顧客志向の変化が成されました．（出典:IHS Automotive 2011 Q2）一方で，石油資源の消費量は世界の10.6%，それに伴う二酸化炭素排出量も世界の25%を占めるに至っております．ガソリン価格も約7元/Lと決して安価とは言えません．（出典: Statistical Review of World Energy 2011）これらのことから，今後も成長を続けながらより一層エネルギーや資源を大切にするという考え方や法規制に移行していくことが予想されます．その変化は先進国が歩んできたスピードより遥かに上をいくものとなるでしょう．同様の成長と変化が今後，ブラジルやロシア，インド，インドネシアなどの新興国あるいはアフリカ諸国においても，保有する石油資源によって左右されることはあるでしょうが，今後数年から10年の間に顕著に遂げられていくのではないかと予想されます．

ジヤトコは2018年に売上高1兆円を目指すことを掲げました．私たちにとって，世界のお客様が必要とするCVT，ATを開発，提供することが使命であり，そのことにより先進国のみならず新興国の成長（運転安全性の向上，生活の快適さなど）と環境（省資源，温暖化防止など）の両立の実現を確実にサポートすることができます．ジヤトコの存在する意義，世界からの期待はおそらく私たちの気づかないほど遥かに大きなものがあります．グローバルにおけるジヤトコのCVTシェアは2010年度で48%に達しました．世界を代表するCVT，ATのTop Transmission Companyと言っても過言ではありません．そして将来に向けてもジヤトコは想像を越える大きな可能性を秘めています．世界中のお客さまが求めるTransmission，安価で丈夫（堅牢），スムーズな変速，しかも高い燃費性能と爽快な運転性能のTransmissionを提供し

emerging economies in particular is beyond imagination. If we make judgments based solely on TV news and media images, we might think that low levels of energy conversion efficiency are acceptable in emerging economies or that it is all right to install facilities with old-style environmental measures or to adopt production methods that are not sufficiently eco-friendly. If such ideas become the starting point for the introduction of products or the construction of assembly plants, we ought to realize that they will not lead to good results even in the near future.

China has now grown to become the world's largest producer and consumer of vehicles. Just ten years ago China's annual production volume was 1.4 million vehicles of which only 6% were equipped with an automatic transmission (AT). By 2010, the production volume had increased virtually overnight to 14.7 million units of which 32% were fitted with an AT, and the market had become focused on customer preferences (source: IHS Automotive, Q2 2011). Meanwhile, China has come to account for 10.6% of the world's consumption of petroleum resources and 25% of the world's carbon dioxide emissions. The price of gas in China is about 7 yuan/liter, which is certainly not cheap (source: Statistical Review of World Energy 2011). While China continues to show strong growth in the future, it can be expected that there will be a shift to a regulatory framework and concepts that place increasing importance on efficient use of energy and resources. That change will presumably take place at a much faster pace than what has occurred so far in the developed countries. It is projected that similar profound growth and change might be achieved in the next few years or coming decade in Brazil, Russia, India, Indonesia and other emerging economies, as well as in some African countries, though the scope will be influenced by the amount of oil resources they possess.

JATCO has set a target of attaining net sales of one trillion yen by 2018. It is our mission at JATCO to develop and supply the CVTs and ATs that our global customers require. In this way, we can reliably support the attainment of both growth (including improved driving safety, daily living comfort, etc.) and environmental quality (including saving resources, combating global warming, etc.) not only in the developed countries but also in emerging

続けることが，Top Companyとしての使命なのです．

「Jatco CVT7」の成功を一つの大きな礎として，ジヤトコに働くすべての社員，パートナーであるサプライヤー，ステークホルダーの皆さんの力を合わせて，更に大きな成長を遂げていこうではありませんか．私たちの挑戦に終わりはありません．

economies. In this regard, the significance of JATCO's existence and the world's expectations of us are probably much greater than what we realize. JATCO's share of the global CVT market in 2010 reached 48%. It is certainly no exaggeration to say that JATCO is one of the world's top transmission companies in terms of CVTs and ATs. JATCO also has an enormous future potential that exceeds our imagination. As a top company in this field, it is our mission to continue to supply our global customers with transmissions that are inexpensive, robust, smooth shifting and ones that also deliver outstanding fuel economy and driving comfort.

Building on the Jatco CVT7 as one of our notable successes, let us all–JATCO employees, supplier company partners and stakeholders–combine our strengths in working together to achieve continued substantial growth in the years ahead. There is no end to our challenge.

CVTの拡大を目指して

Background Behind Expanding Market for Eco-friendly CVTs

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抄　録　本稿では，新興国をはじめとしたグローバル市場での，自動車販売台数の拡大及び自動変速機の搭載率について紹介する．また，環境規制の強化及び省燃費への対応と市場の求める安価な自動変速機を提供出来る弊社の優位性について述べる．

Summary　This article describes the expansion of vehicle sales and the increasing share of AT-equipped vehicles in global markets, especially in emerging economies. It also discusses JATCO's advantageous position for providing ATs complying with tighter environmental regulations and fuel economy standards and meeting market demands for low cost.

1. はじめに

地球環境改善の為のCO_2削減に向けた継続的な活動を背景に，ユーザーの省燃費志向は益々強まっている．また，新興国でも自動車販売が伸びているが，所得水準から見た燃料単価が先進国に比べて相対的に高いということもあり，省燃費に対する関心はよりいっそう高い．

このような背景から，重要な低燃費技術の一つとして，CVTは世界的に認知され，その搭載比率を着実に向上してきている．世界市場での，CVT事業の更なる拡大の可能性について述べる．

2. 自動車市場の拡大

2020年に向けて，自動車市場は，グローバルに拡大していくと予測されている．Fig. 1は，世界市場における地域占有率と2010年と2017年の市場規模の変化率を示したものである．現状は，中国，米国，欧州，日本などの市場占有率が高いが，今後は新興地域であるBRICs（ブラジル一含む南米諸国，ロシア，インド，中国）を考慮しないわけにはいかない状況であることがわかる．2010年の中国の自動車販売台数は1,850.51万台と米国の1,277.63万台を抜き，2年連続の世界第1位となっており，今後も成長を維持すると考えられている．

1. Introduction

Users are expressing an increasingly stronger preference for fuel-saving products against a backdrop of continuous efforts to reduce CO_2 emissions for the sake of improving the global environment. Moreover, vehicle sales are also continually increasing in emerging economies and customers in those markets are much more concerned about lower fuel consumption than they were before. One reason is that the price of fuel in relation to their income levels is relatively high compared with the situation in developed countries.

Against this backdrop, CVTs are recognized globally as a key technology for improving fuel economy, and their installation rate is steadily rising. This article discusses the possibilities for further expanding our CVT business in global markets in the coming years.

2. Expansion of the Global Vehicle Market

It is forecast that the global vehicle market will continue to expand toward the year 2020. Figure 1 shows the share of the global vehicle market for various geographical regions and the projected rate of change in their respective market size between 2010 and 2017. Currently, China, the U.S., Europe and Japan account for the largest shares of the global market. However, it is also clear that consideration

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Fig. 2に2017年までの地域別台数の推移予測を示したが，全世界で1億台に近づくと予測されており，2010年比で見ても約1.5倍に拡大することになる．この中心が，新興国市場の拡大である．

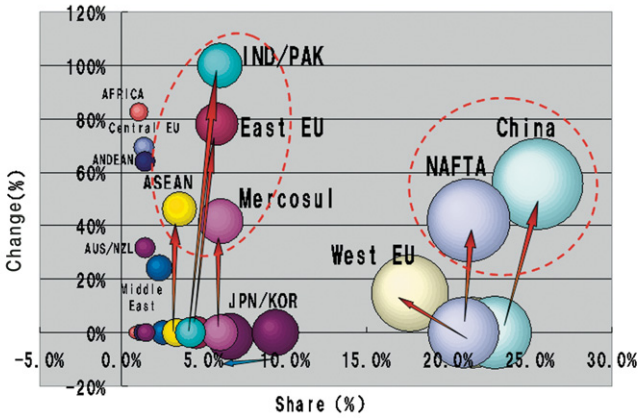

Fig. 1 Regional shares of global vehicle market and rate of change in market size from 2010 to 2017
(Source: IHS Automotive)

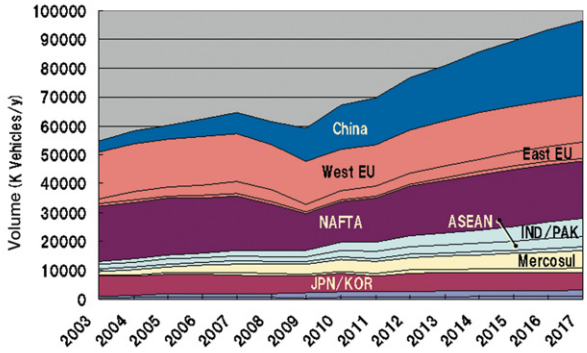

Fig. 2 Actual and projected trends in vehicle sales in various markets
(Source: IHS Automotive)

3. CO_2規制の推移

地球環境改善のため，各国ではCO_2削減に向けた取り組みが進められている．Fig. 3は，2020年までの国別CO_2削減規制を示したものである．

欧州はCO_2削減に最も積極的であり，2020年には100g/kmを切る目標を設定している．中国でも，欧州に近いレベルを目指しており，CO_2削減が2020年に向けて，積極的な技術開発が進められていると考えられる．

このような状況は，自動車各社がCO_2削減に向けての技術開発競争を繰り広げていることからも推定できる．例えば，日本市場では，ハイブリット車が急拡大していることや，電気自動車の出現などがあげられる．

must be given to emerging economies in the future, notably the so-called BRICs (Brazil (and other South American countries), Russia, India and China). Vehicle sales in China in 2010 totaled 18.5051 million units, exceeding the U.S. total of 12.7763 million units and making China the world's largest auto market for the second consecutive year. Presumably, the vehicle market in China will continue to grow in the years ahead.

Figure 2 shows the actual and projected change in vehicle sales in various markets to the year 2017. It is projected that total vehicle sales worldwide will approach 100 million units by 2017, an increase of about 1.5 times compared with 2010's level. The bulk of that increase will likely occur in the markets of emerging economies.

3. Trends in CO_2 Standards

Countries around the world are proceeding with efforts to reduce CO_2 emissions in order to improve the global environment. Figure 3 shows the standards adopted in various countries for reducing CO_2 emissions by 2020.

The EU zone is the most aggressive about reducing CO_2 emissions, having set a target below 100 g/km by 2020. China has also set a reduction target close to the EU's and is presumably working vigorously to develop technologies for reducing CO_2 emissions by 2020.

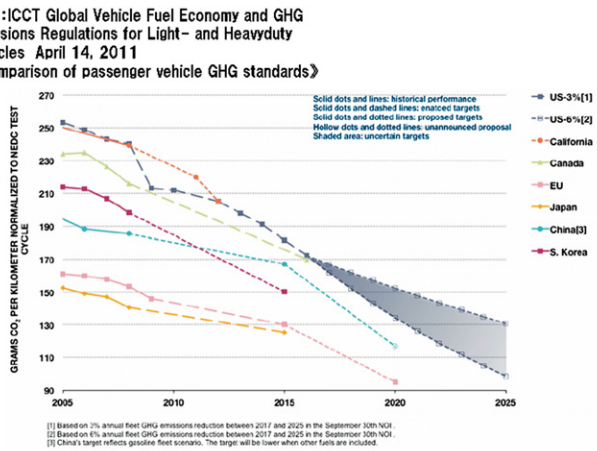

Fig. 3 Trends in CO_2 standards
Source: ICCT, Comparison of Passenger Vehicle GHG Standards, Global Vehicle Fuel Economy and GHG Emissions Regulations for Light- and Heavy-duty Vehicles, April 14, 2011.

4. 自動変速機の進化

自動車用自動変速機（以降:2ペダルTM）は，イージードライブ化に伴い，徐々にその占有率を向上し，燃費向上や変速性能向上など，その時代のニーズに合わせ，技術革新が進められ進化してきた．最近では乗用車でも多段化が進み，8spやCVT，マニュアルタイプのDCTなどが市場に投入されてきている．

Fig. 4にFF車用2ペダルTMのタイプ別台数推移を示す．ステップATの内訳が，従来の4sp･5spATから，6sp以上の多段ATに置き換わる．これに加えCVTおよびDCTが増加することが予測されている．

車両の環境性能に対応したトランスミッションとして，当面は多段AT･CVT･DCTが競合することになる．それぞれ異なった特徴を持つ技術の更なる進化が，今後の市場動向に影響をあたえることになる．

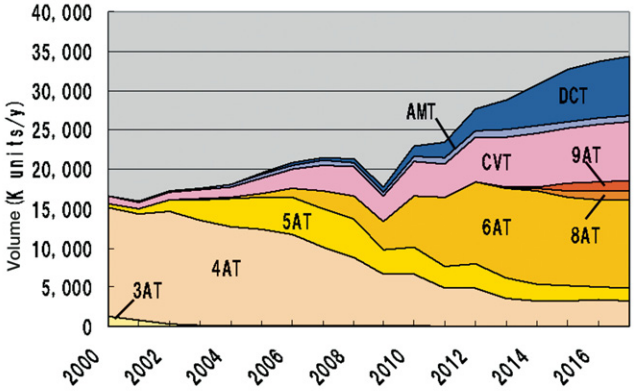

Fig. 4 Actual and projected trends in sales volumes of 2-pedal transmissions for front-drive cars by gearbox type (Source: IHS Automotive)

5. 2ペダルTMのグローバル展開

日米欧の市場だけではなく，新興国市場でも経済発展にともない，イージードライブ化が進み2ペダルTM搭載車の生産/販売が増加していくと考えている．

将来の2ペダルTMの動向を予測するには，地域ごとの特徴を捉え商品を投入することが重要となる．そこで各地域の状況について調査した結果を以下に示す．

◆アメリカ（カナダ，メキシコ含む）

ATが主流の日本，アメリカの2大AT大国のひとつであるアメリカでは，昨今の燃費規制とあいまって

Amid these circumstances, it is expected that stronger competition to develop CO_2 reduction technologies will unfold among the automakers. Examples of such competition in the Japanese market include the rapid expansion of hybrid vehicles and the appearance of electric vehicles, among other trends.

4. Evolution of ATs

Automotive ATs, referred to here collectively as 2-pedal transmissions, have continued to evolve though technological innovations designed to meet the needs of each era. Because they offer greater driving ease and comfort, their share has steadily increased, and continuous efforts have been made to improve fuel economy, shift performance and other attributes. In recent years, more speed ranges have been added to passenger vehicle transmissions and 8-speed ATs, CVTs, manual-type dual-clutch transmissions (DCTs) and other products have been put on the market.

Figure 4 shows the trends in the sales volumes of 2-pedal transmissions for front-drive cars by gearbox type. Among stepped ATs, conventional 4- and 5-speed ATs will continue to be replaced by units with six or more speeds. It is also projected that the respective share of CVTs and DCTs will increase in the coming years.

In the foreseeable future, there will continue to be competition among ATs with additional speed ranges, CVTs and DCTs as the preferred transmissions matching the environmental performance of vehicles. The ongoing technological progress of these transmissions with their different features will influence vehicle market trends in the years ahead.

5. Global Expansion of 2-pedal Transmissions

In addition to the Japanese, European and U.S. markets, it is forecast that production and sales volumes of 2-pedal transmissions will also increase in emerging markets in the future, driven by consumer preferences for greater driving ease and comfort as economic development continues.

In trying to predict future trends for 2-pedal transmissions, it is important to understand the characteristics of each geographical region in order to put the right products on the market. Accordingly, the

CVTの燃費の良さが市場で評価されている．一方，フォード，クライスラーがDCTを市場投入し注目を浴びている．

アメリカ市場では，発進時の性能が重要な要素なっているが，CVTと比較してDCTの性能が受け入れられるかがキーポイントになると考えられる．

◆欧州

欧州市場は，市場全体としては大きな市場だが，AT車がドライバーの意のままの運転にならないと思われていることや，発進時のトルクコンバーターのすべりが，MT車のクラッチがすべるときに似ていて不快に感じられること，また，燃費や価格に関する合理的な考え方がいきわたっているため，2ペダルTM搭載車比率は低い．

それでも将来的には30%程度にはなるとされ，欧州生まれのDCTやCVTがその期待を担っている．

◆中国

年収6,000ドルから30,000ドルの中間層では，収入に対しガソリン代が高いため，車両購入時の重視項目は車両価格と燃費である．優遇税制の対象となる排気量1.6Lの以下の小型車が，市場全体の50%を占め，2010年時点の2ペダルTM搭載率は30.6%である．今後は，低価格で燃費向上が図れるDCT･CVT･AMTの争いが激化することが予測される．

◆ブラジル

1.0L以下の車両が中心で，車両購入時に考慮される項目は，車両価格･ブランド･燃費の順である．1.6L以下の車両では，MT搭載が販売台数の97%以上を占めている．一方，1.6L以上の車両でMT搭載は販売台数の48%以上である．

主たる燃料であるエタノールは，政策的に比較的安価に設定されているため，FLEXFUEL車両が乗用車の95%（'10実績：ブラジル自動車工業会ANFAVEA）まで普及している．

◆ロシア

2.0L以下クラスの車両が中心の市場で，車両購入時に考慮される項目として，シフトクオリティ･悪路

conditions in each geographical region were surveyed and the results are described below.

◆U.S. (including Canada and Mexico)

The U.S. and Japan are the two major AT markets where automatic gearboxes predominate. Along with the tightening of fuel economy standards in recent years, the excellent fuel economy of CVTs has been evaluated favorably by consumers in the U.S. market. At the same time, the DCTs put on the market by Ford and Chrysler are also attracting attention.

In the U.S. market, start-off acceleration is a crucial factor. A key point will be whether the performance of DCTs will be accepted by consumers compared with that of CVTs.

◆Europe

The European market is large overall in terms of volume, but the installation rate of 2-pedal transmissions is low owing to various reasons. For example, there is a general impression that AT-equipped vehicles do not perform as the driver wishes. Many also dislike the slipping of the torque converter at start-off because it resembles the slipping of the clutch in MT-equipped cars. Pragmatic views on fuel economy and price are also widespread.

Nonetheless, it is estimated that 2-pedal transmissions may account for around 30% of the market in the future. It is expected that European-created DCTs as well as CVTs will be the main products promoting this increase.

◆China

For middle class consumers with an annual income of $6,000 to $30,000, the important factors considered when buying a vehicle are the sticker price and fuel economy because the cost of gasoline is high relative to their income. Small cars with an engine displacement of 1.6L or smaller receive special tax treatment and account for 50% of the overall market. As of 2010, 30.6% of them were fitted with a 2-pedal transmission. Competition among DCTs, CVTs and automated manual transmissions (AMTs) is predicted to intensify in the future as further efforts are made to reduce prices and improve fuel economy.

走破性が上位に位置づけられる．収入に対し，ガソリンの価格が比較的安いためか，燃費の優先度はあまり高くない．日本の中古車（AT･CVT搭載の乗用車）が年間約9万台程度輸入されている．

◆インド

1.0Lクラスの車両が中心の市場で，車両購入時に考慮される項目は，車両価格と燃費が極めて高い．ガソリン価格が所得水準に比較して非常に高いことが要因の一つと考えられる．販売車両にモード燃費ラベルも義務化されている．また，町工場で直す習慣があるため，サービス性も考慮する必要がある．

◆Brazil

Vehicles with an engine displacement of 1.0L or smaller account for the bulk of the market. The factors considered when purchasing a vehicle are the sticker price, brand and fuel economy, in that order. Among vehicles with an engine displacement of 1.6L or smaller, 97% are equipped with MTs. On the other hand, MT-equipped vehicles accounted for just 48% of the sales volume of 1.6L or larger vehicles in 2009.

The principal automotive fuel is ethanol, which is priced relatively low as a matter of policy. Accordingly, 95% of the passenger vehicles sold in 2010 were flex-fuel vehicles, according to statistics released by the National Association of Manufacturers (ANFAVEA).

◆Russia

Vehicles with an engine displacement of 2.0L or smaller constitute the core market segment. Shift quality and rough road driveability rank among the top factors considered when purchasing a vehicle. Fuel economy is not given very high priority perhaps because the price of gasoline is relatively inexpensive relative to income levels. Approximately 90,000 used Japanese passenger vehicles fitted with an AT or CVT are imported annually.

◆India

Vehicles with a 1.0L class engine form the core market segment. The sticker price and fuel economy rank exceptionally high among the factors considered when buying a vehicle. Presumably, one reason for that is the fact that the price of gasoline is extremely high relative to income levels. Vehicles for sale are required to bear a label indicating the test mode fuel economy. Serviceability is also a factor that must be considered because of the custom of having repairs done at small local garages.

Table 1 Situation in various markets

China

Basic and regulatory information

Increase in middle class consumers
(annual income: $6,000–$30,000) capable of buying vehicles.
Now expanding expressway network
(70,000 km in 2010; cf. 100,000 km in the U.S.).
High price of gasoline relative to income
(¥90/L. Equivalent to about ¥400/L when calculated in terms of starting salaries of university graduates).

Tax breaks for vehicles with 1.6L or smaller engine displacement.
Tightening of fuel economy standards
(Buy-back incentive system ends in 2011. Phase 3 standards begin in 2012.).
CVT-, DCT- and AMT-equipped vehicles have sufficient fuel economy to qualify for incentives.

Market and consumer information

Small vehicles with engine displacement of 1.6L or smaller have a market share of 50%.
Vehicle uses: commuting, shopping

2-pedal installation rate: 30.6% in 2010 → 38.5% in 2015
Results of consumer questionnaire surveys show strong desire for 2-pedal units.
Strong interest in price and fuel economy.

Severe congestions in urban areas, with frequent stop-go driving. With expansion of expressways in the suburbs, strong demands for acceleration in high-speed driving.
Demands for good fuel economy and driveability in all speed ranges from low to high speed.

Brazil

Basic and regulatory information

Increase in middle class consumers
(annual income: $6,000–$30,000) capable of buying vehicles.

Few paved roads (10% of all roads).
Fuel price is relatively cheap because of the prevalence of ethanol
(E100: ¥54/L, E25: ¥108/L).

Tax breaks for 1.0L or smaller vehicles.
No fuel economy standards yet or buy-back incentives.

Market and consumer information

Top market share for 1.0L or smaller vehicles that receive tax breaks. Small cars of 1.6L or smaller displacement account for about 80% of the total market.
Vehicle uses: shopping, commuting, family leisure on weekends
2-pedal installation rate: 8% in 2010 → 12.6% in 2015

Driving styles similar to Japan's.
Strong demands for driveability and gradeability.

Russia

Basic and regulatory information

Relatively high percentage (over 60%) of middle class consumers capable of buying vehicles.
Many poor roads (bumps/dips, muddy, etc.).
Price of gasoline is relatively cheap relative to income.

No fuel economy standards or buy-back incentives.

Market and consumer information

Small cars made by Russian automakers have a high market share, but foreign luxury brands are also sold.
Vehicle uses: commuting, family leisure, long trips
2-pedal installation rate: 14% in 2010 → 17% in 2016.

Low level of interest in fuel economy (ranks 20th among buying motives).
Strong demands for driveability to get over bumps/dips up to 160 mm in size.
Strong demands for driveability on muddy roads. → Advantages for torque converter-equipped vehicles.
AMTs have poor market reputation because of insufficient driving torque while shifting
(Toyota, Honda and Ford have withdrawn AMT-equipped vehicles.)

India

Basic and regulatory information

Increase in middle class consumers
(annual income: $6,000–$30,000) capable of buying vehicles.
Lagging behind in the construction of an expressway network.
Extremely high price of gasoline relative to income
(¥125/L. Equivalent to about ¥900/L when calculated in terms of starting salaries of university graduates).
Diesel fuel seems cheap by comparison, about 2/3 the price of gasoline in 2009.

Adopted fuel economy labels in 2009.
Considering enforcing tighter fuel economy standards.
(CO_2 target of 128 g/km in 2020, tightened from 179 g/km in 2011)

Market and consumer information

Many small cars, especially 1.0L or smaller cars are numerous.
High percentage of diesel vehicles.
Vehicle uses: commuting and shopping

2-pedal installation rate: 3% in 2010 → 8% in 2015
2-pedal transmissions are noticeably minor products.
Results of consumer questionnaire surveys show strong desire for 2-pedal units.
Strong interest in price and running cost
(fuel economy penalty, high repair cost).

Severe congestion in urban areas with frequent stop-go driving.
Top driving speed of around 100 km/h because an expressway network is still undeveloped.

6. ジヤトコの強み

6.1. ジヤトコのCVTラインナップ

ジヤトコは，CVTに早くから着目し，1997年に世界初の2.0LクラスFFベルトCVTを発表して以来，軽自動車用から3.5Lクラスまでの小型～大型におけるCVTフルラインナップ化を行い，トップメーカーとして市場をリードしている．このCVTラインナップをジヤトコは2系列に統合，小型～大型までのトルクレンジに対応させている．これにより1シリーズあたりのボリュームを拡大し，よりコストを抑えられるようになった．

Table 2 JATCO's CVT history

	1st Generation	2nd Generation	3rd Generation
	1997～	2002～	2009～
Large	370Nm JR006 (toroidal CVT)	350Nm JF010E	Jatco CVT8 Ordinary/High torque / Jatco CVT8 HYBRID
Middle	180Nm F06A	250Nm JF011E	
Small		150Nm JF009E / 110Nm JF012E	Minivehicle use/Ordinary Jatco CVT7 (JF015E)

第三世代のCVTであるJF015E（Jatco CVT7）は，主だった新技術アイテムとして，レシカバ7.3とプーリー小型化を両立させた副変速機･レイアウト見直しによるCVTフルード攪拌抵抗の低減･プーリー&副変速機の協調制御が挙げられる．

これらにより，発進加速，走りのよさを実現した商品性の高いトランスミッションとなっている．

6.2. グローバルなモノづくり

弊社は開発拠点を1995年から米国に，1998年に韓国，2003年にフランス，昨年には中国におき，世界中のお客さまの要望に，迅速かつフレキシブルに対応している．

また生産拠点として，2005年にメキシコ工場，2009年に中国工場を立上げた．昨年，3番目の海外生産拠点として，タイへ進出することを決め，設立準備に入っている．

われわれは，顧客であるカーメーカーの車両工場に近いところで生産できる体制を構築しており（Fig. 5），今後もそのニーズに合わせて拠点を拡大していく．

さらに調達部品についてはグローバルサプライチェー

6. JATCO's strengths

6.1. JATCO's CVT lineup

JATCO began early on to focus on CVTs and announced the world's first steel-belt CVT for use on 2.0L class front-drive cars in 1997. Since then, we have developed a full lineup of CVTs, ranging from small units for use on minivehicles to a CVT for application to large vehicles fitted with a 3.5L class engine. JATCO has consistently been a market leader as a top CVT manufacturer. The CVT lineup has been consolidated into two groupings, with a range of torque capacities corresponding to small to large engine displacements. This has increased the production volume per series so as to hold down costs.

The JF015E (Jacto CVT7) is JATCO's third generation CVT with several new technical features. These include an auxiliary transmission that reconciles the use of downsized pulleys with wider ratio coverage of 7.3, a revised layout that reduces CVT fluid churning resistance, and a cooperative control system for the belt-pulley assembly and the auxiliary transmission.

These new technologies deliver outstanding start-off acceleration and smooth driving performance to create a transmission with high marketability.

6.2. Global monozukuri operations

JATCO opened an engineering center in the U.S. in 1995, in Korea in 1998, in France in 2003 and in China in 2011, in order to respond quickly and flexibly to customers' needs and wants worldwide.

JATCO has two overseas production centers, a plant in Mexico that opened in 2005 and a plant in China that began operating in 2009. In 2011, JATCO decided to build its third overseas production center in Thailand and construction preparations are now under way.

We are building a global production network of plants located close to the vehicle assembly plants of our automaker customers (Fig. 5). We plan to continue to expand our production centers so as to meet customers' needs in the coming years as well.

JATCO has also built a global supply chain for the procurement of parts. We are proceeding with vigorous activities to select suppliers located near our

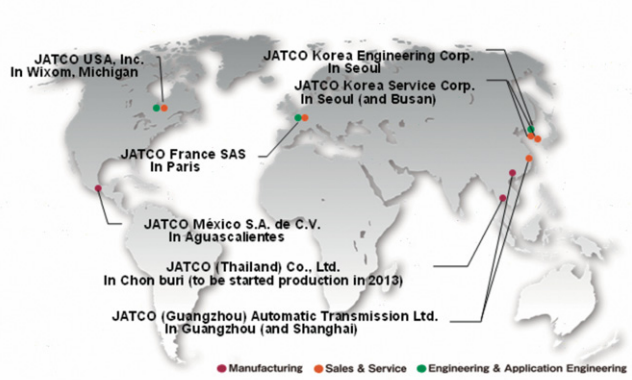

Fig. 5 JATCO's overseas facilities

ンを構築し，諸関税･為替のリスク回避･BCM等の観点からメキシコ･中国･ASEANといった拠点工場に近いサプライヤーの採用活動を積極的に進めている．

以上のことから，ジヤトコではグローバルに最適な地域からの部品供給と生産により，高品質で安価な製品を安定的にお客様へ届けることができる．

7. 今後の展望

2017年の予測では，世界需要の36%が1.6L以下の車両であり，そのうちの多くを新興国需要が占めるとされている．中国をはじめとする新興国へは廉価2ペダルTMの開発が重要であり，また，アメリカ･日本など先行市場の燃費競争を勝ち抜くための高性能な2ペダルTM開発も大変重要である．

従って，今後の2ペダルTM市場に於いては，燃費規制のクリアと，廉価2ペダルTMの開発が拡大の条件となる．

安くて燃費の良いユニット，それがまさにわが社のCVTである．

世界中のお客様に喜んでもらえる世界一の商品を世界一のオペレーションで提供して行くことが我々のビジョンであり，今後も販売の拡大のため，より良い品質の確保と，不断のコスト低減を目指していきたい．

production centers in Mexico, China and the ASEAN region from the standpoints of avoiding tariff and exchange rate risks and ensuring business continuity management (BCM), among other factors.

Based on the global activities described here, JATCO can stably deliver high-quality, low-cost products to our customers through a network of parts supply and production from optimal locations worldwide.

7. Outlook for the Future

According to the forecast for 2017, vehicles with an engine displacement of 1.6L or smaller will account for 36% of the global vehicle demand, with vehicle demand in the emerging economies representing much of the total. It is crucial to develop low-cost 2-pedal transmissions for the markets of emerging economies, notably China. It is also vital to develop high-performance 2-pedal transmissions in order to defeat the competition in the U.S., Japan and other developed countries.

Accordingly, the requisite conditions for the further expansion of the 2-pedal transmission market in the future will be to develop low-cost 2-pedal units capable of clearing tighter fuel economy standards. Affordable transmissions with excellent fuel economy describe JATCO's CVTs to a tee.

JATCO's vision is to provide the world's best products produced by the world's finest operations for pleasing our global customers. In order to expand sales further in the coming years, we aim to ensure higher product quality while tirelessly pursuing cost reductions.

■ Authors ■

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Vプラットフォームの戦略とその戦略を支えるCVT

V-platform Strategy and the Jatco CVT7 Supporting It

守屋　剛*
Tsuyoshi MORIYA

抄　録　Vプラットフォームは今までにない新しい戦略のもとに，すべての性能/機能を新設計した車両プログラムである．

本編では，Vプラットフォームの戦略を紹介するとともに，その戦略を支えた新型CVTの役割と貢献について説明する．

Summary　Under the V-platform vehicle program all performance attributes and functions are redesigned in line with a new strategy never before deployed.

This article describes the V-platform strategy and the role and contributions of the new Jatco CVT7 in supporting it.

1. Vプラットフォーム概要

Vプラットフォームは，タイ，インド，中国，メキシコ等の主に新興国で生産し，世界170カ国で販売することで，2013年に年間販売台数を100万台以上とすることを目指している．

その為に，先進国で勝ち進む圧倒的な商品競争力を有しながら，新興国で受け入れられる価格を実現するコスト競争力が必要となる．

これらを実現した，Vプラットフォームの戦略について説明する．

2. Vプラットフォームの戦略

圧倒的な商品競争力の為に，トップベンチマークとなる車両の軽量化と，すべてのマーケットでの燃費No.1を実現しながら，前型車に対し40%以上のコスト競争力を有することをVプラットフォームの目標としてきた．

2.1. 車両重量のベンチマーク

Vプラットフォームでは，すべてのコンポーネントの役割と性能/機能を新設計した．

新設計にあたり，構造の合理化による軽量化について徹底的に検討を行い，ベンチマークとなる車両質量の軽量車両を達成している．

1. Overview of V-platform

It is planned to produce V-platform vehicles in principal emerging economies, including Thailand, India, China, and Mexico, among others, and market them in 170 countries worldwide. The sales target set for V-platform products is to achieve combined annual sales of over one million vehicles by 2013.

To accomplish that, V-platform vehicles must possess overwhelming product competitiveness to defeat rival models in developed countries, as well as ample cost competitiveness to allow acceptable price levels in emerging economies.

The following section describes the V-platform strategy that attains such competitiveness.

2. V-platform Strategy

One target set for V-platform vehicles is to reduce the vehicle weight and set a new benchmark. A further target is to achieve a 40% improvement in cost competitiveness compared with the previous vehicle model, while ranking No. 1 in fuel economy in every market. These targets are intended to give V-platform vehicles overwhelming product competitiveness (Photos 1 and 2).

All V-platform components are redesigned in terms of their role, performance and functionality. In executing new component designs, exhaustive studies are conducted concerning weight reductions

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Deputy Chief Vehicle Engineer

Photo 1 New V-platform March for the Japanese market

Photo 2 New V-platform Sunny for the Chinese market

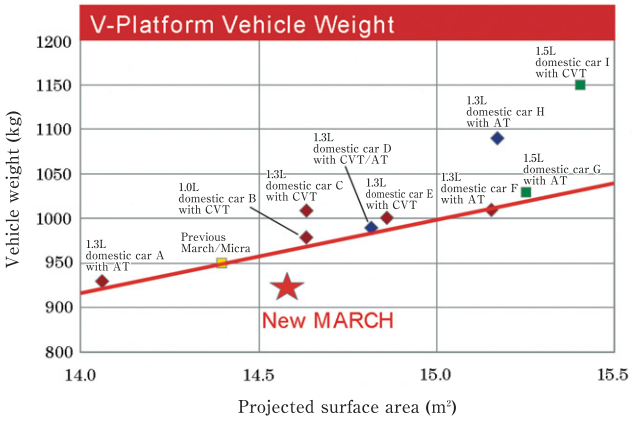


Fig. 1 Vehicle weight benchmark

車体の設計においては，主要構造部材の直線化，断面寸法の拡大，ビード，リブ追加による強度アップを行うことで，板厚の低減，クロスメンバーの廃止等を行い，大幅な車体質量の低減を行っている．

また品質の向上を目的に，構成部品の統合化に取り組んだが，構成部品の統合化は部品の合わせ構造，締結構造の削減につながり，軽量化に寄与した（Fig. 2）．

プラットフォーム全体の構成部品でみると，前型車に対して▲18%の部品点数削減となる機能統合をしている．この成果が，車両燃費，車両コスト，車両品質の大きなポテンシャルとなっている．

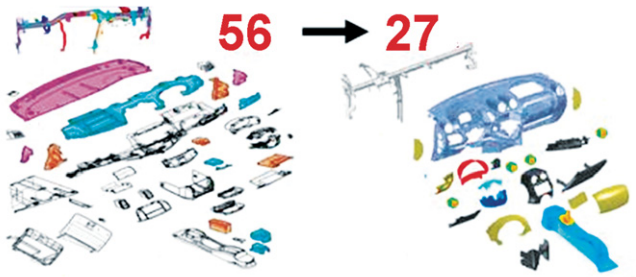
2.2. 車両の燃費性能

Vプラットフォームでは，全地域で共通に高い競争力を訴求される燃費性能を，グローバルNo.1を目標として，日産のすべてのアフォーダブルな新技術を投入した．ダウンサイジング新型3気筒エンジン，副変速機付き新型CVT，日産初のアイドリングストップ機構，セグメントトップの空力性能やベンチマークとなobtainable by rationalizing vehicle structures. As a result, a much lighter weight was achieved for the new March/Micra that has become a new vehicle weight benchmark.

2.1. Vehicle weight benchmark

The new vehicle weight benchmark is shown in Fig. 1, where the vertical axis indicates the vehicle weight (kg) and the horizontal axis shows the projected surface area (m^2). In developing the body design of the new March/Micra, major structural parts were straightened, cross-sectional dimensions were increased, and beads and ribs were added to enhance body strength. These measures made it possible to reduce the plate thickness of components and to eliminate certain cross members, which also contributed to substantial weight savings.

Moreover, efforts were made to integrate parts with the aim of improving quality. This integration of parts helped to reduce mating structures of parts and fastening/joining structures, thereby contributing to a much lighter vehicle weight (Fig. 2).



Previous March/Micra　　New March/Micra

Fig. 2 Weight savings achieved by integration of instrument panel parts

る車両質量などの実現により，その目標を達成している．

2.3. 車両のコスト競争力

グローバル生産車であるVプラットフォームはTdC（トータルデリバリードコスト）をマネージメントすることで，そのコスト競争力を高めている．前述の構成部品の統合化と部品の現地化率の最大化が大きな達成手段となっている．

現地化を推進した結果，パワートレインを除いてタイ生産：93.7%，インド生産：95.0%，中国生産：94.8%など，非常に高い現地化率を達成できている．

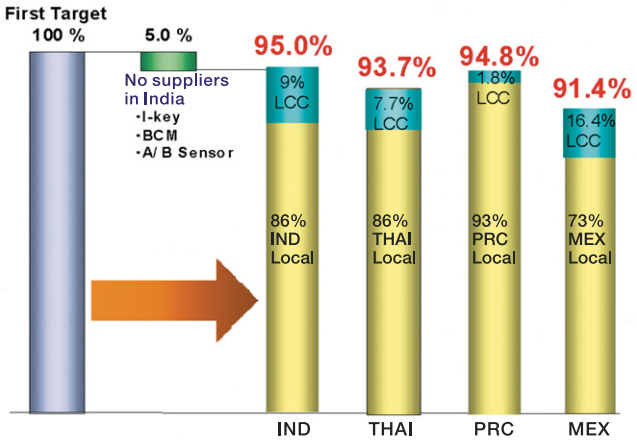


Fig. 3 Local procurement rates for V-platform parts

3. Vプラットフォームの戦略におけるCVTの貢献

Vプラットフォームの開発にあわせて，ジヤトコにて開発した小型車用副変速機付CVTは，Vプラットフォームの戦略実現に不可欠な要素となっている．

小型車用副変速機付CVTはギヤレシオのワイド化（全ギヤレシオ幅のワイド化），軽量，コンパクト化を実現するために遊星ギヤによる副変速機構を採用し，発進時の力強さと燃費向上との両立を図った．副変速機構の採用でベルトプーリー径が小さくなりCVTユニット内部でのオイルの攪拌抵抗低減にも寄与するため，（→ドライブプーリーの位置が高くなり，オイルの攪拌が少なくなったため）新型CVTではフリクションを約30%低減することが出来ている

また，変速比幅（全ギヤレシオ幅）は世界最大の7.3:1を実現し，ロックアップクラッチのダンパー特性を多段化することで，3気筒エンジンでも走行中のエ

In terms of the component parts of the overall platform, functional integration led to an 18% reduction of the part count compared with the previous model. This created significant possibilities for improving vehicle fuel economy, cost and quality.

2.2. Vehicle fuel economy

The target set for V-platform vehicles is to be No. 1 in fuel economy globally, as a shared attribute that will underscore their strong competitiveness in every region of the world. Accordingly, all of Nissan's cost-competitive new technologies have been embodied in V-platform vehicles. These include a new downsized three-cylinder engine, the new Jatco CVT7 featuring an auxiliary transmission, Nissan's first idling stop system, segment-leading aerodynamic performance and a lighter vehicle weight that sets a new benchmark. As a result, the fuel economy target has been attained.

2.3. Vehicle cost competitiveness

The cost competitiveness of globally built V-platform vehicles has been enhanced by carefully managing the total delivered cost (TDC). Key measures for accomplishing this were the integration of parts described above and maximization of the local parts procurement rate. As a result of promoting local purchasing, exceptionally high rates of local procurement have been achieved, excluding the powertrain. As shown in Fig. 3, the rates, including procurement from LCC suppliers, are 93.7% for production in Thailand, 95.0% for production in India and 94.8% for production in China.

3. Contributions of Jatco CVT7 to V-platform Strategy

In conjunction with the development of the V-platform, JATCO developed the Jatco CVT7 featuring an auxiliary transmission and designed for small car application. This CVT is an indispensable element contributing to the success of the V-platform strategy.

The new Jatco CVT7 adopts an auxiliary transmission to widen the overall gear ratio coverage, lighten the weight and obtain a compact package. As a result, it delivers powerful start-off acceleration combined with improved fuel economy. The adoption of the auxiliary transmission made it possible to

ンジン回転数を1000回転付近まで下げることが出来た．その結果，新型マーチではHR12DEエンジンとの組み合わせで，Fig. 4に示すように時速40kmから70kmの幅広い速度域でエアコン使用状態でもガソリン1リットルあたり30km以上の燃費性能を達成している．

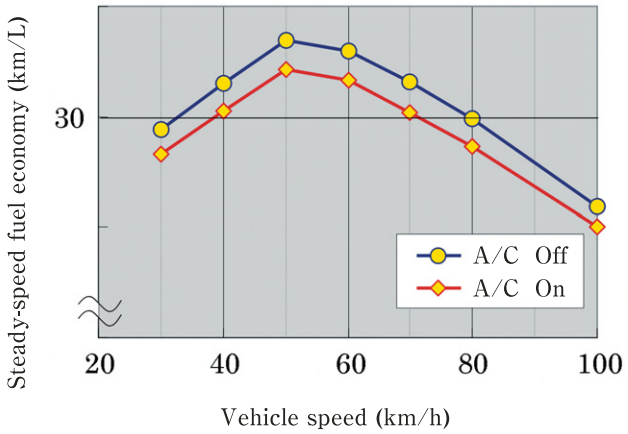


Fig. 4 Fuel economy in steady-speed driving

Vプラットフォームでは新たにアイドリングストップシステムも採用したが，登坂路を含むさまざまな道路環境でもアイドリングストップ作動頻度を高めて燃料消費を削減させるために，小型車用副変速機付CVTの遊星ギヤをインターロックする坂道ずり下がり防止機構を採用した．

このCVTを活用した坂道ずり下がり防止機構はVプラットフォームに適した，軽量，コンパクトかつ実用的なアイドリングシステムを構成することに大きく貢献した．当然のことながら，この機構は世界初の採用となっている．

また，前型CVTに対する▲13%の軽量化及び▲10%のコンパクト化はVプラットフォームの車両軽量化及び車両レイアウト効率化に大きく貢献しているのはいうまでもない．

Highest transmission ratio	7.3 : 1 (against 6.0:1 for similar conventional models)
Friction	30% lower
Weight	13% lighter
Size	10% smaller

Fig. 6 Features of Jatco CVT7 with an auxiliary transmission

reduce the pulley diameter, which has contributed to reducing fluid churning resistance inside the CVT. That was accomplished by positioning the drive pulley higher, thereby reducing fluid churning. As a result, the Jatco CVT7 cuts friction by approximately 30% compared with the previous unit.

Additionally, the Jatco CVT7 achieves the world's highest overall ratio coverage of 7.3:1. The adoption of a lockup clutch damper with three levels of damping characteristics allows the engine speed during driving to be reduced to approximately 1000 rpm even for a three-cylinder engine. As a result, the combination of the Jatco CVT7 and the HR12DE engine on the new March/Micra enables the vehicle to achieve a fuel economy figure of 30 km/L in the vehicle speed range from 40 to 70 km/h even with the air-conditioning system running, as shown in Fig. 4.

An idling stop system has also been newly incorporated in the V-platform. The Jatco CVT7 adopts an interlock mechanism in the planetary auxiliary transmission to prevent the vehicle from slipping back on uphill grades when the engine is turned off. This allows the idling stop system to be used more frequently in diverse road environments, including on uphill slopes, thereby reducing fuel consumption (Fig. 5).

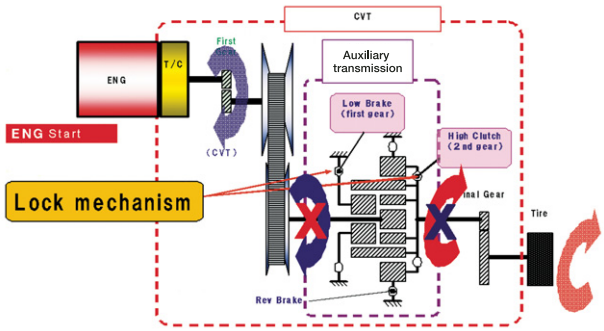


Fig. 5 Interlock system in Jatco CVT7

This interlock mechanism of the Jatco CVT7 for preventing slipping on uphill grades contributed significantly to the configuration of a lightweight, compact and practical idling stop system suitable for the V-platform. Notably, this is the world's first application of such a mechanism.

The Jatco CVT7 is 13% lighter and 10% shorter than the CVT used on the previous March/Micra model, which naturally contributes substantially to reducing the weight and improving the layout efficiency of V-platform vehicles (Fig. 6).

4. VプラットフォームCVTの採用状況と市場反響

現在，VプラットフォームにおけるCVTの採用状況をFig. 7に示す．

Fig. 7 Global application of Jatco CVT7

それぞれの地域の燃費の状況と販売状況をVプラットフォーム2番目の車種である新型グローバルセダンを事例にしてまとめた（2011年9月現在 4-1 to 4-3）．

4-1. New Sunny for the Chinese market

Launch date	December 2010
Fuel economy compliance	Complies with China's Phase III standard (effective from 2012)
Fuel economy competitiveness	Fuel economy standard Segment leader 5.8 km (L)/100 km (CVT)
Sales results (as of Sept. 2011)	Segment leader (No. 1 for 5 straight months*) 17,559 units/month
Response by customers/auto journalists	Favorable: Smoothness of Jatco CVT7 and engine combination Excellent fuel economy Unfavorable: Engine speed tends to flare up during moderate acceleration Insufficient start-off acceleration

*The Sunny ranked second in sales in April 2011 because production was reduced due to the effects of the earthquake/tsunami. Since then it has ranked No. 1 in its segment for five consecutive months.

4. Application of Jatco CVT7 to V-platform and Market Response

Figure 7 is a map showing the markets where the Jatco CVT7 is currently being used on V-platform vehicles as of September 2011. This map is for a new global sedan, the second model to be built on the V-platform, which is being introduced in accord with fuel economy levels and the sales situation in various markets.

The response of customers and automotive journalists differs slightly from market to market, but there have been many favorable comments regarding the excellent fuel economy and smoothness of the Jatco CVT7. This indicates that the combination of the new global sedan and the Jatco CVT7 is being well received in markets worldwide (4-1 to 4-3).

4-2. New Versa for the North America market

Launch date	September 2011
Fuel economy compliance	Complies with U.S. CAFE standard
Fuel economy competitiveness	U.S. combined city/highway mileage rating Segment leader 33 mpg (CVT)
Sales results	Segment leader 6,777 units/month
Response by customers/auto journalists	Favorable: Smoothness of CVT No rubber band feeling in ordinary driving Unfavorable: Engine speed rises too high during WOT acceleration Dull acceleration

お客様，ジャーナリストの反響に関しては地域ごとに多少の差異はあるものの，燃費がよいこととCVTのスムーズさに対するコメント数が多く，新型グローバルセダンとCVTの組み合わせが市場に受け入れられていると考えられる．

5. 終わりに

VプラットフォームにおけるCVTの役割について述べてきたが，現在のVプラットフォーム販売台数におけるCVTの占める割合は約30%である

Fig. 8よりわかるように，新興国でのCVTの採用率はまだまだ低い状況である．

昨今の不安定な世界状況に起因する燃料価格の高止まりや，地球規模でのCO_2排出削減の必要性を鑑みると，燃費に対する市場要求は更に厳しくなることは明白であり，その動向は新興国でも先鋭化する可能性がある．

その為にも，継続的にCVTの性能を向上させていくと共に，新興国へのCVT採用を積極的に進めていく必要がある．

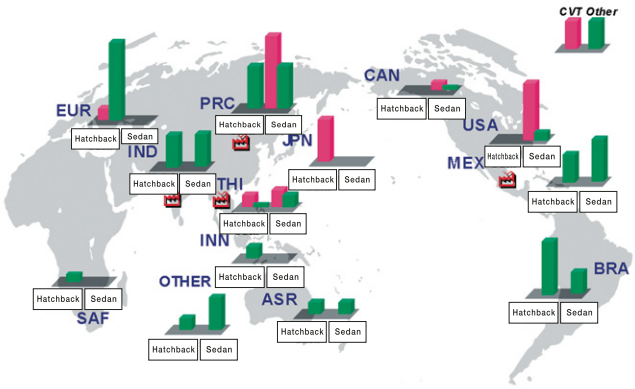


Fig. 8 Jatco CVT7's share of V-platform vehicle sales

4-3. New Almera for the Thailand market

Launch date	October 2011
Fuel economy compliance	Complies with Thailand's eco-car certification standard (only the March and Almera comply with this standard)
Fuel economy competitiveness	The only eco-car certified sedan 5.0L/100 km (CVT)
Sales results	6,528 units ordered in first month after Oct. 7 release
Response by customers/auto journalists	Favorable: Smoothness of CVT CVT is ideal for city driving Unfavorable: Noisy during kickdown shifting Dull acceleration but no problem for an eco-car

5. Conclusion

This article has described the role of the Jatco CVT7 in the V-platform strategy. Jatco CVT7-equipped vehicles currently account for approximately 30% of overall V-platform vehicle sales. As indicated in Fig. 8, the installation rate of the Jatco CVT7 is still low in emerging economies.

Considering the sharp rise in fuel prices due to recent unstable global circumstances and the need to reduce CO_2 emissions worldwide, it is clear that market demands for better fuel economy will become even stronger. That trend will probably become more pronounced in emerging economies as well. For that reason, it will be necessary to continue to improve CVT performance and to vigorously promote the adoption of CVTs in emerging economies.

■ Author ■

Tsuyoshi MORIYA

Jatco CVT7の技術紹介

Introducing the Technologies of Jatco CVT7 Featuring an Auxiliary Transmission

中川　善朗*
Yoshiro NAKAGAWA

抄　録　ジヤトコ(株)は，2009年7月にJatco CVT7の生産を富士地区で開始した．このCVTは従来の軽自動車用CVTと小型車用CVTを統合した幅広い適用領域をカバーすると同時に，副変速機構を有することにより大幅な低燃費を実現した新世代CVTである．今回はユニット全体の開発と最新技術について説明する．

Summary　JATCO launched production of the Jatco CVT7 in the Fuji area in July 2009. This next-generation CVT can cover a wide range of applications, combining the coverage of existing CVTs for use on minivehicles and small cars. Moreover, it also features an auxiliary transmission for substantially improved vehicle fuel economy. This article describes the overall development of this new CVT and the latest technologies it embodies.

1. はじめに

ジヤトコ(株)は，2009年7月にJatco CVT7の生産を富士地区で開始した．このCVTは従来の軽自動車用CVTと小型車用CVTを統合した幅広い適用領域をカバーすると同時に，副変速機構を有することにより大幅な低燃費を実現した小型CVTである．

近年，法規制を含めて地球環境問題への関心がますます高まる中で，自動車業界では燃費向上が環境維持の貢献へ繋がると捉えている．いろいろな燃費向上技術が実施されるなかで，CVTはその中でも有力な技術の一つであり，この数年の間に各メーカーでそのシェアを広げてきた．

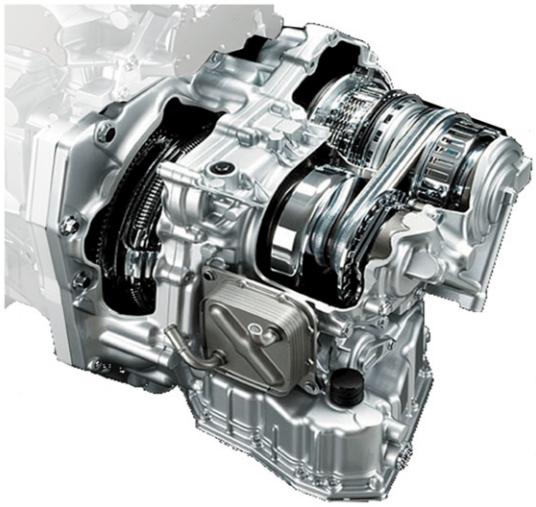


Fig.1 Jatco CVT7

1. Introduction

JATCO began producing the Jatco CVT7 in July 2009. This small CVT has a broad range of application, combining the coverage of existing CVTs used on minivehicles and small cars. It also provides substantially improved fuel economy as a result of incorporating an auxiliary transmission.

Amid the heightened concern about global environmental issues in recent years, including stricter laws and regulations, the automotive industry sees improvement of vehicle fuel economy as an important way of contributing to environmental sustainability. Among the various measures being taken to improve fuel economy, CVTs represent one of the most effective technologies available today. These last few years all of the automakers have increased the proportion of their product lineup fitted with CVTs.

The Jatco CVT7 is slated to be used on a wide range of vehicles from minivehicles to small cars. This article presents a product overview of the Jatco CVT7 and the principal technologies it incorporates (Fig. 1).

* プロジェクト推進室
Project Promotion Office

本CVTは，軽自動車から小型自動車まで幅広く搭載されていく予定である．本稿ではこのJatco CVT7の商品概要と主要構造技術について紹介する（Fig. 1）．

2. 商品・新技術

2.1. 商品コンセプト

Jatco CVT7は以下のコンセプトで開発を行った．

1）超ワイドレンジ化による低燃費，動力性能の両立
2）フリクション低減による低燃費化
3）小型・軽量化による軽～小型自動車までの共通化

Table 1 Product Concept

Major features		
Ratio coverage	7.3	(6.0 for a conventional CVT)
Friction reduction	30%*	(compared with an existing CVT)
Weight reduction	13%*	(compared with an existing CVT)
Length reduction	10%*	(compared with an existing CVT)

*Based on a simple comparison done at JATCO with an existing JATCO CVT of the same class

環境，経済性の両面で世界的な燃費向上要求は，ますます高まっている．燃費向上の対応として，電気自動車やハイブリッド車などの対応を各社で加速させている．しかしながら，グローバルに台数影響を考慮すると最量販であるレシプロエンジンとの組合せで使われるトランスミッションの燃費向上はCO_2排出の面積効果を出す上で，非常に重要になる．

一方，自動車が本来もっている「走る楽しみ」も進化しなければならない．Jatco CVT7は超ワイドレシオ化に低燃費と動力性能の両立，さらに小型・軽量化を達成するために世界初となる副変速付CVTの構造を採用した（Fig. 2）．

2. Product Overview and New Technologies

2.1. Product concept

The Jatco CVT7 was designed and engineered around the following product concept (Table 1).

(1) To provide both lower fuel consumption and better power performance through ultra-wide ratio coverage
(2) To improve fuel economy by reducing friction
(3) To achieve common application to both minivehicles and small cars through downsizing and weight reductions

Demands for improved fuel economy are increasing worldwide today from both environmental and economic perspectives. Automakers everywhere are accelerating their work on environmentally friendly vehicles, including electric vehicles and hybrid vehicles, in order to improve fuel economy and address environmental issues. However, considering the potential effect with respect to global sales volumes, it is essential to improve the fuel economy obtained with transmissions mated to volume-selling reciprocal engines in order to reduce CO_2 emissions over the widest possible area.

At the same time, it is also necessary to enhance "driving pleasure," which is one of the intrinsic attractions of vehicles. The Jatco CVT7 provides ultra-wide ratio coverage to deliver power performance combined with lower fuel consumption. Moreover, it is also the world's first CVT to be built with an auxiliary transmission for achieving further size and weight reductions (Fig. 2).

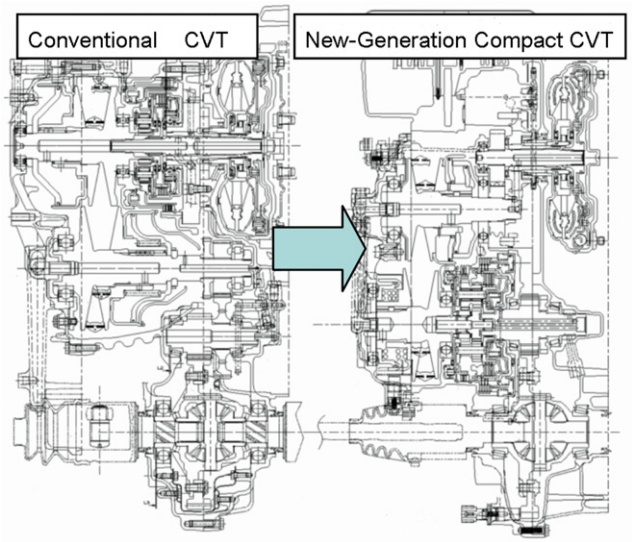


Fig. 2 Structural comparison

2.2. CVTラインナップ

ジヤトコは軽自動車用から排気量3.5リットルクラスまでのCVTフルラインナップを実現しており，機種構成は軽自動車用･小型車用･中型車用･大型車用の4機種構成を採ってきた．Jatco CVT7は副変速機の追加により軽自動車･小型車用を1機種でカバーすることができた．これにより台数規模が拡大しコスト低減に貢献した(Fig. 3)．今回開発したJatco CVT7の諸元を示す(Table. 2)．

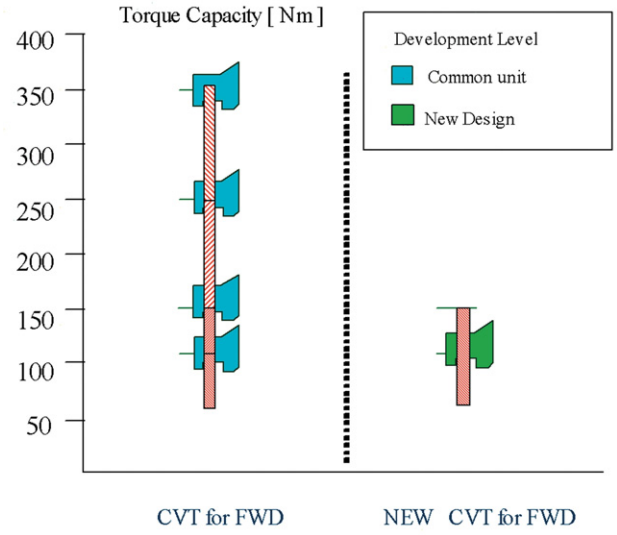


Fig. 3 Torque range

2.3. 構造

発進要素はトルクコンバーターを採用し，エンジンからの入力トルクは，このトルクコンバーターからカウンタギヤを介し，変速機構であるベルト&プーリーへ伝達される．そして副変速機構と前後進切替え機構部を介し，リダクションギヤ列を介して，デフギヤにより左右の駆動輪を駆動する．

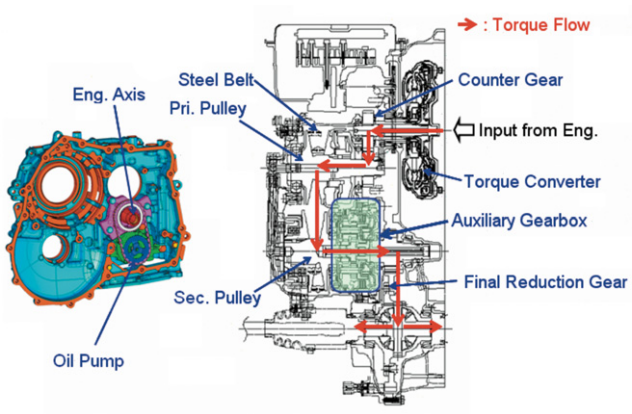


Fig. 4 Main cross section

2.2. JATCO's CVT lineup

JATCO offers a full lineup of CVTs, ranging from units for use on minivehicles to a CVT for vehicles equipped with a 3.5-liter class engine. The CVT model mix has so far consisted of four types designed for application to minivehicles, small cars, midsized cars and large cars. With the addition of the auxiliary transmission, the Jatco CVT7 alone can cover both minivehicle and small car applications. This allows a larger production volume that contributes to reducing costs (Fig. 3). The specifications of the newly developed Jatco CVT7 are given in Table 2.

Table 2 Major specifications

Item		Jatco CVT7	Conventional-CVT
Torque capacity		**150 Nm**	150 Nm
Gear ratios	Ratio coverage	**7.3**	6.0
	Pully ratio	**2.200～0.550**	2.561～0.427
	Final gear ratio	**3.753 (0.967x3.882)**	5.473 (1.486x3.684)
	Sub planetaly gear ratio(1st)	**1.821**	None
	Sub planetaly gear ratio(2nd)	**1.000**	None
	Reverse gear ratio	**1.714**	1.023
Through low ratio		**15.035**	14.016
Weight (kg)		**67.5**	77.4
Overall length (mm)		**323.3**	354.7
Distance between Pulley axles		**147**	156
Distance between 1st and 4th axles		**183**	186

2.3. Structure

The Jatco CVT7 adopts a torque converter as the start-off element. Torque input from the engine is transferred from the torque converter via a counter gear to the belt-pulley system that functions as the shift mechanism. Torque is then transferred via the auxiliary transmission and the forward/reverse changeover mechanism through the final reduction gear to the differential and then to the right and left drive wheels.

The oil pump that generates the hydraulic pressure for torque transfer and shifting is positioned under the first shaft and is driven via a chain system from the input shaft connected directly to the engine. As with conventional CVTs, the hydraulic circuit for the control system is located in the oil pan below the case (Fig. 4).

トルク伝達や変速のための油圧を発生させるオイルポンプは1軸の下方に配置され，エンジンと直結された入力軸から，チェーンシステムを介して駆動される．制御系の油圧回路は従来同様，ケース下方のオイルパン内に配置した（Fig. 4）．

2.4. 主要技術

（1）Jatco CVT7

前後進の切り替え機構のみ有する従来CVTの遊星歯車とは異なり，Jatco CVT7はベルト変速機構の後流に前進2段，後進1段の変速が可能な副変速機を有す（Fig. 5）．副変速機の構造は入力頻度，全長短縮のためラビニヨ式遊星を採用し，コンパクトに収めた．

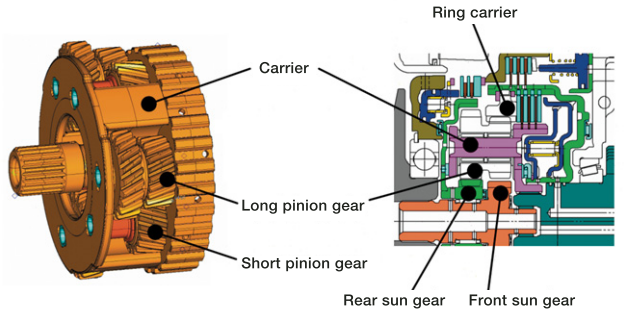


Fig.5 Structure of planetary auxiliary transmission

Jatco CVT7に採用した遊星歯車機構は，1速：1.821，2速：1.0，Rev：1.714というギヤ比を有する．

従来CVTに対してLowブレーキ，サンギヤ各1つの要素を追加した．また，走行頻度が多い2速走行時に遊星歯車を直結し，遊星歯車での動力伝達を1速，Rev走行時のみとした（Fig. 6）．この結果，遊星歯車機構の幅を小さくでき，レイアウト効率の良い構造を実現することができた．

従来のCVTに副変速機を追加することで，既存CVT，Step ATの中でも広いレシオカバレッジを実現し，低燃費・動力性能の両立へ貢献している（Fig. 7）．

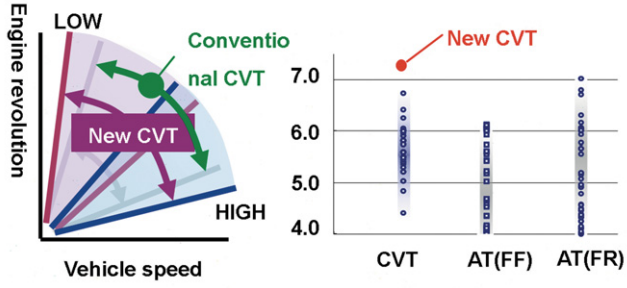


Fig. 7 Ratio coverage

2.4. Principal technologies

(1) Jatco CVT7

A conventional planetary CVT has only a changeover mechanism for switching between forward and reverse gears. In contrast, the Jatco CVT7 features an auxiliary transmission that is positioned downstream of the belt-pulley shifting mechanism and can shift between two forward speeds and one reverse speed (Fig. 5). The compact auxiliary transmission is built with a Ravigneaux planetary gear set in consideration of input frequency and for compactness that reduces the overall CVT length.

The planetary auxiliary transmission adopted for the Jatco CVT7 has gear ratios of 1.821 in first gear, 1.0 in second gear and 1.714 in reverse. In comparison with a conventional CVT, it adds one Low brake and one sun gear as additional elements. When a vehicle is traveling in second gear, which is used frequently, the planetary gear set is coupled directly; it transfers drive torque only when a vehicle is traveling in first gear or reverse (Fig. 6). As a result, the tooth face width of the planetary gears was reduced to achieve a structure with a highly efficient layout.

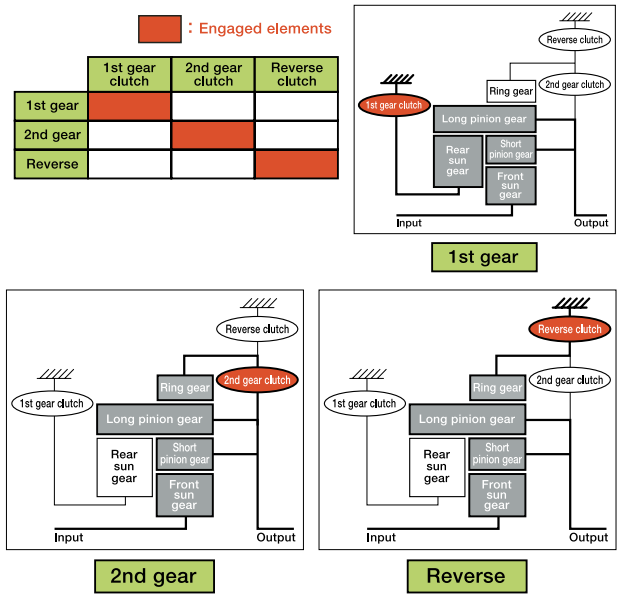


Fig. 6 Schematics of shift elements of the auxiliary transmission

The addition of this auxiliary transmission to a conventional CVT has resulted in one of the widest ratio coverages among existing CVTs and stepped ATs, which contributes to the attainment of both power performance and low fuel consumption (Fig. 7).

（2）プーリーの小型化

Jatco CVT7はベルト&プーリーによる変速と遊星ギヤ式の副変速機を併用することでベルト&プーリーのレシオカバレッジを4.0とした．レシオカバレッジを4.0とすることによりプーリーの外径&ストローク長さを小さくして，軽･小型車のエンジンルームへの搭載を可能とした．さらにCVTの中で大型部品であるプーリの重量を従来比約30%低減しプーリーにも貢献した（Fig. 8）．

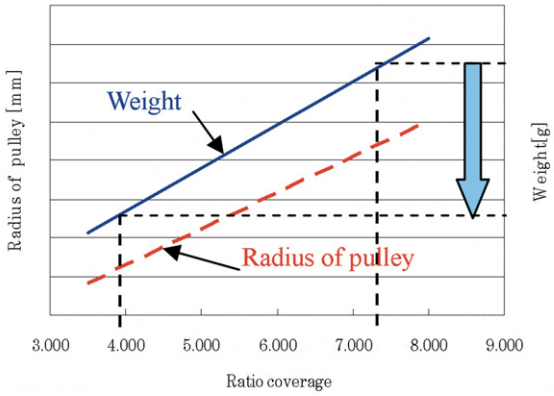


Fig. 8 Sheave weight benchmark

（3）フリクション低減技術

Jatco CVT7は1−2軸間をカウンタギヤ，2−3軸間をベルト&プーリー，3−4軸間をリダクションギヤの配置とした．

通常第1軸にあるプーリー入力軸のプライマリプーリーは従来CVTに対しユニット上方配置とした（Fig. 9）．

これによりプライマリプーリーがオイル油面と接触しない回転運動が可能となり，オイル攪拌によるフリクションのロスを低減させることができた．

また，CVTは定常走行状態において，プーリー比1.0付近がベルトフリクションの観点で最も効率がよい．

Jatco CVT7は，副変速機の1速を用いることで発進性能に有効な総減速比を確保できるので，従来CVTよりも終減速比を小さくすることができる．

これにより，2速で走行する領域において，同一車速では従来CVTよりもベルト&プーリーの効率がよいプーリー比1.0付近を多用でき，CVTのフリクションが低減できた（Fig. 10）．

(2) Downsizing of pulleys

The parallel use of the planetary auxiliary transmission and the belt-pulley system for ratio changes in the Jatco CVT7 enabled the ratio coverage of the belt-pulley assembly to be set at 4.0. This ratio coverage allowed the outer diameter of the pulleys and the stroke length to be reduced, enabling the Jatco CVT7 to be mounted in the engine compartment of both minivehicles and small cars. In addition, the smaller pulley size contributed to an approximately 30% weight reduction for the pulleys, which are large components of a CVT, compared with existing pulleys (Fig. 8).

(3) Friction reduction techniques

The layout of the Jatco CVT7 has the counter gear positioned between the first and second shafts, the belt-pulley assembly between the second and third shafts and the reduction gear between the third and fourth shafts.

The primary pulley on the pulley input shaft, which is the first shaft of an ordinary CVT, is positioned higher than in existing CVTs (Fig. 9). This enables the primary pulley to rotate without touching the CVT fluid surface, thereby reducing fluid churning for a reduction of friction loss.

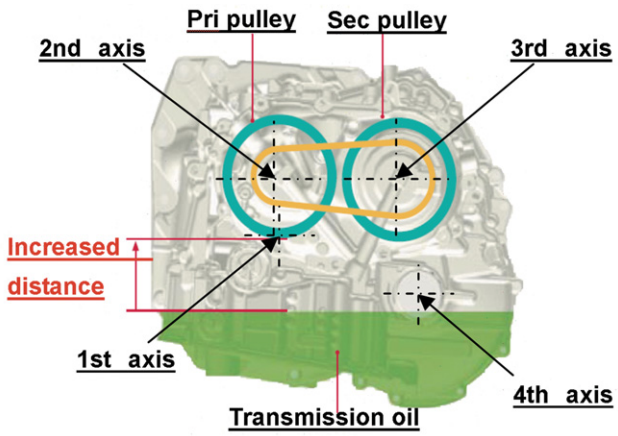


Fig. 9 Axis layout

During steady-speed driving, a CVT usually operates at maximum efficiency in terms of belt friction at a pulley ratio near 1:1. The Jatco CVT7 uses the first gear of the auxiliary transmission to secure an overall reduction ratio advantageous for good start-off acceleration. This allowed the final reduction ratio to be set smaller than that of existing CVTs.

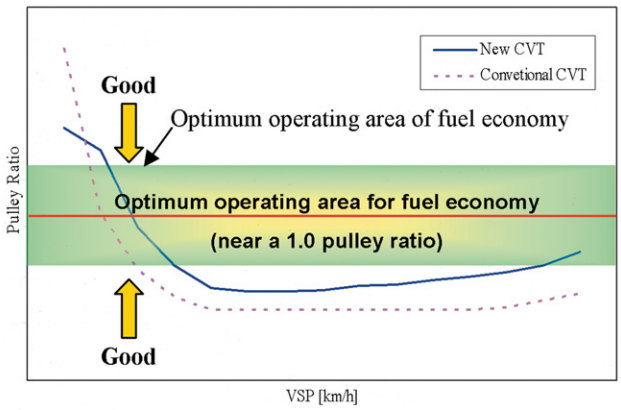


Fig. 10 Pulley ratio chart

3. 副変速機の変速制御

CVTはStep ATと比較して変速ショックのないスムースな加速が好評を得ており，副変速機を有するJatco CVT7でも従来と同様のスムースな加速が望まれる．スムースな変速を実現するためには，副変速機の変速中に於いてもエンジン回転やトルクの変動を抑制する必要があり，その実現手法としてベルト&プーリーと副変速機の変速を協調させる制御を採用した（Fig. 11）．

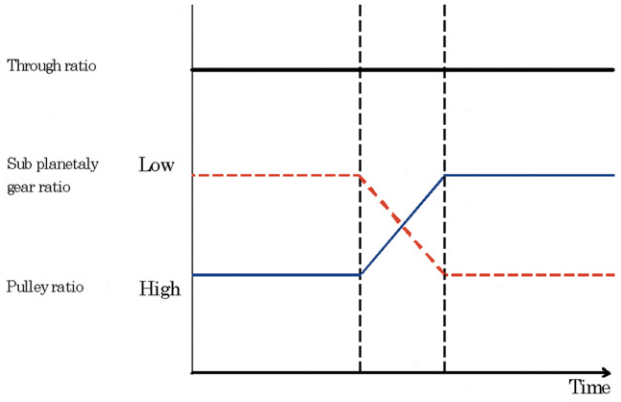


Fig. 11 Shift up chart

このような協調変速を行う場合，副変速機の変速進行をきめ細かく制御する必要があるので，開放側クラッチ，締結側クラッチそれぞれの特性バラツキや作動油圧応答特性を補正する多様な学習制御，変速進行をリアルタイムにフィードバックする制御を採用している．

さらに，副変速機の変速は，変速時のトルク変動を最小限とする為，ベルト&プーリーの変速比が最High付近で，1速から2速へ変速させる．走行頻度の多い低開度側では，伝達効率のよい2速を多用

As a result, compared with existing CVTs, the Jatco CVT7 can operate more often near a pulley ratio of 1:1 where the efficiency of the belt-pulley system is higher, when traveling in the second gear at the same vehicle speed. This makes it possible to reduce CVT friction (Fig. 10).

3. Shift Control of Auxiliary Transmission

CVTs have a good reputation for smooth acceleration free of shift shock compared with stepped ATs. It was desired to achieve the same smooth acceleration as that of conventional CVTs for the Jatco CVT7 with its auxiliary transmission. In order to ensure smooth shifting, fluctuations in engine speed and torque must also be suppressed while the auxiliary transmission shifts. As a way of accomplishing that, a cooperative control system was adopted that coordinates the shifting of the belt-pulley system and that of the auxiliary transmission (Fig. 11).

Executing this kind of cooperative shifting requires fine-tuned control over the shifting action of the auxiliary transmission. That has been achieved by adopting various adaptive learning control features that compensate for the CVT fluid response characteristics and variation in the performance characteristics of both the releasing-side and engaging-side clutches. Feedback control has also been adopted for real-time feedback of information during the progress of a shift.

Moreover, the auxiliary transmission shifts from first to second gear near the highest shift ratio of the belt-pulley system so as to minimize torque fluctuation when the transmission shifts. A control feature has been adopted for shifting the auxiliary transmission to second gear when the belt-pulley system is on the Low ratio side. This facilitates more frequent use of second gear with its good torque transmission efficiency at a small throttle opening where vehicles are frequently driven. This control feature achieves both minimal shift shock and high transmission efficiency.

できるように，ベルト&プーリーがLOW側で変速するように切り替える制御を採用することで変速ショックと高効率の両立を達成している．

4. まとめ

Jatco CVT7の開発により，以下の効果が得られた．

1）超ワイドレシオによる動力性能と燃費の両立

副変速機の採用によるレシオカバレッジを拡大することより排気量の小さい軽･小型車用で，発進性能の確保と巡航走行時の低回転走行が可能になることによる低燃費化，低騒音化が達成できた．

2）フリクションの低減

従来CVTとは異なる軸配置を採用したことにより，伝達効率を向上させることができた．

3）小型･軽量化

副変速機を採用したことでプーリーの小型化が実現し，軽自動車から小型車まで搭載が可能なコンパクトなCVTが開発できた．また，軽量化により車両燃費へも貢献できた．

4）変速品質の確保

変速部とエンジンとの協調制御および変速に要する油圧の精度向上により，CVTの持つ滑らかな変速を実現することができた．

昨今の地球環境問題に対する燃費向上に貢献することが変速機の使命であるが，CVTに副変速機を組み合わせる独自の新構造にチャレンジした結果，極めて競争力の高い変速機を開発することができた．

4. Conclusions

The newly developed Jatco CVT7 provides the following benefits.

(1) Ultra-wide ratio coverage for power performance combined with low fuel consumption

The adoption of the auxiliary transmission has greatly widened ratio coverage to secure excellent start-off acceleration as well as reduced fuel consumption and quieter operation by allowing a lower engine speed during highway cruising when the Jatco CVT7 is used on minivehicles and small cars with small displacement engines.

(2) Reduced friction

The adoption of a shaft layout different from that of conventional CVTs made it possible to improve power transmission efficiency.

(3) Size and weight reductions

The adoption of the auxiliary transmission allows the use of smaller pulleys, making it possible to develop a more compact CVT applicable to a wide range of vehicles from minivehicles to small cars. The lighter CVT weight also contributes to improving vehicle fuel economy.

(4) Assurance of smooth shift quality

Smooth shifting characteristic of a CVT has been achieved by adopting cooperative control of the transmission and engine and by improving the control accuracy of the clutch pressure needed for shifting.

It has become the mission of automotive transmissions in recent years to contribute to improving vehicle fuel economy as part of efforts to address global environmental concerns. As a result of undertaking the challenge to create a unique structure that combines an auxiliary transmission with a conventional CVT belt-pulley system, we have succeeded in developing a new compact transmission with exceptionally strong competitiveness.

■ Author ■

Yoshiro NAKAGAWA

Jatco CVT7用 ラビニオ式遊星歯車機構の開発

Development of Ravigneaux Planetary Gear Set for Auxiliary Transmission of Jatco CVT7

立石　純一郎*
Junichiro TATEISHI

抄　録　ジヤトコは2009年7月に世界初の副変速機を有するCVT（Jatco CVT7）の生産を開始した．

本稿では，Jatco CVT7に採用されたラビニオ式遊星歯車機構の構造と作動原理，及び主要技術について紹介する．

Summary　In July 2009, Jatco launched production of the Jatco CVT7, the world's first CVT to incorporate an auxiliary transmission. This article describes the structure, operating principle and major technical features of the Ravigneaux planetary gear set adopted for the auxiliary transmission.

1. はじめに

遊星歯車機構は，同軸上で変速，前後進切替えが可能な機構であり，ジヤトコの歴史においても創業当初からステップATの分野で採用されてきた技術の一つである．

また，近年の燃費向上を目的とした多段化要求などの背景から，2ペダル市場においては，今後も活用され続ける技術の一つであると予測される．

一方，CVTでは，前後進切替え機構の一部として遊星歯車機構が採用されてきた．

Jatco CVT7は，燃費性能向上を目的として，変速比幅拡大と同時に小型化を実現する為の副変速機を有する世界初のCVTである．この副変速機は，従来の前後進切替え機能に加えて，前進2段の変速を可能とするラビニオ式遊星歯車機構が，採用された．

本稿は，Jatco CVT7で採用されたラビニオ式遊星歯車機構の主要諸元，及び技術を紹介する．

2. 主要諸元

2.1. 部品レイアウト

Fig. 1に示す通り，従来のジヤトコ製CVT（図中は，前型のJF009E）は，バリエータ部上流に前後進切換え部が配置されたが，Jatco CVT7は，バリエータ部の後部に配置された．これはCVT全体のレイアウト効率を最適化を追究した結果である．この

1. Introduction

A planetary gear set allows shifting and forward-reverse changeover to be executed on the same shaft. This is one technology that Jatco has historically adopted for its stepped ATs since the company was founded. It is expected that this technology will continue to be used in the two-pedal transmission market in view of the demand in recent years for the addition of more speed ranges to ATs for improving vehicle fuel economy.

A planetary gear set has also been used over the years as one part of the forward-reverse changeover mechanism of CVTs.

The Jatco CVT7 is the world's first CVT to feature an auxiliary transmission, which was adopted to expand ratio coverage for the purpose of improving fuel economy, while at the same time achieving a smaller unit size. The auxiliary transmission is built with a Ravigneaux planetary gear set that can be shifted between two forward speeds, in addition to the conventional forward/reverse mechanism.

This article describes the major specifications and technical features of the Ravigneaux planetary gear set adopted for the Jatco CVT7.

2. Major Specifications

2.1. Layout of parts

As shown in Fig. 1, a conventional JATCO CVT (denoted as the previous JF009E model in the figure)

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レイアウトによって，プーリの小型化，CVTの車両への搭載性の向上が実現できた．

しかしながら，遊星歯車機構から見ると従来CVTと比較し，インプットトルクは，従来に対し約150%～200%（適用エンジンにより異なる）の増加となる．一方で副変速機を配置できるスペースはユニットの小型化要求もあり，遊星とクラッチ部品の配置は困難な作業であった．この厳しい制約下での高トルク対応が，Jatco CVT7向けラビニオ式遊星歯車機構の大きな技術課題であった．

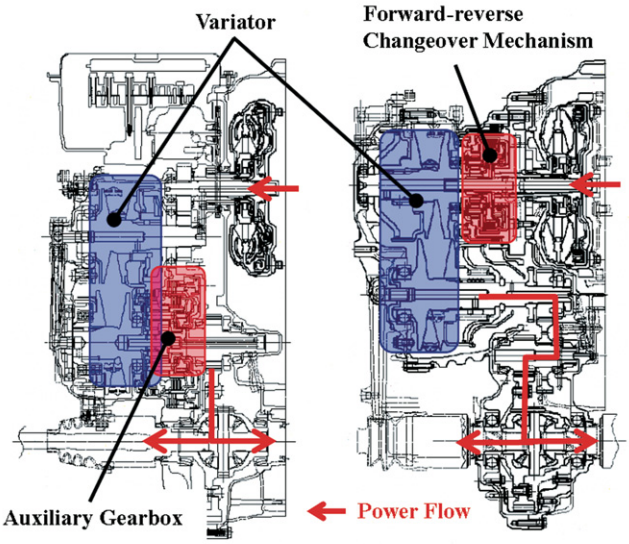

Fig. 1 CVT structural comparison

2.2. ラビニオ式遊星歯車機構の構造

Table 1に示す通り，JF009Eは，従来の前後進切替え機能に加えて，1速減速比1.821，2速減速比1.000の変速が可能な遊星歯車とクラッチの構成となっている．

この前進2段の変速機能追加と最適なパワートレーン系部品レイアウトの両立を考慮した結果，Fig. 3の3Dモデルで示すラビニオ式遊星歯車機構が採用された（Fig. 2）．

Table 1 Planetary gear ratios

CVT Model		Jatco CVT7	JF009E
Type of planetary		Ravigneaux	Double Pinion
Gear ratio	1st	1.821	None
	2nd	1.000	None
	Rev	1.714	1.023

has the forward-reverse changeover mechanism positioned upstream of the variator, whereas it is located behind the variator in the Jatco CVT7. This position resulted from pursuit of optimum efficiency for the overall CVT layout. The resulting layout enabled the pulleys to be downsized and improved vehicle mountability of the Jatco CVT7.

However, from the perspective of the planetary gear set, the input torque increased by approximately 150-200% (varies depending on the engine application) compared with the conventional CVT. On the other hand, it was difficult to lay out the planetary gears and the clutches, partly because of the need to downsize the unit to create space for installing the auxiliary transmission. One of biggest technical issues for the Ravigneaux planetary gear set adopted for the Jatco CVT7 was to accommodate the higher torque level under these layout constraints.

2.2. Structure of Ravigneaux planetary gear set

As shown in Table 1, the Ravigneaux planetary gears and clutches adopted for the Jatco CVT7 (JF015E) provide shifting between a 1st gear ratio of 1.821 and a 2nd gear ratio of 1.000, in addition to the conventional forward-reverse changeover mechanism.

Figure 2 shows a 3D model of the Ravigneaux planetary gear set, which was adopted after considering how to reconcile an additional shift function providing two forward speeds with the optimal layout of the powertrain parts.

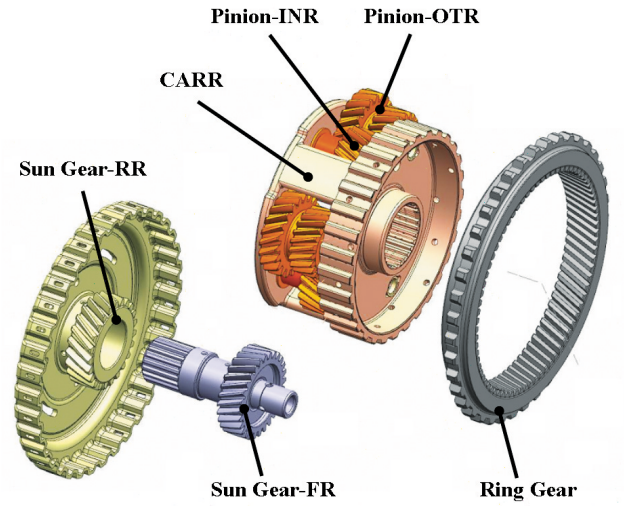

Fig. 2 Configuration of planetary gear set

A 2nd gear ratio of 1.000 means that the reduction ratio of 1st gear and the step ratio are the same. In

また，2速減速比は1.000の為，1速減速比と段間比が同一である事を意味する．つまり，今回の構造では段間比は，1.821である．この段間比が大きいほどクラッチで吸収エネルギが増大し，変速性能を悪化させる．

従って，動力性能から求められる1速減速比と変速性能から求められる段間比，及びレイアウト要件を満足する歯数設定が必要になる．この結果，アウターピニオンは，2つの歯車諸元を持つ2段歯車となった（Fig. 3）．

Fig. 3 Pinion Planet-OTR

次に遊星歯車機構の作動原理について説明する．はじめにJF009Eで採用されたダブルピニオン式遊星歯車機構のスケルトン，共線図を用いて従来の前後進切換え部の構造について説明する（Fig. 4）．

従来の遊星歯車機構はRev走行時のみトルク伝達を行う．リングギヤを固定し，キャリア（C）から入力された回転をサンギヤ（SUN）で逆転し出力する．前進時は，サンギヤ，キャリアをFwd/Cで締結させることで，遊星歯車機構は一体回転し，回転数比は1でタービントルクをダイレクトにバリエータ部へ伝えている．ここで図中のαは，サンギヤ（Zs）とリングギヤ（Zr）の歯数比（Zs/Zr）で表される．

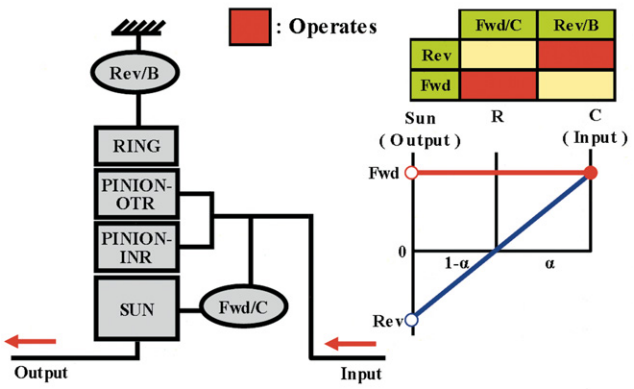

Fig. 4 Schematic diagram and collinear speed diagram of Jatco CVT7

other words, the step ratio of this transmission structure is 1.821. As the step ratio becomes larger, the amount of energy absorbed by the clutches increases, causing shift performance to deteriorate.

Accordingly, the number of gear teeth had to be designed to satisfy the 1st gear ratio required for the desired power performance, the step ratio required for the desired shift performance and the layout requirements. Therefore, a two-stage gear with two different gear specifications was adopted for the outer pinion (Fig. 3).

Next, the working principle of the planetary gear set is explained. First, the structure of the conventional forward-reverse switchover mechanism is described using the schematic diagram and collinear graph of rotational speeds shown in Fig. 4 for the double pinion planetary gear set adopted for the JF009E CVT.

The conventional planetary gear set transmits drive torque only when the vehicle is traveling in reverse gear. The ring gear is stationary, while the sun gear (SUN) rotates in reverse and outputs the rotational motion input from the carrier (C). When traveling in a forward gear, the sun gear and the carrier are engaged by the forward clutch (Fwd/C) and the planetary gear set rotates in unison. The rotational speed ratio is 1:1, so the turbine torque is transferred directly to the variator. The notation α in the figure is expressed as the gear ratio (Zs/Zr) between the sun gear (Zs) and the ring gear (Zr).

With this traditional structure, it has only been necessary to ensure the strength and noise/vibration performance of the planetary gear set of a conventional CVT for operation in reverse gear. Compared with the planetary gear set used in stepped ATs, this structure has been advantageous with respect to the usage environment.

In contrast, the planetary gear set adopted for the Jatco CVT7 has to shift between two forward speeds, as mentioned above. For that reason, it must have sufficient strength and noise/vibration performance to withstand driving modes equal to those of ordinary stepped ATs. As the schematic diagram in Fig. 5 indicates, a rear sun gear (SUN-RR) and a low brake (Low/B) have been added as new elements compared with the conventional structure.

以上の様な構造から，従来CVTの遊星歯車はRev走行時の強度，音振のみ保証をすれば良く，ATで使用される遊星歯車と比較すると使用環境面で有利であった．

一方，Jatco CVT7用の遊星歯車機構は，前述の通り，前進2段の変速を求められる為，AT並みの走行モードに耐えうる強度と音振性能を有する必要があった．スケルトンは，Fig. 5に示す通り，従来に対して，サンギヤ（図中SUN-RR）とLowブレーキ（図中Low/B）の新規要素を追加した．

また，1つのキャリアでサンギヤを2つ持つラビニオ式とすることで，レイアウト効率の良いギヤ配置となっている．

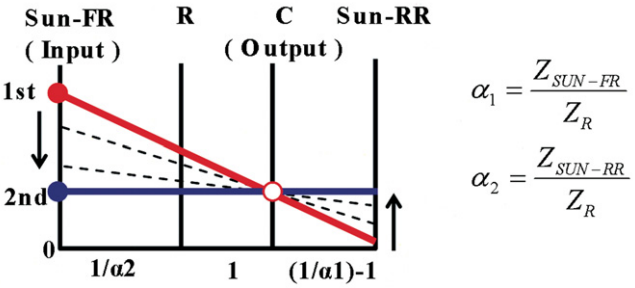

Fig. 6 Collinear speed diagram of Jatco CVT7

次にラビニオ式遊星歯車機構の作動について，Fig. 6の共線図で説明する．図中のα1は，フロントサンギヤ（SUN-FR）とリングギヤの歯数比であり，α2は，リアサンギヤ（SUN-RR）とリングの歯数比である．1速走行時は，SUN-RRを固定し，出力メンバーはキャリアである．この時減速比1.821でトルク，回転伝達を行う．

変速時は，Fig. 6に示す様にLow/Bを開放し，High/Cを締結する．この時，遊星歯車機構は，一体回転を行う事で減速比は，1.000となる．また共線図で示す通り，バリエータ部のプーリ比もHighからLowへ同時に変速する．これにより，インプットメンバーのフロントサンギヤの入力回転数は減速しながら締結する．結果として，キャリア回転数を一定に保った変速が可能となり，ショックの低減を実現できた．

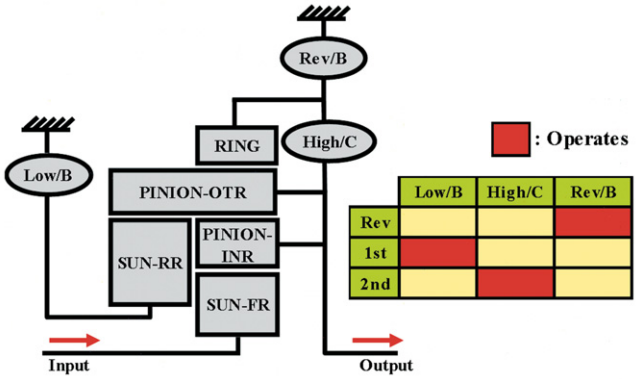

Fig. 5 Schematic diagram of planetary gear set of Jatco CVT7

In addition, the adoption of the Ravigneaux type in which one carrier has two sun gears achieved a highly efficient gear layout.

The operation of the Ravigneaux planetary gear set is explained next using the collinear diagram of rotational speeds in Fig. 6. The notation α1 in the figure is the gear ratio between the front sun gear (SUN-FR) and the ring gear, and α2 is the gear ratio between the rear sun gear (SUN-RR) and the ring gear. When traveling in 1st gear of the auxiliary transmission, the rear sun gear is stationary and the carrier serves as the output member. In this state, drive torque and rotational motion are transferred at a reduction ratio of 1.821.

As shown in Fig. 6, a shift is executed by releasing the low brake and engaging the high clutch. The planetary gear set rotates in unison at that time and the reduction ratio becomes 1.000. Moreover, as shown in the collinear diagram, the pulley ratio of the variator is also simultaneously shifted from High to Low. Consequently, the front sun gear, which serves as the input member, is engaged as its rotational speed decreases. As a result, this facilitates shifting while keeping the rotational speed of the carrier constant, which works to reduce shift shock.

3. 技術課題

3.1. 小型化への対応

モジュールの異なる歯車とサイズを相対比較する為に，噛合い率相場マップを用いる(Fig. 7)．歯車対の作用線上の噛合い長さで決まる横軸の正面噛合い率は，歯の大きさ(モジュール等)を表し，縦軸の重なり噛合い率は，歯幅を軸方向ピッチで除した値で表されるヘリカルギヤ特有の指標である．

Jatco CVT7遊星歯車は，正面と重なりの和である全噛合い率で見ると相場下限に位置する．従って，サイズにおいて，Jatco CVT7は下限相当である旨を主張し，位相差設計と動的な歯面変位量と予測した歯車精度の狙い値修正を行なった．

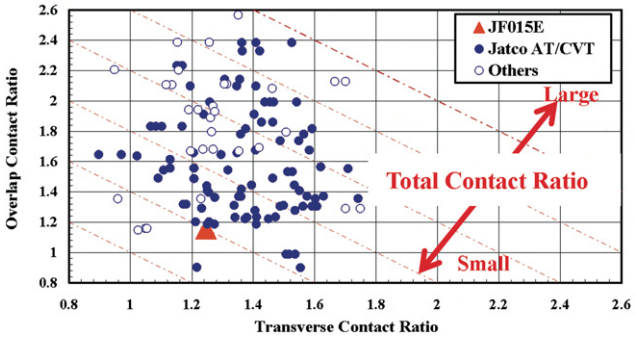

Fig. 7 Comparison of contact ratios

3.2. 高トルク対応

歯車の強度向上対策として，マイクロショットピーニングを採用した．残留圧縮応力を管理する為に投射圧，重量，時間と応力の感度特性を取得し，強度用件と生産用件を両立する管理範囲を決定した．Fig. 8は，ピーニング条件を振った際の応力ピーク値を示した一例である．

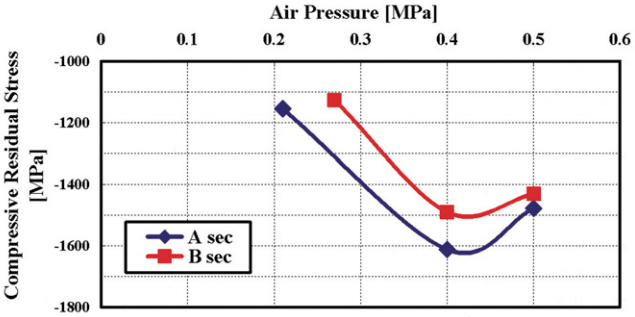

Fig. 8 Sensitivity of residual compressive stress to air pressure

3. Technical Issues

3.1. Measures facilitating smaller gear size

Figure 7 shows a map of typical contact ratios, which is used here in making a relative comparison of gears and sizes having different modules. The horizontal axis shows the transverse contact ratio, which expresses the size of the gear teeth (module, etc.) and is determined by the contact length along the line of action of a gear pair. The vertical axis shows the overlap contact ratio that is an index specific to helical gears and is expressed as the value obtained by dividing the tooth face width by the axial pitch.

The planetary gears of the Jatco CVT7 are positioned near the small end of the typical range of the total contact ratio, expressed as the sum of the transverse and overlap ratios. This clearly indicates that the planetary gears of the Jatco CVT7 are the gear size benchmark.

It is generally said that gears having a small total contact ratio are at a disadvantage with respect to noise/vibration performance. This issue was addressed by adopting a phase difference design and by using a prediction of dynamic tooth face displacement to correct the targeted gear accuracy.

3.2. Measures supporting high torque capability

Micro-shot peening was adopted as a measure for enhancing gear strength. For controlling residual compressive stress, the sensitivity of stress to the air pressure, shot weight and exposure time was found, and a control range was determined that satisfies both the gear strength requirement and production requirements. Figure 8 shows one example of peak stress values in relation to the air pressure of the shot peening process.

As one example of the effect of micro-shot peening, Fig. 9 compares the dedendum strength of planetary gears with and without the shot peening process.

マイクロショットピーニング効果の一例として，遊星歯車の歯元強度は，Fig. 9に示す効果が得られた．

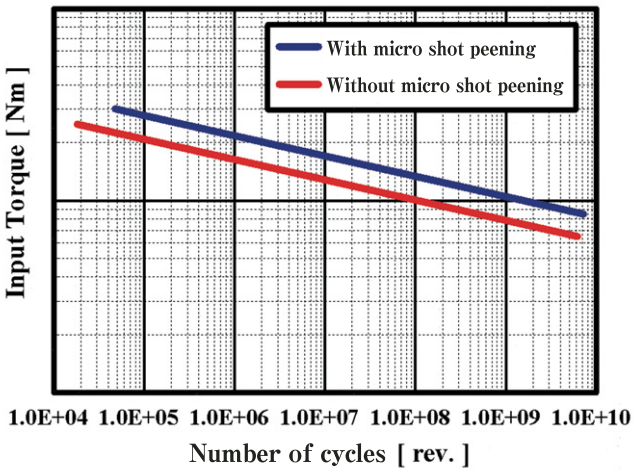

Fig. 9 T-N diagram of dedendum strength

4. まとめ

Jatco CVT7の小型化要求に対応する為にレイアウト効率の良いラビニオ式遊星歯車機構を採用した．同時に，ショットピーニングを採用することで高強度化も実現した．

最後に本開発にあたって多大なご協力頂いた生産技術部，サプライヤーの方々へあらためて謝意を表する．

4. Conclusion

A Ravigneaux planetary gear set providing high layout efficiency was adopted for the auxiliary transmission of the Jatco CVT7 to meet the downsizing requirements. Simultaneously, a micro-shot peening process was adopted to ensure high gear strength as well.

Finally, the author would like to express appreciation to JATCO's Production Engineering Department and to the suppliers involved for their invaluable cooperation with the development of the Jatco CVT7.

■ Author ■

Junichiro TATEISHI

小型軽量トルクコンバーターの開発

Development of a Compact, Lightweight Torque Converter

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抄　録　Jatco CVT7用トルクコンバーターには，燃費改善と軽量化を目的として，トルクコンバーターサイズ系列見直しによるサイズダウンし軽量化･軸長短縮を実現すると共に，更なる燃費改善を目的とした低剛性ダンパーを採用した．

本稿では，これらの達成結果について紹介する．

Summary　The torque converter adopted for the Jatco CVT7 was downsized through a review of torque converter size variations to achieve a lighter weight and a shorter axial length for improved vehicle fuel economy and weight savings. In addition, a low-stiffness damper was adopted for the purpose of improving fuel economy further. This article describes the improvements achieved for this torque converter.

1. はじめに

トルクコンバーター（以下TCとする）は，エンジン（以下ENGとする）のトルク変動を減衰させ，かつ入出力回転数の違いに応じて外部からの制御なしにトルクを可変増幅する機能を持った流体継ぎ手である．

TCは，自動変速機に要求される信頼性，応答性，滑らかさ，駆動力特性など総合的にバランスの良い性能を備えた発進要素であり，自動変速機のほとんどに採用されている．

しかし，燃費や重量の点では改善要求が強く，コスト低減を図りながら小型化やロックアップ（以下LU）の高機能化のニーズは高い．

本稿では，上記の要求を背景に開発されたJatco CVT7用TCについて紹介する．

2. 小型TCへの挑戦

2.1. TCの目標値と達成度合い

Jatco CVT7は小型車のみならず軽自動車に対しても搭載可能なサイズにすることが求められた．そのため，TCの全長短縮が必須となり，−15%の軸長短縮を自主目標と置いた．また，質量低減は当時のベンチマークでトップを目指すべく，−10%を自主目標値とした．

1. Introduction

A torque converter is a type of hydrodynamic coupling that functions to dampen fluctuations in engine torque and to amplify torque variably without any external control according to the difference in input and output rotational speeds. Nearly all automatic transmissions today incorporate a torque converter as the start-off element that provides an excellent all-around balance of the performance required of ATs, including reliability, responsiveness, smoothness and driving force characteristics.

However, there have been strong demands for further improvement of torque converters with respect to fuel economy and weight. There are definite needs for a smaller size and higher lockup functionality while reducing costs.

This article describes the torque converter developed for use with the Jatco CVT7 against the backdrop of these requirements.

2. Challenge to Downsize the Torque Converter

2.1. Torque converter performance targets and degree of attainment

The Jatco CVT7 had to be configured in a size that would allow application not only to small cars but also to minivehicles. That required shortening the

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軸長短縮･質量低減を達成しなければならないが，従来TCより，流体性能･ダンパー特性は性能を悪化させることは許されず，特にダンパー特性については，燃費向上するため，LU低車速化は必須要件であり，ダンパーの特性は従来特性をより低剛性にしたダンパーが求められた．

各々の目標値の達成度合いは，

トルクコンバーター全長　－17%（従来比）

トルクコンバーター質量　－11%（従来比）

ダンパー捩り角度　＋190%（従来比＋3段特性化）

を達成した．

次項より夫々の達成方法を説明する．

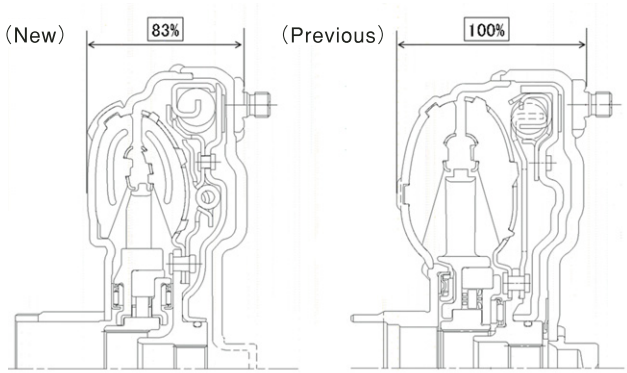

Fig. 1 Length comparison of new and previous torque converter

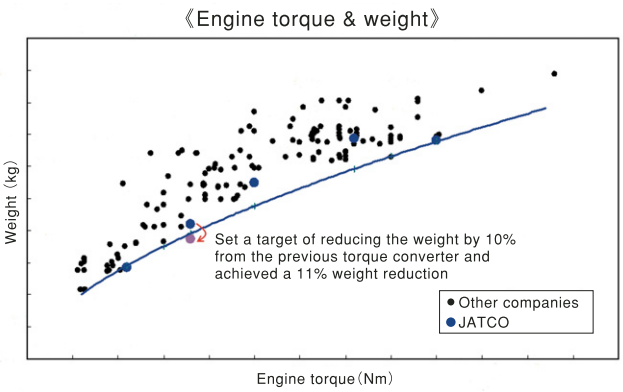

Fig. 2 Engine torque vs. weight benchmark

2.2. TC小型･軽量化

トルクコンバーター全長　－17%（従来比）

トルクコンバーター質量　－11%（従来比）

軸長短縮し，且つ低剛性ダンパー化すると，どうしてもダンパー部分に従来より多くレイアウトがとられてしまう．

そこで，CVTに必要な特性を考え，TCで大きく占有している流体継ぎ手部分（トーラス）の小型化を実施した．

overall torque converter length. A 15% reduction of the axial length was set as a self-defined target. Additionally, a weight reduction of 15% was set as a self-defined target with the aim of achieving the lightest weight in relation to the benchmark at that time.

While the axial length had to be shortened and the weight reduced, the hydrodynamic performance and damping characteristics could not be any less than that of the existing torque converter. Damping characteristics in particular had to be achieved with a damper having less stiffness than existing dampers because lockup operation at a lower vehicle speed was a requisite condition for improving vehicle fuel economy.

Each target value was attained to the following extent:

Overall torque converter length:

17% shorter than the existing unit

Torque converter weight:

11% lighter than the existing unit

Damper torsional angle:

190% larger than that of the existing unit and with three levels of damping characteristics

The methods employed to attain the targets are explained below.

2.2. Torque converter size and weight reductions

- 17% shorter overall torque converter length compared with the existing unit
- 11% lighter torque converter weight compared with the existing unit

In order to shorten the axial length and also reduce damper stiffness, the damper itself would necessarily require larger layout space compared with the existing torque converter. Therefore, taking into account the performance characteristics required of a CVT, it was decided to downsize the torus, or fluid coupling circuit, that accounts for a large portion of the size of a torque converter.

The first possibility we considered was to use a fluid coupling. Lightening the weight of a hydrodynamic coupling to its ultimate level would result in a fluid coupling. However, because a fluid coupling has no torque amplification effect, it could not meet the power performance required of vehicles.

We then focused on the wide ratio coverage of 7.3, which is one of the biggest features of the Jatco

まず考えたのが，フルードカップリング（以下FCとする）である．流体継ぎ手として，究極的に軽量化しようとすれば，FCとなるが，FCではトルク増幅作用が無く車両の動力性能を満足することが出来なかった．

そこで，Jatco CVT7の最大の利点である7.3のレシオカバレッジを持つことに注目し，スルーローにおけるトルクをギヤ側に分担して使用することができるため，TCの流体性能，特に必要トルク容量を小さくすることが可能となった．また，LU領域の拡大によって，流体でのトルク伝達領域を発進時のみに限定できると考え，従来のTCサイズ系列をJatco CVT7に限定し見直しを実施した．その結果小型にシフトし，軸長短縮･質量低減の大きな助けとなった（Fig. 3）．

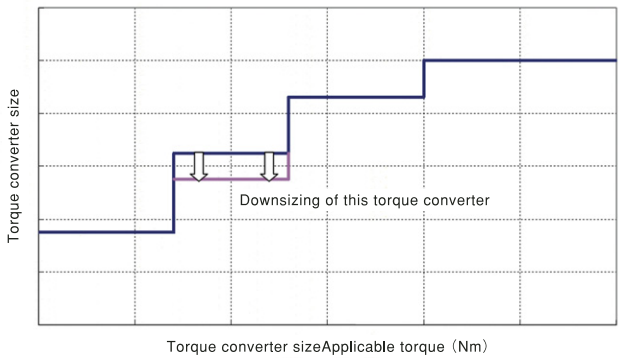

Fig. 3 Torque converter size variations applied to different torque levels

2.3. 低剛性ダンパーの必要性

LU低車速化をしていくと，車両の重要な特性である静粛性の中で，LU時のこもり音と車両の振動特性が悪化する可能性がある．Jatco CVT7は，副変速機を搭載しプーリーを小型化している．またTC自体も小型･軽量化しているため従来のトランスミッションよりイナーシャが小さい．加えて，従来の4気筒ENGに対して，回転変動の大きい3気筒ENGへの適用であり，LU時のこもり音と車両の振動特性，特にステアリング（以下 STGとする）振動の悪化が課題であった．解決するために，従来のダンパー特性をより低剛性化させる必要があった．ダンパーを低剛性化させる場合，スプリング（以下 SPRとする）作用径を大きくする，SPRの外径を大きくする，捩り角度を増やす等が考えられるが，車両搭載性から，TCの軸方向･径方向ともレイアウトの拡大は不可能であった．必要レイアウト内に収めつつ，更なる低剛性ダ

CVT7. In the through low state, the gears alone can provide sufficient torque transmission, making it possible to reduce the hydrodynamic performance of the torque converter, especially the necessary torque capacity. Moreover, we reasoned that expanding the range of lockup operation would make it possible to limit the region of torque transfer by the fluid to just vehicle launch alone. The existing torque converter size variations were then reviewed, and a smaller size was adopted specifically for the Jatco CVT7 (Fig. 3). This shift to a smaller size contributed significantly to shortening the axial length and reducing the weight.

2.3. Necessity of a low-stiffness damper

Expanding lockup operation to a lower vehicle speed might possibly worsen booming noise and vehicle vibration during lockup. That would degrade quietness, which is a critical vehicle attribute. The Jatco CVT7 incorporates an auxiliary transmission and downsized pulleys. Moreover, because the torque converter is also smaller and lighter, this CVT has less inertia than conventional transmissions. In addition, the Jacto CVT7 will be mated to three-cylinder engines that have larger speed fluctuations than their conventional 4-cylinder counterparts. The possible worsening of booming noise and vibration, especially steering system vibration, during lockup operation was an issue of concern.

The solution required reducing the stiffness of the existing damper to a lower level. Various approaches can be considered when reducing damper stiffness, such as increasing the working diameter of the springs, making the outer diameter of the springs larger or increasing the torsional angle, among others. However, considering vehicle mountability, it was not possible to increase the layout in either the axial or radial direction of the torque converter. Therefore, a damper with three levels of damping characteristics was developed in order to keep the size within the required layout space and achieve the necessary reduction in damper stiffness.

Figure 4 outlines the damper requirements schematically. Reducing the stiffness of the first-level spring (solid green line) did not cause any problem in previous vehicle applications. However, a smaller number of engine cylinders caused the resonance orders to change; one that ordinarily occurred before

ンパーが必要とされ，今回3段特性ダンパーの開発を行った．

Fig. 4は必要性を示す模式図である．1段目SPR剛性を下げた緑の線（緑実線）では，従来車両では問題無かったが，車両側のENG気筒数減により共振次数が変わり，通常LU車速前にあったものがLU中に発生してしまうようになる（黄波線）．そしてその変動が1段目SPR剛性域でトルク変動に加算され，こもり音とは別のステアリング振動限界を超えることになった．これを抑えるため，1段目SPR剛性を更に低剛性化させる必要があった．1段目SPR剛性をさらに低剛性化させるには，よりダンパーの捩り角度を大きくとらなければならないが，エンジントルクを1段目SPR剛性でカバーできなくなる．しかし，前述で述べた通り，決められたスペースの中では捩じり角度を増やすことは出来ず．

途中で1段目SPR剛性から2段目SPR剛性へ見かけ上の剛性変更を行わせることにより成立解を得た．

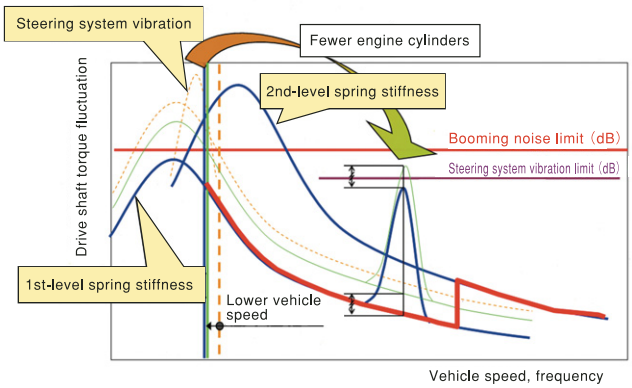

Fig. 4 Schematic diagram showing the necessity of a low-stiffness damper

2.4. 低剛性ダンパーの構造

低剛性化を実現するためにLong Travel Damper（以下 LTDとする）を採用した．従来構造の概念図及び今回採用した3段特性ダンパーの概念図をFig. 5に示す．またダンパー特性をFig. 6に示す．

Fig. 5の構造概念の比較を参照して頂きたい．

従来構造のLTDはホールドプレートを入力，ドリブンプレートを出力とした場合，イコライザープレートを挟んで隣り合ったSPRを同じ剛性とし，直列に作動させて1段目の剛性を発生させていた．

それに対して，今回採用した3段特性ダンパーは，イコライザープレートを挟んで隣り合ったSPRを異なる

the lockup vehicle speed tended to occur during lockup operation (dashed yellow line). That change was added to the torque fluctuation which occurred in the stiffness region of the first-level spring, thereby exceeding the steering system vibration limit, specified separately from the booming noise limit. In order to suppress that resonance, the stiffness of the first-level spring had to be reduced further. Lowering the stiffness of the first-level spring further would require a larger torsional angle for the damper, but that would make it impossible to dampen the engine torque with the stiffness of the first-level spring. As mentioned earlier, however, the torsional angle could not be increased within the limits of the allowable space. A viable solution was found during this process by making an apparent stiffness change from the first-level spring stiffness to the second-level spring stiffness.

2.4. Structure of low-stiffness damper

A long travel damper (LTD) was adopted in order to reduce damper stiffness. The structure of the newly adopted damper with three levels of damping characteristics is shown schematically in Fig. 5 in comparison with the conventional structure. The characteristics of the dampers are compared in Fig. 6.

The concepts of the two structures are compared here in reference to Fig. 5. The conventional LTD is constructed with a holding plate as the input and a driven plate as the output. The two adjacent springs that sandwich an equalizer plate have the same stiffness. The springs act in tandem to generate the first level of stiffness.

In contrast, in the newly adopted damper with three levels of damping characteristics, the adjacent springs sandwiching the equalizer plate have different levels of stiffness. When the springs act in tandem, the stiffness of outer spring B is less than that of outer spring C. As a result, the lower-stiffness spring first acts positively to produce the first level of stiffness. The second level of stiffness is produced by the action of the higher-stiffness spring, with the first-level spring compressing tightly to become a stopper.

The adoption of this new damper with three levels of damping characteristics enabled the damping characteristics to be achieved at a lower level of stiffness than before. This contributes to improving

剛性とし，直列に作動させている．
（この時SPRの剛性は，外周SPR（B）＜外周SPR（C））
これにより先に剛性の低いSPRが積極的に作動することによって1段目の剛性を発生させている．

2段目の剛性は，1段目のSPRが線間密着しストッパーになることで剛性の高いバネが作動し発生させている．

3段特性ダンパーを採用することにより，従来よりダンパー特性を低剛性化させることが可能となり，LU時の車両の振動特性改善（2.3. 項）に寄与することが出来た．

また，従来と同等のスペースで，ダンパーの部品点数を増加させることなくダンパー特性の低剛性化を実現した．

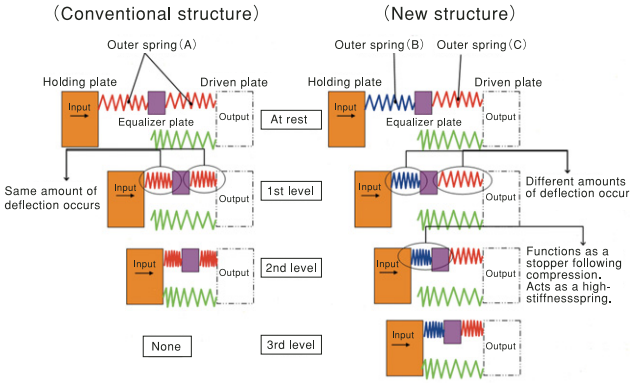

Fig. 5 Structural diagrams

3. おわりに

TCは，自動変速機において車両の動力性能や燃費性能に大きく寄与する機能部品であり，更なる高性能化が要求されている．今後も自動変速機の主力発進要素とすべくLUの高性能化開発に積極的に取り組んで行きたい．

本TC開発にあたりご協力いただいた株式会社エクセディの皆様をはじめ，関係者の方々に深く感謝の意を表します．

vehicle vibration characteristics during lockup operation, as mentioned in the previous subsection.

In addition, the lower damper stiffness characteristics were obtained without increasing the part count of the damper, thereby enabling it to be installed in the same space as the conventional damper.

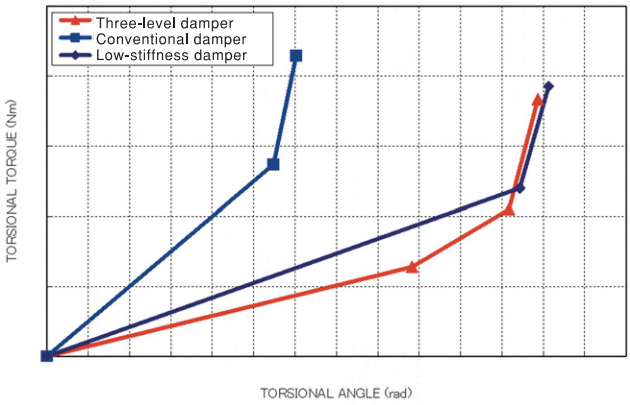

Fig. 6 Comparison of damper characteristics

3. Conclusion

A torque converter is a key functional component that contributes significantly to the power performance and fuel economy of an AT-equipped vehicle. Accordingly, its performance must be further enhanced. In future work, we intend to direct vigorous efforts toward developing higher lockup performance and functionality so that the torque converter will continue to be the principal start-off element of ATs.

The authors would like to thank EXEDY Corporation and various other people involved for their cooperation with the development of this torque converter.

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高効率小型ベーンオイルポンプの開発

Development of a Small, High-efficiency Vane Oil Pump

西山　裕之*　Hiroyuki NISHIYAMA
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抄　録　本稿では，中型CVT用に開発した次世代高効率ベーンオイルポンプを，小型CVTに採用するにあたって，更なる燃費性能向上，小型軽量化，コスト低減技術を投入したので，その開発内容について紹介する．

Summary　A next-generation high-efficiency vane oil pump previously developed for a mid-sized CVT was modified for use with a small CVT. This article describes the development work undertaken to incorporate various technologies in the new oil pump for further improving vehicle fuel economy, reducing the pump size and weight and achieving cost reductions.

1. はじめに

オイルポンプは，プーリー，クラッチ，トルクコンバーターといった油圧作動部品へのオイル供給，ギヤ，ベアリング，ベルトへの潤滑油の供給，また，オイルクーラーへの油供給，とCVTにとって重要な部品の一つである．

近年の環境対応から，オイルポンプのフリクション低減が求められると共に，他社との競争力を維持するために，更なるコストダウンも求められている．

現在の中型CVT（JF011E）では，高効率ベーンオイルポンプを採用することで，大幅なポンプフリクション低減を達成した．このオイルポンプを小型CVT用に採用するにあたって，更なる燃費性能向上，小型軽量化，コスト低減を図った．ここでは，0.66～1.6Lクラスの車に適用するJatco CVT7用に開発したオイルポンプの技術解説を行う．

1. Introduction

The oil pump supplies working fluid to the pulleys, clutches and torque converter that are operated by hydraulic pressure, lubricant to the gears, bearings and belt, and fluid to the oil cooler. As such, it is a vital part of a CVT.

Environmental concerns in recent years have required a further reduction of oil pump friction for improving vehicle fuel economy. It has also been necessary to reduce the cost of the pump in order to maintain competitiveness with other companies.

A high-efficiency vane oil pump was adopted for the current mid-sized JF011E CVT, resulting in a substantial reduction of pump friction. In adapting this oil pump for application to a small CVT, steps were taken to improve fuel economy further, to downsize and lighten the pump and to reduce costs.

This article describes the technologies incorporated in the new oil pump developed for the Jatco CVT7, which is designed for application to vehicles with an engine displacement of 0.66-1.6 liters.

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2. オイルポンプ主要諸元

Table 1にJF011EとJatco CVT7のオイルポンプ主要諸元を示す．Fig. 1にオイルポンプレイアウト図を示す．

Table 1 Major specifications of pumps

	CVT7	JF011E
Torque capacity (Nm)	180	250
Installation configuration	External	External
Speed increase ratio	1.088/1.029	1.129
Basic displacement (cc/rev)	13.1/12.3	18.7
Oil pump type	Vane	Vane
Weight (g)	1050	1600

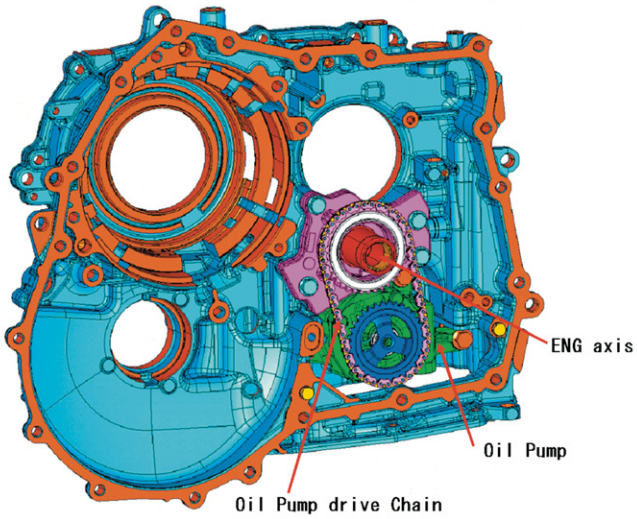

Fig. 1 Oil pump layout

3. 採用した技術的特徴

3.1. 燃費性能向上

Jatco CVT7のオイルポンプ形式は，JF011Eで採用した高効率ベーンオイルポンプを採用した．特徴は，内接型ギヤポンプに比べ摺動抵抗が小さく，かつ容積効率が高く，理論吐出量を小さくする事ができ，ポンプ駆動トルクを大幅に低減できることである．

オイルポンプの駆動トルクを下げるには，ローターの小径化が有効である．しかしながら一定の吐出量を確保する為には小径化した分ローター幅を厚くする必要があり，これによりベーン室への油の充填性が低下しキャビテーションが発生し易くなる．

効率向上とキャビテーション発生の相反する性能を成立させる為に，オイルポンプにフローコントロールバルブを内蔵させた．Fig. 2にポンプ内油路構成を示す．

2. Major Oil Pump Specifications

Table 1 compares the major specifications of the oil pumps used with the JF011E (CVT2) and the Jatco CVT7. The layout of the oil pump is shown in Fig. 1.

3. Features of Adopted Technologies

3.1. Improvement of fuel economy

A high-efficiency vane oil pump of the same type applied to the JF011E was also adopted for the Jatco CVT7. The pump is characterized by its lower sliding resistance and higher volumetric efficiency compared with an internal gear pump. These characteristics make it possible to reduce the theoretical discharge rate, enabling the drive torque of the pump to be substantially reduced.

Reducing the rotor diameter is one effective way of lowering the torque needed to drive the oil pump. However, in order to secure a certain pump discharge rate, it is necessary to increase the rotor width to the extent that the diameter is reduced. A thicker rotor, however, reduces the supercharged pressure of the fluid flowing into the vane chamber, which tends to cause cavitation.

A flow control value was built into this oil pump to satisfy the conflicting performance requirements for improved efficiency and prevention of cavitation. Figure 2 shows the configuration of the hydraulic circuit inside the pump.

The function of the flow control valve is to return excess fluid to the pump suction side, while supplying the necessary flow rate to the hydraulic circuit. The flow passage geometry was designed so that the excess fluid from the flow control valve is effectively forced into the suction side of the pump. That improves the supercharged pressure of the fluid flowing into the vane chamber, which works to prevent cavitation. A key factor in preventing cavitation from occurring in the vane chamber is to accurately determine the amount of excess fluid that must be returned to the pump suction side. If too little fluid is returned to the suction side, the supercharged pressure of the fluid flowing into the vane chamber will decrease, making it impossible to effectively force the fluid into the suction side of the pump. Cavitation will occur as a result.

このフローコントロールバルブの機能は，油圧回路側へは必要な流量を供給しつつ，余剰流量はポンプ吸入側に戻すことである．このフローコントロールバルブからの余剰流量をオイルポンプの吸い込み部へうまく押し込む事ができる流路形状にして，ベーン室への油の充填性（スーパーチャージ性）を向上させることで，キャビテーション発生を防止している．ベーン室のキャビテーション発生を防止するためには，ポンプ吸入側に戻す必要余剰流量の見極めが重要であり，ポンプ吸入側に戻す量が少ない場合には，ベーン室への油の充填性（スーパーチャージ性）が低下し，オイルポンプの吸い込み部へうまく押し込む事ができず，キャビテーションを発生させてしまうことになる．

また，このフローコントロールバルブは，フリクションにも強い相関を持っている．フローコントロールバルブを作動させるために，ポンプ吐出側にチョーク絞りを設けている．このチョーク絞りにより，ポンプ内圧が上昇し，ポンプフリクションが増加する．このフローコントロールバルブによるフリクションを減らそうとすると，このチョーク径を拡大することになるが，それによりフローコントロールバルブの開口が減り，ポンプ吸入側への戻し流量が減る．Jatco CVT7では，フリクション増加代を最小化させるために，流量配分を最適化した．流量配分を最適化するにあたっては，車両適用の広さからJF011Eオイルポンプよりも使用回転数が高く，パワートレイン攪拌により発生したエアを混入した油がスーパーチャージ性を大きく低下させることを考慮し，吐出流量と吸入側への戻し流量の配分を最適化した．

以上の結果として，ポンプ内圧上昇によるフリクションを約30%低減することができた．

3.2 小型軽量化

Table 1に示すように，重量で550gfの軽量化を図った．重量低減はカバー部のアルミ化，固有吐出量低下によるロータ，カムリングの厚さ低減によるものである．また軸長では，吸入回路および内部油路の最適化により，JF011E用オイルポンプに比べて12mm削減している．

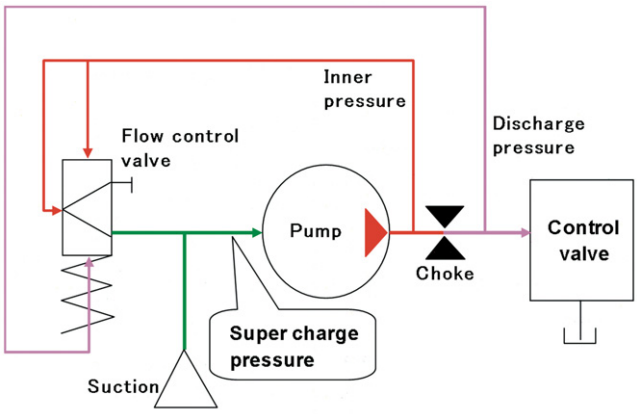

Fig. 2 Oil flow in pump

The flow control valve also has a strong relation to pump friction. A choke is provided on the pump discharge side for operating the flow control valve. The choke raises the inner pressure of the pump, which increases pump friction. Attempting to reduce the friction induced by the operation of the flow control valve would require a larger choke diameter, but that would reduce the aperture of the flow control valve. As a result, the volume of fluid returned to the pump suction side would be reduced.

For the Jatco CVT7 oil pump, the flow rate distribution was optimized to minimize the increased friction attributed to the flow control valve. Optimization of the flow rate distribution took into account the higher operating speed of this oil pump than that of the JF011E oil pump owing to the wider range of vehicle application of the Jatco CVT7. The distribution of the discharged flow and the return flow to the suction side was therefore optimized by considering that the supercharged pressure of the fluid is greatly reduced by air that intermixes with the fluid due to churning in the powertrain at high operating speeds.

As a result of these measures, the friction caused by the higher pump inner pressure was reduced by approximately 30%.

3.2. Size and weight reductions

As shown in Table 1, the weight of the Jatco CVT7 oil pump was reduced by 550 gf compared with the JF011E pump. This weight reduction was achieved by using aluminum for part of the cover and by reducing the thickness of the rotor and cam ring in connection with the lower discharge rate specific to this pump. The new oil pump is also 12 mm shorter in axial

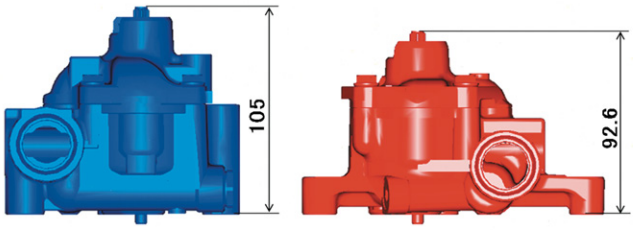

Fig. 3 JF011E vs Jatco CVT7 Oil pump

3.3. コスト低減

一般的にギヤポンプより構造上高価となるベーンオイルポンプだが，すでに量産しているJF011E用オイルポンプとの部品共用化や，JF011E，Jatco CVT7両ポンプの加工基準用の共通ボス（Fig. 4）を設けて，加工ライン共用化も行うことで，大幅にコストダウンを計った．

また，先述した流量配分の最適化で高回転化対応させているため，軽自動車より多くの吐出量を必要とする小型車適用をオイルポンプ駆動チェーン・スプロケットの増速比変更で対応可能とした．これによりポンプを一仕様とすることができ，台数効果による原価低減を実現した．

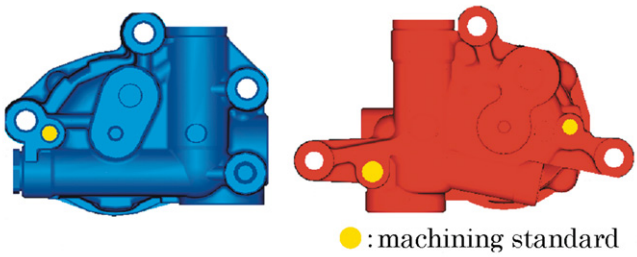

Fig. 4 Common machining standard

4. まとめ

ベーンポンプ開発により，Jatco CVT7の燃費性能向上，小型軽量化，コスト低減を実現した．

（1）燃費性能向上

ポンプ吸入側への戻り流量を最適化することで，フローコントロールバルブのポンプ内圧上昇によるフリクションを約30%低減することができた．

（2）小型軽量化

オイルポンプの小型化及び使用材料変更により，550gfの軽量化と，軸方向寸法でマイナス12mmの小型化を行った．

length than its CVT2 counterpart as a result of optimizing the suction circuit and the internal fluid passages.

3.3. Cost reductions

Vane oil pumps are generally more expensive than internal gear pumps owing to their structure. However, large cost reductions were achieved for this new oil pump by sharing parts with the JF011E oil pump that is already being mass-produced and by sharing machining lines. The latter was accomplished by providing a common boss (Fig. 4) as a machining standard for both the JF011E pump and the Jatco CVT7 pump.

It was noted earlier that the flow distribution in the new oil pump was optimized to facilitate higher operating speeds. The increase speed ratio of the drive chain sprocket of the new oil pump was changed in order to provide the higher discharge rates needed by small cars compared with those for minivehicles. This made it possible to unify the pump specifications and reduce the unit costs owing to the effect of larger production volumes.

4. Conclusion

The development of this small, high-efficiency vane oil pump resulted in a smaller, lighter and lower-cost Jatco CVT7 that improves vehicle fuel economy.

(1) Fuel economy improvement

Optimization of the return flow volume to the pump suction side reduces by approximately 30% the friction generated by the higher pump inner pressure due to the use of the flow control valve.

(2) Size and weight reductions

The smaller oil pump size and changes made to the materials used reduced the pump weight by 550 gf compared with the JF011E oil pump. Additionally, the axial length of the new pump was reduced by 12 mm for a more compact size.

(3) Cost reductions

The sharing of parts with the JF011E oil pump and the unification of specifications for the pumps used on minivehicles to small cars achieved significant cost reductions due to the effect of larger production volumes.

(3)コスト低減

JF011E用オイルポンプとの部品共用化，軽～小型車に同一仕様のポンプを採用することによる台数効果にて，大幅なコスト低減を実現することが出来た．

最後に本オイルポンプの開発にあたり，多大なご協力を頂いたKYB(株)の関係者ならびに社内外の多くの方々に深く感謝する．

Acknowledgments

The authors would like to thank the people concerned at KYB Co., Ltd. as well as many other individuals within and outside JATCO for their valuable cooperation with the development of this vane oil pump.

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FF車用副変速機付きベルトCVTのベルト&プーリー開発

Development of Belt-pulley Assembly for Steel-belt CVT7 with an Auxiliary Transmission for Front-drive Cars

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抄　録　当社は，2009年7月より，副変速機付き小型車向けJatco CVT7（以下，CVT7）の生産を開始した．

このCVT7は，従来の当社製JF009Eと比較して，副変速機を採用することでプーリーの変速比幅を小さくし，それにより，プーリーの小型化，軽量化，及び部品の簡素化を行った．また，本CVT7は，グローバルでの競争力を確保するため，最近目覚しい発展を遂げている新興国での交通事情をも考慮し開発を行った．特に，ベルト&プーリーについては，新たな開発に取り組み，新型6層ベルト（エレメント幅24mm，リング6層×2列）を実用化し，性能･品質とその生産性との両立を図った．本論文では，CVT7のベルト&プーリーに関する特徴とその取り組みについて紹介する．

Summary　In July 2009, JATCO launched production of the Jatco CVT7 featuring an auxiliary transmission and intended for small car application. The adoption of the auxiliary transmission allowed the ratio coverage of the belt-pulley assembly to be reduced compared with that of JATCO's existing JF009E CVT. As a result, the pulleys were downsized, reduced in weight and their parts were simplified. The road and traffic conditions in emerging economies, which have been achieving remarkable growth in recent years, were also taken into account in developing the CVT7 so as to ensure its global competitiveness. Efforts were especially undertaken to develop a new belt-pulley assembly for the CVT7. A new belt with 24-mm-wide elements and two steel rings with six laminated layers each was adopted to reconcile performance and quality with improved productivity. This article describes the development efforts undertaken and the features of the new belt-pulley assembly for the CVT7.

1. はじめに

近年，地球環境問題及び経済性の観点から，自動車の燃費向上の要求は，ますます高まってきている．加えて，新興国での自動車需要の伸びは衰えることなく，インフラ整備や所得増加に伴い，手動変速機からの代替として，自動変速機の需要も急激に増加傾向にある．そのような背景から，燃費性能の高い自動変速機は，先進国のみならず，新興国において，今後も益々需要が増加すると予想されている．

ジヤトコ（株）は，現在，軽自動車用から3.5Lクラス大型車用まで幅広いトルク容量に対応したCVTを生産しているが，新興国の需要などから，小型車を中心に大幅に増加することが予測されている．ま

1. Introduction

Calls for improvement of vehicle fuel economy have continually risen in recent years owing to global environmental concerns and economic issues. In addition, demand for ATs has also tended to increase sharply as a substitute for MTs accompanying the construction of road infrastructure and rising incomes in emerging economies where the growth of vehicle demand shows no sign of weakening. Against this backdrop, it is projected that demand for ATs with high fuel efficiency will continue to increase further not only in developed countries but also in emerging economies in the coming years.

JATCO is currently producing a full lineup of CVTs to accommodate a wide range of torque capacities, from units for use on minivehicles to a unit

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た，新興国での使用環境は，先進国より厳しい使用環境下での使用が考えられることから，強度･耐久性などを含めた信頼性の確保も重要な開発要素となる．

本稿では，2009年7月より，生産を開始したCVT7のベルト及びプーリーの特徴と，その開発内容について紹介する．

2. CVT7ベルト･プーリー諸元

Fig. 1に示すように，変速比幅を拡大するために副変速機を採用している．そのため，Fig. 2に示すように，CVT7は，ユニットの変速比幅7.3とトップクラスであるが，プーリーの変速比幅は4.0に，重量は約30%の低減，プーリー外径も大幅に小型化することができた．

主要諸元をTable 1に示す．CVT7には，プーリー小型軽量化のために，スライドプーリー支持部位の

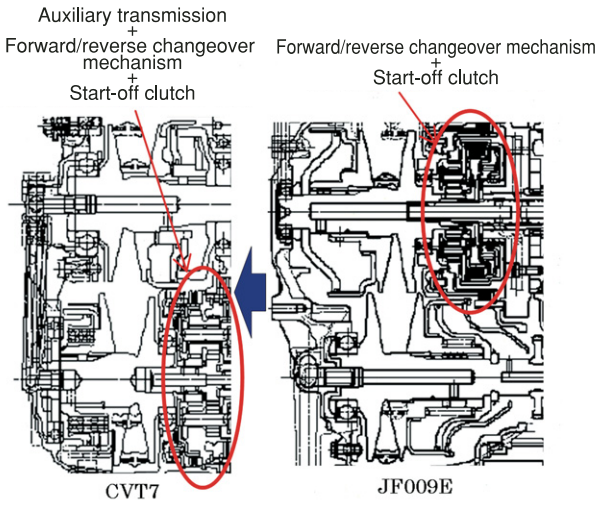

Fig. 1 Comparison of pulley structures

for application to large 3.5-liter class vehicles. It is projected that demand for small cars will increase markedly in the coming years owing primarily to demand for such vehicles in emerging economies. Assurance of reliability, including strength and durability, will be a key factor in developing CVTs for small cars because vehicles are driven under much harsher environmental conditions in emerging economies than in developed countries.

This article describes the development process and features of the belt-pulley assembly of the CVT7 that went into production in July 2009.

2. Specifications of Belt-pulley Assembly of CVT7

As indicated in Fig. 1, the CVT7 incorporates an auxiliary transmission for attaining wider ratio coverage. As a result, the CVT7 achieves world-leading ratio coverage of 7.3 as shown in Fig. 2. Yet the ratio coverage of the belt-pulley assembly has been set at 4.0, enabling a substantially smaller pulley outer diameter and a weight reduction of about 30% compared with the existing JF009E CVT.

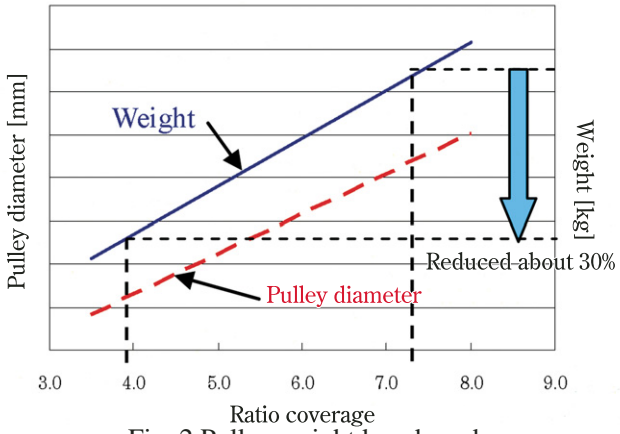

Fig. 2 Pulley weight benchmark

Table 1 Comparison of major specifications of belt-pulley assembly

Major specification / Year first adopted		JF009E		CVT7	
		2003	2006	2009	2012
Ratio coverage		6		4	
Pulley ratio	Low	2.561		2.200	
	High	0.427		0.550	
Belt	Number of ring layers	12	9	9	6
Pulleys	Sliding pulley half support	Three-row roller bearing		Single-row cylindrical roller bearing	
	Primary pulley pressure chamber	Single		Tandem	
	Centrifugal pressure cancelling mechanism	With		Without	

円筒コロ1溝化，プライマリー油圧室のタンデム化，及び遠心キャンセル機構の廃止を織り込んでいる．

また，ベルトは，エレメントとリングで構成されている（Fig. 3）が，適用される各CVTユニットの最大トルクに応じて，強度･耐久性要件を満足させるため，リングの枚数を変更し対応している．

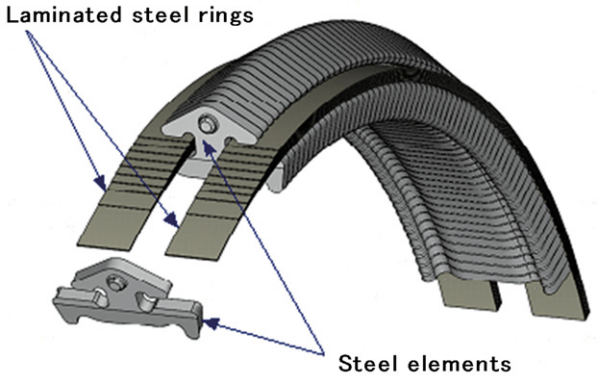

Fig. 3 Structure of belt

2009年のCVT7生産開始時には，JF009Eと同タイプのベルト（PHASE6）で，リング層数は9層であったが，2012年より，新タイプのベルト（PHASE7）を採用することで，リング層数を6層に削減した．

3. CVT7プーリーの特徴について

3.1. CVT7プーリーの軽量化，コンパクト化

前章で説明したとおり，ベルト･プーリーには，プーリー構造を工夫した軽量化アイテム，更にCVT7の特徴を活かしたコンパクト化アイテムを織り込んでいる．

3.1.1. スライドプーリー支持部位における軽量化

CVT7以前の当社製CVTでは，プーリーの支持方式は，ボール溝3点で支持することが一般的であった．Fig. 4に示すとおり，CVT7では，円筒コロ方式でかつ1点支持へと設計変更した．これにより，スナップリング溝の廃止も可能となり，プーリー軸方向長さを短縮することも可能となり，軽量化が実現できた．

3.1.2. CVT7の特徴を活かしたプーリーのコンパクト化

CVT7は，副変速機があるため，他機種のCVTと比較すると，プーリーの最ロー比を2.2と小さくして

The main specifications of the belt-pulley assembly are given in Table 1. For the purpose of reducing the size and weight of the CVT7 pulleys, a single-row cylindrical roller bearing was adopted to support the sliding pulley half, a tandem pressure chamber was adopted for the primary pulley, and the mechanism for cancelling centrifugal pressure was discontinued.

The CVT belt is composed of elements and laminated rings as shown in Fig. 3. The number of ring layers is varied to satisfy the strength and durability requirements corresponding to the maximum torque capacity of the CVT in which the belt is used.

At the time CVT7 production was launched in 2009, a phase 6 belt with nine-layer rings was used, the same type as in the JF009E. Beginning in 2012, a new phase 7 belt has been adopted that reduces the number of ring layers to six.

3. Features of CVT7 Pulleys

3.1. Smaller, lighter pulley design

As mentioned in the previous section, innovations were made to the pulley structure to reduce the weight of the belt-pulley assembly. In addition, the features of the CVT7 were also utilized to incorporate measures for achieving a more compact size.

3.1.1. Lighter support structure for sliding pulley half

Prior to the CVT7, JATCO CVTs have generally used three-row roller bearings to support the sliding pulley half. As shown in Fig. 4, the support structure of the CVT7 pulleys was redesigned to a single-row cylindrical roller bearing. This design change also

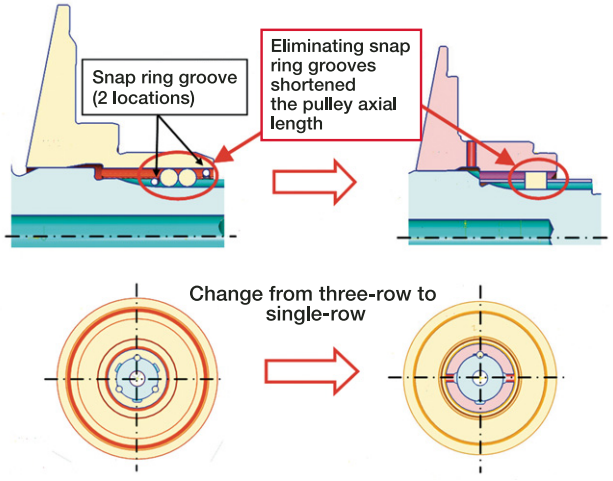

Fig. 4 Measures for reducing weight of sliding pulley half

いる．それにより，最大プーリー出力トルクが低くなり，必要なベルトクランプ力（プーリー推力）が小さくなるため，受圧面積を小さくしている（Fig. 5）．その結果，プーリーASSYの小型軽量化を行うことができた．

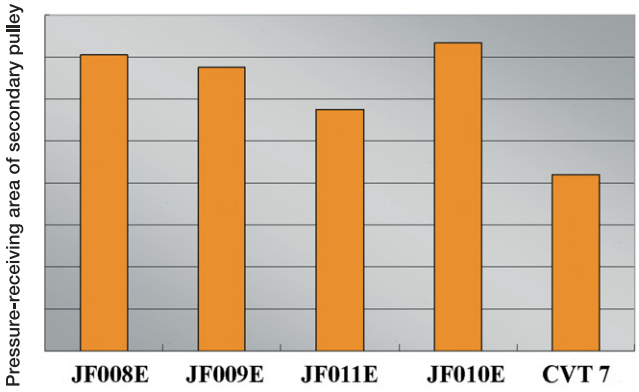

Fig. 5 Comparison of pressure-receiving area of secondary pulley

また，CVT7は，プーリー油圧方式が，プライマリー側のみ調圧可能な片調圧方式である．本方式では，調圧する機構（電子ソレノイド）を1個削減できるため，CVT7では，バルブボディ（油圧制御機構）の小型化が可能となった．このバルブボディ小型化により，CVT7のレイアウトでは，ユニットの全高を低く抑えることができ，ユニットの軽量化と，車両の地上高UPを抑制することに大きく貢献している．

ただし，片調圧方式は，変速する際にプライマリー，セカンダリーの各スライドプーリーの推力差を大きくしなければいけないため，受圧面積比が大きくなるように設計する必要がある．プライマリー側は，タンデムピストンにより，油圧室径を大きくすることなく，受圧面積を拡大している．セカンダリー側は，受圧面積を小さくできるため，油圧室径を小さくしている．通常，セカンダリー側は，回転数が非常に高くなるため，油圧室内の油にかかる遠心力が大となり，油圧室内の油圧を上昇させる．この遠心力による油圧を遠心油圧と呼ぶが，遠心油圧は油圧を制御する上で障害となりえるため，遠心油圧キャンセル機構（Fig. 6）を設けて，対処している．CVT7では，油圧室径を小さくしているため，油圧室にかかる遠心油圧が小さくなる．そのため，CVT7では，遠心油圧キャンセル機構を廃止でき，プーリーASSYの軽量小型化が可能となった．

made it possible to discontinue the snap ring grooves, thereby allowing the pulley axial length to be shortened and resulting in further weight savings.

3.1.2. More compact pulley size

Because the CVT7 features an auxiliary transmission, its lowest pulley ratio of 2.2 is smaller than that of other CVT models. This means that the maximum pulley output torque is lower, so the necessary belt clamping force (pulley thrust) is smaller. This allows a smaller pressure-receiving area compared with other CVTs as indicated in Fig. 5. As a result, this structural feature of the CVT7 made it possible to reduce the size and weight of the pulley assembly.

Additionally, a single-side pulley pressure modulation system has been adopted for the CVT7 that modulates only the primary pulley pressure. With this system, the number of electronic solenoid valves used for pressure modulation can be reduced by one, thereby allowing a smaller valve body that serves as the pressure control mechanism. The smaller valve body enabled the overall height of the CVT7 layout to be reduced, which contributed substantially to lowering the weight of the unit and to suppressing any increase in vehicle ground clearance.

However, with a single-side pressure modulation system, it is necessary to increase the thrust difference between the sliding halves of the primary and secondary pulleys when shifting. Therefore, the pulleys must be designed so that the ratio of their pressure-receiving surfaces increases. The primary pulley pressure chamber of the CVT7 adopts a tandem piston for increasing the pressure-receiving area without any increase in the chamber diameter. The secondary pulley pressure chamber has been designed with a smaller diameter so that the pressure-receiving area can be reduced. Ordinarily, the fluid in the secondary pulley pressure chamber is subjected to large centrifugal force owing to the markedly higher rotational speed of this pulley. That force causes the hydraulic pressure in the chamber to rise. The pressure produced by this centrifugal force is referred to as centrifugal pressure, which can interfere with proper pressure control. To avoid that, a mechanism for cancelling centrifugal pressure has generally been provided as shown in Fig. 6. Because the secondary

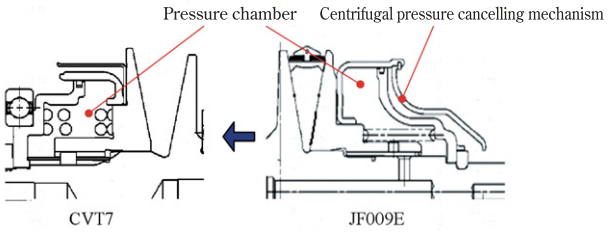

Fig. 6 Comparison of structure of secondary pulley pressure chamber

3.2. プーリーの耐衝撃性について

これまで，CVTは，先進国向け車両を中心に採用されてきたが，本開発では，新興国向け車両への採用も前提に，過酷な使用環境下となることが予想されるため，ベルト&プーリーへのタイヤ側からの衝撃荷重はより厳しくなる．

そこで，発進クラッチをプーリーの後方へ配置することにより，タイヤ側からの衝撃荷重が大きい場合，発進クラッチで衝撃荷重を緩和したり，発進クラッチの締結を解除することで，ベルト&プーリーへの衝撃荷重を大幅に低減させることができる．これにより，プーリー強度設計において，耐衝撃性の確保のための設計要件が少なくなり，プーリーの軽量化，小型化に大きく貢献している．

4. 新タイプベルトの特徴

CVT7では，従来の同サイズCVTと同タイプのベルト（PHASE6-リング9層，エレメント幅24mmベルト）を採用してきたが，昨今のCVT需要増加に対応すべく，性能，品質を確保しつつ，生産性を大幅に向上させることを目標に開発に取り組み，新型ベルト（PHASE7-リング6層，エレメント幅24mmベルト）を開発したので，その特徴の1つであるリング材料について紹介する．

CVTベルトのリングは，高張力鋼板であるマルエージング鋼を採用しているが，CVTベルトとしては，0.2mm以下の薄板で使用されることもあり，破損の起点が介在物であることが一般的であった．

そこで，新型リングでは，添加元素を変更し，大きな介在物がリング表面近傍に含有される確率を大幅に低減することができた（Fig. 7）．

この材質変更により，リングの耐久性を大幅に向上させることができ，CVT7では，9層から6層へリング枚数を削減することが可能となった．

pulley pressure chamber of the CVT7 has a smaller diameter, the centrifugal pressure acting on the fluid in the chamber is smaller. That allowed the mechanism for cancelling centrifugal pressure to be discontinued in the CVT7, enabling the size and weight of the pulley assembly to be reduced.

3.2. Pulley impact resistance

To date, CVTs have mainly been used on vehicles marketed in developed countries. The CVT7 was developed on the assumption that it would also be adopted on vehicles sold in emerging economies. Accordingly, it was assumed that this CVT would be used in harsher driving environments with more severe impact loads applied to the belt-pulley assembly from the tires.

Therefore, the start-off clutch has been positioned behind the pulleys for the purpose of mitigating large impact loads transferred from the tires. Releasing the start-off clutch makes it possible to substantially reduce the impact load applied to the belt-pulley assembly. That allowed the design requirement for assuring impact resistance to be relaxed when executing the pulley strength design, which contributed significantly to reducing the pulley weight and size.

4. Features of New Type of Belt

The CVT7 initially adopted the phase 6 belt with nine-layer rings and 24-mm-wide elements, which is the same type of belt that has been used previously in identical-size CVTs. However, a new phase 7 belt with 6-layer rings and 24-mm-wide elements was subsequently developed and applied to the CVT7. This new belt was developed with the aim of dramatically improving productivity, while ensuring performance and quality, so as to meet the increased demand for CVTs in recent years. One feature of this new belt is the ring material, which is described below.

The CVT belt rings are made of maraging steel, one type of high-tensile steel. Because CVT belt rings are thin plates of 0.2 mm or less in thickness, inclusions in the steel are generally the origin of ring damage.

For the rings of the new belt, the additive elements

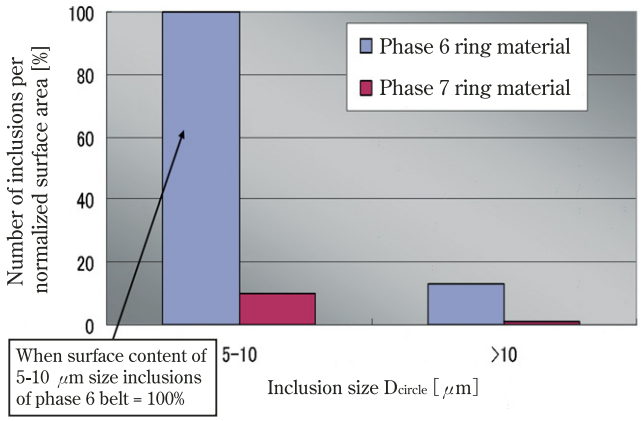

Fig. 7 Comparison of inclusion content between old and new belt rings

5. まとめ

CVT7は軽自動車から小型車まで　国内および海外の拠点での拡大展開が計画され，他社製品と比べても極めて競争力の高い商品とするため，新たにベルト&プーリーの基礎開発に取り組み，効果の高い改良案創出･実用化できた．一方，CVTのキー部品となるベルト開発では，ボッシュ株式会社との共同開発により，CVT7用新型6層ベルトを採用することができたことも相まって，更なる性能改善，生産性向上の成果を上げることができた．

これらの施策によって，今後，より安価で，より環境に優しいCVTが世界各地で数多く普及し，環境問題解決の一躍を担うことができることを願うとともに，今後も継続的な改良を行い，究極の変速機を追い求めていく所存である．

were changed to markedly reduce the likelihood that large inclusions would be present near the ring surface (Fig. 7). This material change substantially improved ring durability, making it possible to reduce the number of ring layers from nine to six for the CVT7 belt.

5. Conclusion

It is planned to expand production of the CVT7 at both domestic and overseas manufacturing centers for application to a wide range of vehicles from minivehicles to small cars. In order to achieve a transmission with exceptionally high competitiveness compared with the products of other companies, we undertook fundamental development activities to develop a new belt-pulley assembly. Many highly effective measures were devised and adopted toward that end.

As one of the key components of a CVT, a new 6-layer belt was jointly developed with Bosch Corporation for the CVT7. That development was also notably effective in further improving the performance and productivity of this unit.

It is hoped that the measures described here will help to promote the spread of large volumes of more reasonably priced, environmentally friendly CVTs worldwide in the future and that they will play a significant part in resolving various environmental issues. We intend to undertake further efforts to achieve continuous improvements in the coming years in the pursuit of the ultimate automotive transmission.

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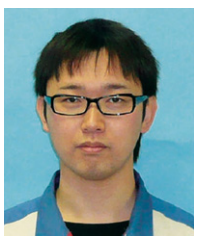
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燃費と動力性能の両立を実現した副変速機の変速制御

Shift Control of Auxiliary Transmission that Delivers Fuel Economy Combined with Power Performance

野々村　良輔*
Ryosuke NONOMURA

抄　録　Jatco CVT7の最大の特徴は，燃費と動力性能の両立，小型･軽量化を達成するために世界で初めて採用された副変速機である．本稿では，従来CVTと同等のスムーズなシフトフィーリングと加速性を実現するために開発した副変速機の変速制御技術，中でも動力性能目標達成のために必要な変速制御技術の内容を紹介する．

Summary　The most distinctive feature of the Jatco CVT is the world's first application of an auxiliary transmission for reconciling power performance with fuel economy and achieving size and weight reductions. This article describes the shift control technology developed for the auxiliary transmission to secure the same smooth shift feeling and acceleration as that of conventional CVTs. Special focus is put on the details of the shift control technology needed to achieve the power performance target.

1. 副変速機の構成とシフトパターン

副変速機はベルト変速機構の後ろに配置され，前進2段，後進1段の変速が可能である．前進側の1速ではLow Brake（以後LB）を締結し，2速ではHigh Clutch（以後HC）を締結する．この副変速機はOne Way Clutchを持たない構造で，1-2速，2-1速の切り替えは全てクラッチの掛け替え変速となる．

副変速機の変速パターンであるが，まず，副変速ギア比を1速から2速へ変速させるアップシフトに関しては2種類あり，1つ目は，プーリ比最High付近で変速するパターンで，中高車速域での車両加速度，及びアクセル開度一定のオートアップや，アクセル開度変化のある足離しアップシフト時に選択する．これには，副変速時のクラッチ掛け替え変速による変速ショックを可能な限り低減させるため，副変速機への入力トルクの小さい領域で変速させたい，という意図がある（Fig. 1）．

もう1つは，低車速の足離しアップシフト時に，上述よりもややプーリ比Low側で変速するパターンである．これには，燃費向上を狙った運転時に頻繁に使われる，低車速･低エンジン回転の領域で，積極

1. Configuration and Shift Patterns of Auxiliary Transmission

The auxiliary transmission is positioned behind the belt-pulley shift system and provides two forward speeds and one reverse speed. On the forward speed side, a low brake (LB) is engaged in 1st gear and a high clutch (HC) is engaged in 2nd gear. Because the auxiliary transmission is built without a one-way clutch, 1st-2nd upshifts and 2nd-1st downshifts are all executed by switching between the clutches.

The following is an explanation of the shift patterns of the auxiliary transmission. First, there are two types of upshift patterns for changing the auxiliary gear ratio from 1st to 2nd gear. The first pattern is for upshifting near the highest pulley ratio. This pattern is selected for vehicle acceleration in the intermediate to high speed range, for an automatic upshift at a certain given accelerator pedal position, and for an upshift when the accelerator pedal position changes because the driver lifts up on the accelerator. The intention of this pattern is to shift in the region of small input torque to the auxiliary transmission so as to reduce as much as possible the shift shock induced by switching between clutches when the auxiliary transmission shifts (Fig. 1).

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的に2速へ変速し，トランスミッション動力伝達効率の良いプーリ比1付近を使用したい．という意図がある（Fig. 2）．

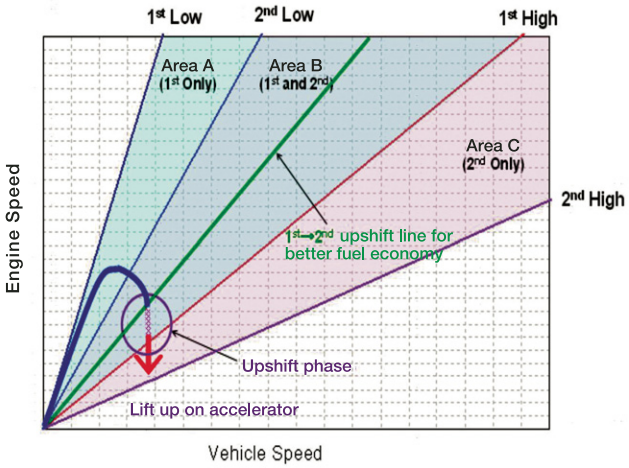

Fig. 2 Upshift patterns for fuel economy

次に2速から1速へのダウンシフトであるが，基本的にはプーリ比最Low付近で変速する．これには，主に変速頻度を最小限に抑えたい．という意図があり，また，プーリ比に加えて，車速とアクセル開度を元に決められるアクセル開速度の条件を持ち，ドライバーの加速意図を判断してダウンシフトさせることで，副変速2速で実現出来る以上の加速を必要とするシーンに限定してダウンシフトさせることが出来，変速頻度の低減とシフトクオリティを最適化させている（Fig. 3）．

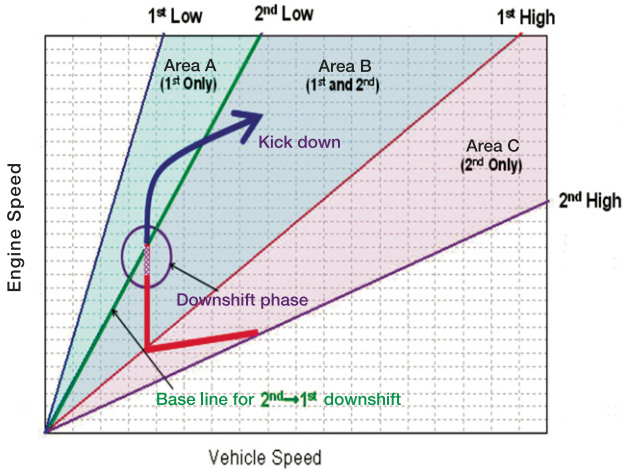

Fig. 3 Downshift patterns

また，ダウンシフトには，停車後に瞬時にクラッチの掛け替えを行うパターンもある．

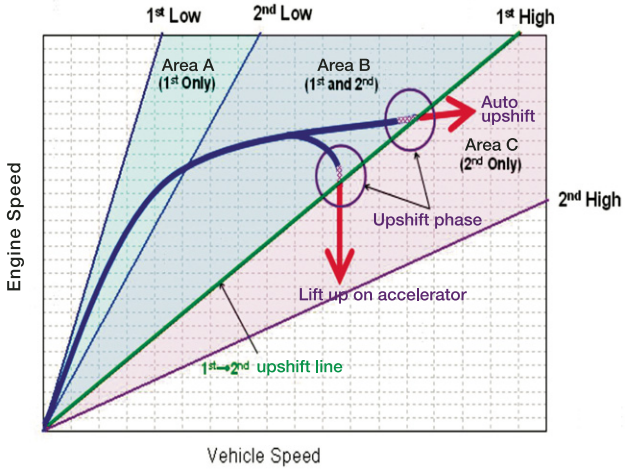

Fig. 1 Upshift patterns

The second pattern is for shifting when the pulley ratio is more on the low side than in the first pattern above, such as an upshift when the driver lifts up on the accelerator pedal at a low vehicle speed. The strategy of this pattern is to intentionally upshift to 2nd gear so as to use a pulley ratio near 1:1 for transferring power efficiently by the transmission (Fig. 2). This pattern is aimed at improving fuel economy at low vehicle/engine speeds where vehicles are frequently operated in everyday driving.

Next, the pattern for a 2nd-1st downshift is basically executed near the lowest pulley ratio. The primary intention of this pattern is to minimize as much as possible the shift frequency of the auxiliary transmission. In addition to the pulley ratio, the conditions in this pattern include the accelerator depression speed, as determined on the basis of the vehicle speed and the accelerator pedal position. The idea is to judge the driver's intention to accelerate and downshift accordingly. This makes it possible to limit downshifts to situations where the driver's demanded acceleration exceeds what is obtainable in 2nd gear of the auxiliary transmission. As a result, it reduces the frequency of shifting by the auxiliary transmission and optimizes shift quality (Fig. 3).

Another downshift pattern involves switching between clutches immediately after the vehicle is stopped.

2. 副変速技術

2.1. アップシフト（1−2変速）

副変速制御におけるクラッチ圧制御方法とその目的は，従来のステップATと基本的には同様であるが，Jatco CVT7固有の制御として，イナーシャフェーズでのプーリとの協調制御を行っている．それは，ステップATのようなエンジン回転段差を発生させることなく，従来CVTと同様のエンジン回転軌跡を実現するため，目標トータルギア比と目標副変速ギア比から目標プーリ比を算出し，それぞれの目標に従って，プーリとクラッチの油圧制御を行うというものである．

また，トルクフェーズにおけるクラッチ掛け替え時に発生する変速ショックの低減のために，クラッチのミートポイントを学習する学習制御，及び締結時の必要クラッチトルク容量を学習する学習制御を行い，初期品の油圧やハードの寸法バラツキ，また摩擦材の摩擦係数などの経時劣化による特性変化を保証している．

2.2. キックダウン2−1変速

キックダウン2-1変速も，フェーズの種類はオートアップ1-2変速と同一であり，各フェーズにおけるクラッチ圧制御方法とその目的は，従来のステップATとほぼ同様である．Jatco CVT7固有の制御については，次のとおりである．

まず，変速判断と同時に，イナーシャフェーズにより副変速機入力回転数（以後Sec回転数）を1速回転まで持ち上げる．その際，回転停滞，または回転吹け上がりによる車両の加速遅れ（ヘジテーション）を防止するために最適なクラッチ圧を指示し，目標の回転変化を実現する．Sec回転数が1速回転まで持ち上がったところでトルクフェーズを開始し，クラッチの掛け替えを行う．

また，安定した変速を実現するため，キックダウン2-1変速判断に伴って，クラッチの元圧であるライン圧を，通常必要以上の，クラッチ圧が安定する高さまで昇圧させている（Fig. 4）．

2. Shift Technologies for Auxiliary Transmission

2.1. 1st -2nd upshifts

The method and purpose of controlling the clutch pressure in the auxiliary transmission shift control are basically the same as for conventional stepped ATs. The only control procedure unique to the Jatco CVT7 is cooperative control with the belt-pulley shift system in the inertia phase. In this control procedure, the target pulley ratio is calculated based on the target total gear ratio and the target gear ratio of the auxiliary transmission. The pulley and clutch pressures are then controlled in line with the two targets so as to obtain the same engine speed profile as with a conventional CVT and without causing any engine speed discontinuity like what occurs with a stepped AT.

Adaptive learning control is performed to learn the clutch engagement points so as to reduce shift shock caused by switching between clutches in the torque phase. Adaptive learning control is also used to learn the clutch torque capacity needed for engagement, which works to compensate for initial variability in hydraulic pressure and hardware dimensions and for changes in characteristics due to aging, including the coefficients of friction of clutch friction materials.

2.2. 2nd-1st kickdown shifts

The types of phases in 2nd-1st kickdown shifts are the same as those of automatic 1st-2nd upshifts. The method and purpose of controlling the clutch pressure in each phase are virtually the same as for a conventional stepped AT. A control procedure that is unique to the Jatco CVT7 is described below.

First, simultaneously with a shift judgment, the input rotational speed of the auxiliary transmission (referred to here as the secondary pulley speed) is raised to that of 1st gear. The optimum clutch pressure is indicated at that moment so as to achieve the target pulley speed change and thereby prevent any vehicle acceleration delay (hesitation) due to engine speed sluggishness or flare-up. At the point where the secondary pulley speed has been raised to that of 1st gear, the torque phase begins and switching between clutches is performed.

Concomitant with the judgment of a 2nd-1st kickdown shift, the line pressure, which is the original

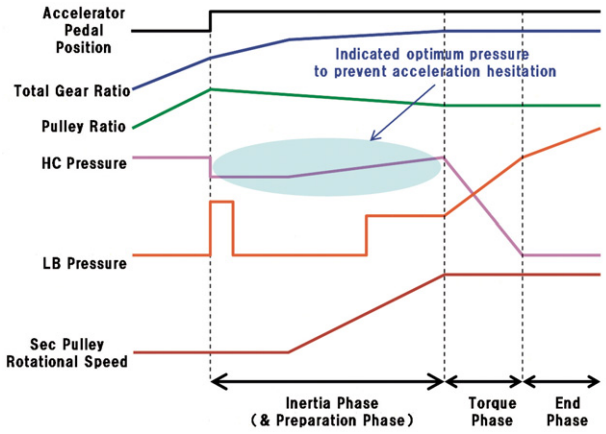

Fig. 4 Kickdown control

2.3. キックダウン2−1変速学習制御

キックダウン2-1変速では，踏込み時のヘジテーションを抑え，掛け替え変速時の変速ショックを個体差や経時劣化に依らず安定させるため，各フェーズにおけるクラッチ圧を学習している．その詳細は次のとおりである．

まず，イナーシャフェーズ開始からSec回転変化開始までの時間をモニタリングし，予め設定した目標値との相対関係から，イナーシャフェーズで前半のHC指示圧を決め，学習する．さらに，イナーシャフェーズ後半の時間とSec回転の吹け上がり有無をモニタリングし，目標値との相対関係から，イナーシャフェーズ後半におけるHC指示圧とLBのリターン棚指示圧，及びトルクフェーズにおけるLB指示圧の立ち上げタイミングを決め，学習する（Fig. 5）．

これらの学習制御により，イナーシャフェーズ時間が安定し，またSec回転の吹け上がりも防止されるため，踏込み時のヘジテーションを抑えられ，トルクフェーズにおけるクラッチ掛け替えタイミングが安定するため，変速ショックも安定し，従来CVTと同等の変速性能を実現している（Fig. 6）．

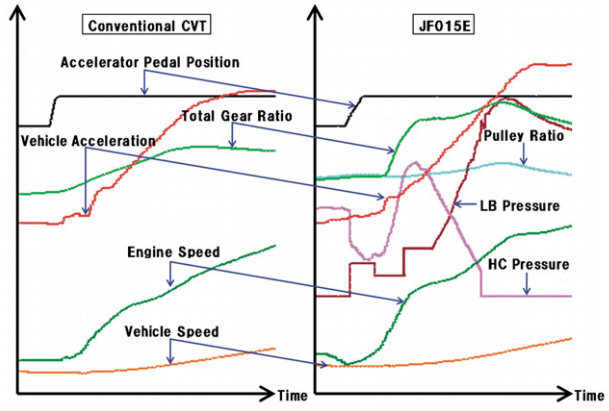

Fig. 6 Experimental waveforms of kickdown shift

pressure for the clutches, is raised more than what is normally necessary to a level where the clutch pressures are stable so as to obtain stable shift quality (Fig. 4).

2.3. Adaptive learning control for 2nd-1st kickdown shifts

Clutch pressures in each phase of a 2nd-1st kickdown shift are learned so as to avoid vehicle hesitation when the accelerator pedal is depressed and achieve stable shift quality when switching between clutches regardless of individual component variability or deterioration due to aging. The details of this adaptive learning control are explained below.

The duration from the start of the inertia phase to the onset of the change in the secondary pulley speed is monitored. Based on the relationship with a predetermined target value, this control procedure determines and learns the HC command pressure in the first half of the inertia phase. It also monitors the duration of the second half of the inertia phase and whether there is any flare-up of the secondary pulley speed. Based on the relationship with the target value, the control determines and learns the HC command pressure and the LB return command pressure in the second half of the inertia phase as well as the rise time of the LB command pressure in the torque phase (Fig. 5).

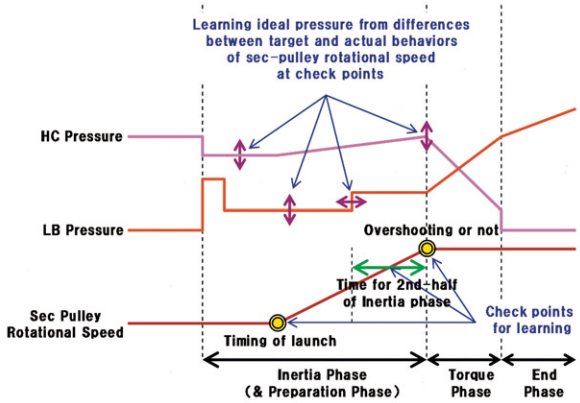

Fig. 5 Adaptive learning control for kickdown shifts

These adaptive learning control features serve to stabilize the duration of the inertia phase and prevent flare-up of the secondary pulley speed. Therefore, vehicle hesitation is suppressed when the driver depresses the accelerator pedal. Additionally, clutch switching timing in the torque phase is stabilized, thereby providing stable shift quality to deliver smooth shift performance equal to that of conventional CVTs (Fig. 6).

2.4. 停車時2−1変速制御

従来のステップATでは，走行中にコーストダウン変速を行っているが，Jatco CVT7では，上述のとおり，遊星ギアの前にプーリが配置されており，副変速時の実プーリ比が減速度に依って変化し，副変速機への入力トルクも変化するため，変速ショックレベルを安定させることが出来ないという理由から，走行中のコースト2-1変速を行わず，停車時に行っている．制御の詳細は次のとおりである．

走行中の副変速とは異なり，停車中はSec回転数を変化させることが出来ないため，イナーシャフェーズを行わない．停車判定は，確実に停車している状態を検知するため，車速ではなく，プライマリ軸，セカンダリ軸，出力軸の各回転センサパルス停止をもって行っている．停車判定後，トルクフェーズにて直ちにクラッチの掛け替えを行うが，LB回路に設定されているアキュームレータによる実LB圧の応答遅れを考慮し，LB指示圧をステップで上昇，HC指示圧をランプで下降させ，さらにエンジントルク上限規制を行うことにより，副変速中の踏込み時等におけるクラッチトルク容量不足を防止している（Fig. 7）．

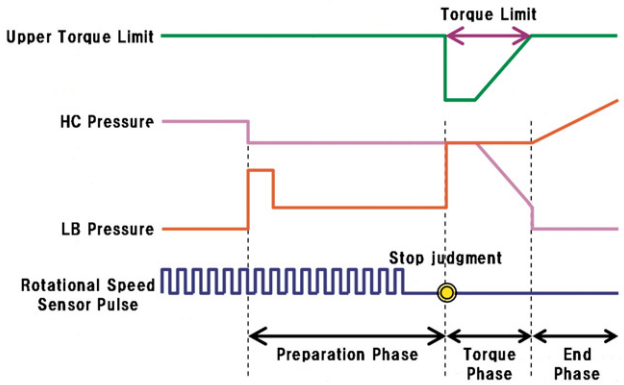

Fig. 7 Downshift control at vehicle stop

3. おわりに

以上のように，世界初のプーリと副変速機の協調制御や，学習制御を駆使したクラッチ圧制御を用いて，従来CVTと同等のスムーズなシフトフィーリングと加速性を実現した．

一方，Jatco CVT7が発売されて2年以上が経つが，その間，さらなる性能向上のための新規制御の開発を進めている．中でも，重要度の高いキックダウン2-1変速時の加速性向上のための制御開発を

2.4. 2nd-1st shift control at vehicle stop

A conventional stepped AT executes a coast downshift while a vehicle is still moving, but the Jatco CVT7 executes a 2nd-1st coast downshift after the vehicle stops, rather than while it is moving. The reason for that is as follows. At mentioned earlier, the belt-pulley system is located before the planetary auxiliary transmission. The actual pulley ratio when the auxiliary transmission shifts changes according to the rate of deceleration. Because the input torque to the auxiliary transmission also changes, the level of shift shock cannot be kept stable. The details of this control procedure are explained below.

There is no inertia phase while a vehicle is at rest because the secondary pulley speed cannot be changed, unlike the shifting of the auxiliary transmission. Judgment that the vehicle is stationary is made based on the suspension of the signal pulses from the rotational speed sensors on the primary pulley shaft, secondary pulley shaft and the output shaft, rather than using the vehicle speed. This strategy facilitates reliable detection that the vehicle is stopped. After judging that the vehicle is stationary, the clutches are immediately switched in the torque phase. The LB command pressure is raised in consecutive steps, taking into account a possible response delay of the LB pressure due to the accumulator provided in the LB hydraulic circuit. The HC command pressure is ramped down and the upper engine torque limit is also controlled. This control procedure serves to prevent insufficient clutch torque capacity if the driver depresses the accelerator pedal while the auxiliary transmission is shifting (Fig. 7).

3. Conclusion

This article has described the world's first cooperative control technology for a belt-pulley system and an auxiliary transmission as well as clutch pressure control techniques using adaptive learning control. These shift control features achieve a smooth shift feeling and acceleration equal to conventional CVTs.

Two years have passed since the Jatco CVT7 was released. During this time, we have been working to develop new control techniques for further improving its performance. Special priority has been put on

重点的に行っており，逐次市場に投入していく計画である．これを含めたさらなる副変速性能向上にご期待頂きたい．

developing a control procedure for improving acceleration performance at the time of a 2nd-1st kickdown shift, which is a high priority item. It is planned to implement new control procedures successively in the Jatco CVT7, which can be expected to result in further improvement of auxiliary transmission performance.

■ Author ■

Ryosuke NONOMURA

Jatco CVT7の最新制御と適合技術

Newest Control System and Calibration Techniques for the Jatco CVT7

森　真人*
Masato MORI

抄　録　小型･軽量化，燃費と動力性能の両立を達成する為に，世界で初めて副変速機を備えた小型のCVTを世に送り出した．本稿では，Jatco CVT7における副変速制御の適合技術について紹介する．

Summary　JATCO released the small CVT7 incorporating the world's first auxiliary transmission for achieving fuel economy combined with power performance in a smaller and lighter package. This article describes the techniques used to calibrate the shift controls applied to the auxiliary transmission of the Jatco CVT7.

1. はじめに

2009年7月，当社では副変速機を備えた小型のCVTを製品化することに成功した．副変速機を備えることで，従来のCVTよりも幅広いレシオカバレッジを有し，動力性能と燃費を大幅に向上することが可能となった．

しかし，副変速機を有し，有段でありながらCVTとして求められる滑らかな変速を実現しなければならない大きな課題が発生した．

本稿では，我々性能･制御実験グループが取り組んだ，従来CVTと同等レベルの変速性能を実現する為の副変速制御適合技術について紹介する．

2. 副変速1→2アップシフト

2.1. パワーON加速時の1→2変速

発進加速（以下「オートアップ」とする）時に副変速機を2速へとアップシフトし，副変速機の段間差分だけプーリーをダウンシフトすることで，回転変動無く，加速と共にHigh側への変速を続けることができるようになる（Fig. 1）．

この為には，実際には副変速機の切り替えとプーリーの変速を対称的に，かつ正確に行なわなければトータル変速比が上下変動し回転変化を招き，ドライバーへの不快感へ繋がってしまう（Fig. 2）．それを防ぐ為に，副変速機をいかにプーリーの動きに合

1. Introduction

In July 2009, JATCO successfully launched production of the small CVT7 featuring an auxiliary transmission. The addition of an auxiliary transmission gives the CVT7 much wider ratio coverage than conventional CVTs, making it possible to improve both power performance and fuel economy substantially. However, incorporating a stepped planetary auxiliary transmission in the CVT7 gave rise to a critical issue of ensuring the smooth shift performance demanded of a CVT.

This article describes the control system and calibration techniques developed by the Product Performance and Control System Experiment Group to achieve seamless shift performance equal to that of conventional CVTs.

2. 1st-2nd Upshifts of Auxiliary Transmission

2.1. 1st-2nd upshifts during power-on acceleration

During vehicle launch acceleration, the auxiliary transmission automatically upshifts to 2nd gear and the pulley ratio is downshifted to the extent of the step difference between 1st and 2nd gears of the auxiliary transmission. This control procedure ensures continuous shifting to the high ratio side as the vehicle accelerates without any fluctuation in engine speed (Fig. 1).

To actually accomplish that, the upshifting of the

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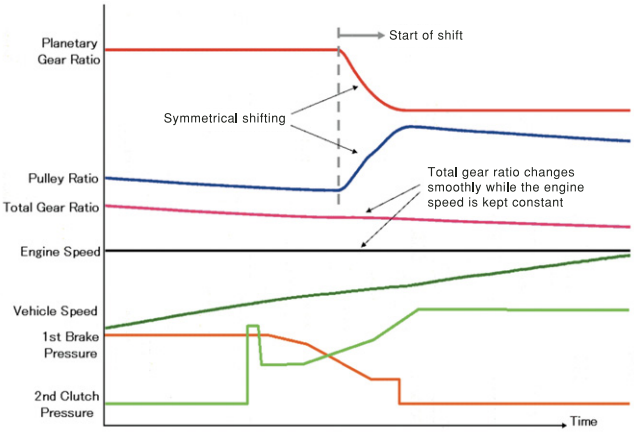

Fig. 1 Ideal automatic upshift control

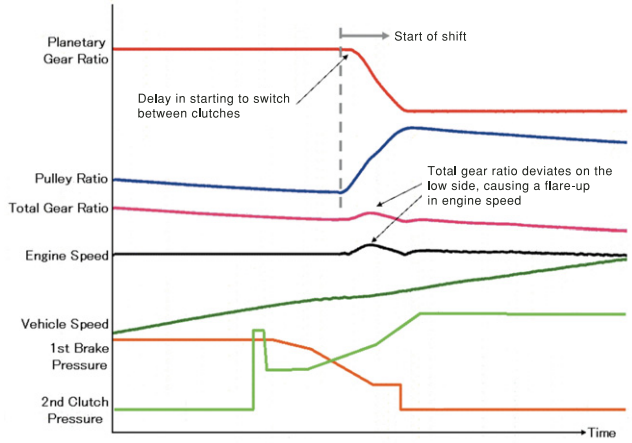

Fig. 2 Poor automatic upshift control

わせて，またはプーリーを副変速機に合わせて滑らかに変速させることができるかが重要となる．

副変速には，エンジンの推定トルク精度，クラッチクリアランスや摩擦特性，油圧応答性などのバラツキ要素が多々あり，同じ走行条件で変速していても，環境や個体差により変速制御中に回転吹け上がりや回転落ちが発生し挙動が安定しない．

そこで，この固体差を吸収するためにクラッチの学習を行っている．CVT各個体においてクラッチの学習が進むことでバラツキを吸収し安定した変速が可能となる．

ここで，適合技術が必要となるのは，クラット学習領域の決定である．例えばオートアップ1→2変速で，クラッチ指示圧はエンジンのコントロールユニットからCAN通信で送られてくる推定エンジントルクの大きさによって変化する．この推定トルクと実トルクとの差をクラッチ学習が吸収する．

auxiliary transmission and the downshifting of the pulley ratio must be done symmetrically and accurately. If that is not done, the total gear ratio will fluctuate up and down, causing the engine speed to vary and giving the driver an unpleasant sensation (Fig. 2). To avoid that, it is necessary to coordinate and harmonize both the action of the auxiliary transmission and that of the belt-pulley system so that both shift smoothly.

The auxiliary transmission is affected by many fluctuating factors, including the accuracy of the estimated engine torque, clutch clearance and friction material characteristics, and hydraulic pressure response, among others. Even if shifts are executed under the same driving conditions, the operating environment or individual component variability may cause engine speed flare-ups or dips during shift control, thereby giving rise to unstable vehicle behavior.

Therefore, the clutch pressure is learned in order to absorb such individual variability. Adaptive learning control of clutch pressure behavior is performed for each CVT component so as to absorb individual variability and ensure smooth, stable shifting.

A calibration technique is needed here for determining the region of adaptive learning of the clutch pressure. For example, in an automatic 1st-2nd upshift, the clutch command pressure varies according to the magnitude of the estimated engine torque sent from the engine control unit via CAN communication. Adaptive learning control of the clutch pressure works to absorb differences between the estimated and actual torque values.

However, torque estimation accuracy is not the same in all speed ranges. Error of the estimated torque value tends to differ between low engine speeds with a small throttle valve opening and high engine speeds with a large throttle valve opening. For example, consider a vehicle mounted with an engine where the actual torque tends to be is less than the estimated value for a small throttle valve opening and larger than the actual value for a large throttle valve opening. If the vehicle is accelerated repeatedly at a small throttle valve opening, the actual torque will be learned only in a region that is lower than the estimated torque. In this case, the AT control unit will calculate the clutch torque capacity needed for clutch engagement at a higher level than what is actually

しかし，トルク精度は全域同じではなく，アクセル低開度側低回転と高開度高回転では推定値誤差が異なる場合がある．例えば，低開度側は推定トルクに対して実トルクが低く出ていて，高開度側は推定トルクに対して実トルクのほうが高く出る特性のエンジンを搭載した車両があったとする．この車両で低開度加速を繰り返すと，実トルクが推定よりも低い領域のみで学習することになる．この場合ATCUはクラッチ締結に必要なクラッチトルク容量を実際よりも高く算出するため，クラッチ指示圧を下げる方向に学習補正が働く．油圧を低く学習したこの状態で，アクセル高開度でのオートアップ1→2変速を行なうと，必要油圧が不足しクラッチが回転上昇を抑えきれずに吹け上がることになってしまう．

実際に前述のような事例が存在し学習制御に影響を与えてしまうこともあるため，実験の中で推定トルクと実トルクとを測定し，乖離の影響を受けない領域を見極め，学習許可領域の最適適合を行い，学習収束性，安定性を向上している．

2.2. 足離し時の1→2変速

前述したオートアップ時の回転を保つ1→2変速に対し，足離しのように回転を下げながらアップシフトを行う足離し時1→2変速においても，前述の学習制御が作動していれば問題ない．しかし，足離し1→2変速制御中にエンジンがフューエルカットを行うと入力トルクの急変が発生し安定した変速が困難となる．

入力トルクに合わせてクラッチ油圧が急変しクラッチ急締結することによるショックを発生させないように，エンジンとの協調によりフューエルカットをディレイする制御も行っている．この制御は，足離し1→2変速中においては，変速が終了するまでフューエルカットを一時的に遅らせる適合を行うことで運転性を確保した．

2.3. 1→2変速規制

燃費向上のためには，伝達効率の良い2速への変速をできるだけ行ないたいが，再加速時の運転性向上の為，シーンに応じて1→2変速を規制しプーリー変速のみを行っている．例えば低車速でのウインカー作動時には，右左折後の再加速意図がある

required. As a result, adaptive learning compensation will work to lower the clutch command pressure. Under this condition where a lower clutch pressure has been learned, the required pressure for an automatic 1st-2nd upshift with a large throttle valve opening will be insufficient. This will make it impossible to control the increase in clutch speed and will result in a speed flare-up.

The situations described above actually occur and can influence adaptive learning control. Therefore, the estimated torque and actual torque were measured experimentally and a region was determined where adaptive learning control would not be influenced by the divergence in values. Optimized calibration of the region where adaptive learning control is allowed thus works to improve the convergence and stability of the control procedure.

2.2. 1st-2nd upshifts with accelerator released

In the automatic 1st-2nd upshift described above, the engine speed is maintained, whereas in a 1st-2nd upshift with the accelerator pedal released the transmission shifts up as the engine speed is being reduced. In this case as well, there is no problem if adaptive learning control operates as described above. However, if the fuel supply to the engine is cut off during 1st-2nd upshift control with the accelerator pedal released, the input torque to the transmission will change abruptly, making it difficult to execute a stable upshift.

Cooperative control with the engine is executed to delay the fuel cut-off. This works to prevent shift shock that might otherwise occur due to sudden clutch engagement caused by the abrupt change in the clutch pressure matching the input torque level. The control procedure is calibrated to delay a fuel cut-off momentarily until a 1st-2nd upshift with the accelerator pedal released has been completed, thereby ensuring good driveability.

2.3. 1st-2nd upshift restriction

It is desirable to upshift to 2nd gear as much as possible to obtain good power transmission efficiency for enhancing fuel economy. However, for improving driveability during re-acceleration, 1st-2nd upshifts are restricted depending on the driving situation and only the pulley ratio is changed. For example, at a

と判断し，2速へのアップシフトを規制する．また登り勾配でも駆動力を確保する為に勾配に応じて規制を行なう．ブレーキが踏まれた場合には，停車もしくは減速後の再加速意図があると判断し規制する．以上のように，路面の状況やドライバー動作を予測し，変速頻度を低減し架け替えを繰り返すことによるラグを防止する適合を行うことで，運転性向上を図っている．

3. キックダウン2→1変速

3.1. キックダウン2→1変速判定

副変速機が2速にいる状態でのアクセル踏み込み時，目標変速比が2速領域内の場合には，プーリー変速のみでLow側へ変速して駆動力を確保するが，状況に応じて副変速機を1速へ架け替える．また2速での低車速時にはプーリーは最Low付近にある為，再加速時にさらに駆動力を確保する為には1速へ変速する必要がある．低車速ではない場合でも比較的速い踏み込み操作があった場合には，急加速意図があると判断し，早めに1速へ変速を行なう．

以上のように，副変速の架け替えタイミングは，状況に応じて最適に設定しており，車速，アクセル開度，そしてアクセル踏み込み速度などのパラメータより，総合的に判断を行っている．

エンジン排気量，車両重量，その他電子制御スロットル特性等の違いにより，踏み込みに対して得られる出力が異なるため，最適適合が必要となってくる．また，燃費への影響も考慮し，クラッチ架け替えによるロスを低減するために，この変速開始判断は重要となってくる．

3.2. 油圧応答との戦い

キックダウン2→1変速ではオートアップ1→2変速とは異なり速い変速レスポンスが要求される．変速をゆっくりと行なえば無段変速機のような滑らかな変速を行なうことができるが，1速駆動力に切り替わるまで時間がかかってしまいドライバーはもたつきを感じる．

速い変速を行なわせる場合には，それに応じた油圧応答が必要となる．応答が間に合わない場合には，クラッチが吹け上がってしまい締結時のショック

low vehicle speed with one of the turn signals on, the system judges that the driver intends to accelerate again after making a right or left turn, so an upshift to 2nd gear is restricted. The upshift restriction is also activated on uphill grades to secure ample driving torque depending on the road grade. In cases where the brakes are applied, the upshift restriction is activated because the system judges that the driver intends to accelerate again after stopping or slowing down the vehicle. The system is calibrated to improve driveability in these situations by preventing any lag due to repeatedly switching between clutches. This is accomplished by estimating the road surface condition and the driver's driving operations so as to reduce the frequency of shifting.

3. 2nd-1st Kickdown Shifts

3.1. Judgment of 2nd-1st kickdown shifts

When the driver depresses the accelerator pedal with the auxiliary transmission in 2nd gear, only the pulley ratio is shifted to the low ratio side to secure sufficient driving torque, if the target gear ratio is within the 2nd gear range. Depending on the driving conditions, however, the clutches may be switched to downshift the auxiliary transmission to 1st gear. Moreover, because the pulley ratio is near the lowest ratio when the vehicle is traveling at low speed in 2nd gear, it is necessary to downshift the auxiliary transmission to 1st gear in order to secure more driving torque to accelerate the vehicle again. Even in cases where the vehicle speed is not low, if the driver depresses the accelerator pedal relatively quickly, the system judges that the driver wants to accelerate rapidly and downshifts to 1st gear earlier.

As described here, the timing for switching between the auxiliary transmission clutches is optimally set to match various driving conditions. Comprehensive judgments are made based on the vehicle speed, accelerator pedal position, accelerator depression speed and other parameters.

Optimized calibration is necessary because the power obtained when the driver depresses the accelerator pedal varies depending on differences in engine displacement, vehicle weight, electronic throttle characteristics and other specifications. Judgment of the right timing for initiating shifting is

に至る．これを防ぐ為に次のような手段をとった．

まず変速前に1速ブレーキ圧をクラッチトルク伝達開始状態付近で待機させておく．そしてクラッチの回転変化に合わせて，1速ブレーキ指示圧を早出しし実圧の応答を促す．このような制御および適合により，1速ブレーキが締結する際の油圧応答が遅れることを防いでいる．

しかし1速ブレーキ圧を上昇させる高さやタイミングを誤ると，油圧応答が追いつかずにエンジン回転数が吹け上がりクラッチ締結時にショック，また油圧応答が早すぎると1速と2速でクラッチ容量が過多となり駆動力の落ち込みに繋がる為，適切な適合が必要となる．ショックに対するロバスト性向上の為，油圧を上昇させるタイミングについては，学習制御によって微調整している．1速ブレーキ締結時の微小な吹け上がりを検知し，昇圧タイミングと量を学習補正することで，油圧応答バラツキを吸収している．上昇させる高さ設定は，前述した学習値が，学習領域内で収束可能な値に設定する．このように1速ブレーキ圧を最適適合･学習補正することで，性能が破綻することなく，安定した変速を行なうことができる．

3.3. キックダウン2→1変速レスポンスの適合

レスポンスについては，2速クラッチ圧の抜き方を変えることで調整することができる．2速クラッチ圧をゆっくり落としていけば回転変化が緩やかになり，滑らかな変速フィーリングが得られる反面，レスポンスは遅くなる（Fig. 3）．

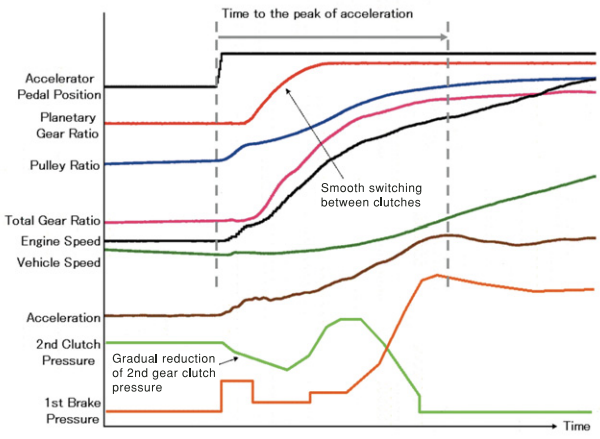

Fig. 3 2nd-1st kickdown shift calibrated with priority on smoothness

also important for reducing power losses due to switching between clutches so as to minimize the impact on fuel economy.

3.2. Struggle with pressure response

Unlike an automatic 1st-2nd upshift, a 2nd-1st kickdown shift requires a fast shift response. If a kickdown shift is executed gradually, it is possible to obtain a smooth shift like that of a CVT, but it takes time for the auxiliary transmission to change to the driving torque level of 1st gear. As a result, the driver would feel that the transmission is shifting too slowly.

Executing this shift quickly requires an equally fast pressure response. If the pressure response is not fast enough, the clutch speed will flare up, resulting in a shock at the time of engagement. The following measure was adopted to prevent such shock.

First, before the shift is executed, the 1st gear brake pressure is raised and held near the level where the clutch begins to transmit torque. The 1st gear brake command pressure is then output in advance to match the change in the clutch rotational speed, thereby prompting the actual pressure response. This control procedure and calibration technique prevent any pressure response delay when the 1st gear brake engages.

However, if the 1st gear brake pressure is raised to an incorrect level or at the wrong time, the pressure response may not be able to follow properly, resulting in an engine speed flare-up that causes a shock when the clutch engages. If the pressure response is too fast, excess clutch capacity may occur between 1st gear and 2nd gear, leading to a drop in driving torque. Optimal calibration is needed to avoid these problems. Adaptive learning control is applied to fine-tune the timing for raising the pressure so as to improve robustness against shocks. By detecting tiny speed flare-ups at the time the 1st gear brake engages, the control procedure learns and compensates the timing and amount of pressure increase. This works to absorb variation in the pressure response. The level of the pressure increase is set to a value to which the learned pressure value can be converged within the range of adaptive learning control. This optimized calibration and adaptive learning compensation of the 1st gear brake pressure ensure stable shifting without any performance degradation.

クラッチ圧を速く落とせば回転上昇が早くなりレスポンスは向上するが，1速ブレーキ締結までの時間が短くなる為，1速ブレーキ圧の応答が課題となり，前述した1速ブレーキ圧を上昇させるタイミングや高さの適合精度がより要求される（Fig. 4）．またキックダウン2→1変速の際には，当然のことながら副変速の切り替えと同時にプーリーも変速を行なっている．トータルの変速比はLow側に変速するが，副変速機がLow側に大きく変速する分，プーリーをHigh側に変速し，トータルの変速比が滑らかにLow側へ変速するように協調制御している．しかしプーリーの変速比はそのままに副変速機の切り替えのみで変速を行い，あえて駆動力段差を出すことでCVTながらステップATのようなフィーリングを演出することも可能となる．

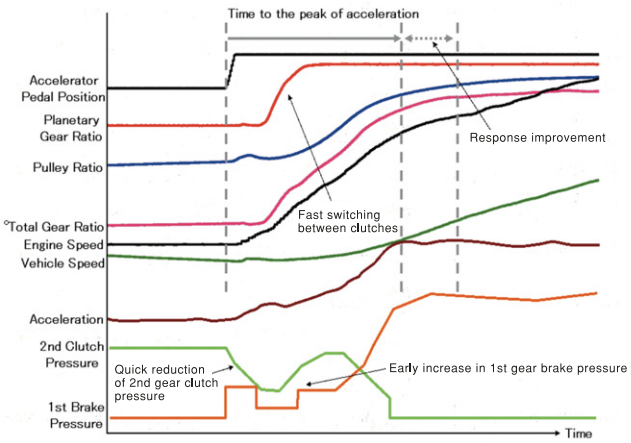

Fig. 4 2nd-1st kickdown shift calibrated with priority on response

3.3. Calibration of 2nd-1st kickdown shift response

Response can be adjusted by changing the manner of reducing the 2nd gear clutch pressure. If the pressure is reduced slowly, the clutch rotational speed changes gradually, resulting in a smooth shift feeling, but the response is slow (Fig. 3).

Reducing the clutch pressure quickly improves response by quickening the rise in the clutch rotational speed. However, the 1st gear brake pressure response becomes an issue because of the shorter time until this brake engages. That means the timing for raising the 1st gear brake pressure and the level of increase must be calibrated more accurately (Fig. 4). When a 2nd-1st kickdown shift is executed, the pulley ratio is also naturally changed simultaneously with the shifting of the auxiliary transmission. While the total gear ratio is shifted to the low side, the pulley ratio is shifted to the high side to the extent of the large shift in the auxiliary transmission ratio to the low side. Cooperative control is performed so that the total gear ratio is shifted smoothly to the low ratio side. However, shifting is executed only by switching the auxiliary transmission clutches while leaving the pulley ratio as it is. Accordingly, this also makes it possible even for the CVT7 to deliberately produce a step-like difference in driving torque similar to the shift feel of a stepped AT.

4．最後に

以上のような副変速制御の適合技術により，副変速機を備えながらもCVTとしての変速を実現し，燃費と動力性能，運転性の両立を果たした．しかしまだまだ改善の余地は残されており，ハードのポテンシャルを使い切れていない部分も数多く残している．Jatco CVT7を発売してから2年が経過するが，今も尚，燃費や動力性能を向上させる新規制御が次々と開発され成長している．この更なる成長のポテンシャルを秘めたJatco CVTを，これからも成長させ続け，より良いものをお客様へ提供できるよう全力で貢献していきたい．

4. Conclusion

This article has explained the calibration techniques applied to the auxiliary transmission incorporated in the CVT7 to achieve CVT shift smoothness combined with fuel economy, power performance and driveability. However, there is still room for much more improvement, as the potential of the hardware is not being fully utilized in many aspects. Two years have now passed since the Jatco CVT7 was put on the market. We plan to advance this unit further by developing a succession of new control features for improving fuel economy and power performance even more. Given the unit's latent potential for further evolution, every effort will be made to continue to advance the Jatco CVT7 to a higher level of sophistication so as to provide customers with an even better product.

■ Author ■

Masato MORI

Jatco CVT7中国現地化の苦悩と喜び

Difficulties and Joys of Localizing Jatco CVT7 Production in China

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佐藤　勇一*　Yuuichi SATO

1. はじめに

JATCO Guangzhou Automatic Transmission Ltd.（以下JGZと称す）は，2009年4月より中型CVT JF011Eの生産を開始した．その2年後の2011年4月から最新小型CVT，Jatco CVT7を生産することになり，本報ではそのモノづくりの苦悩と喜びについて記述する．

JGZ創業時の社員の車輌通勤者は，たった2名しかいなかったが，現在では15名に急増し，中国での乗用車の急激な増加を肌で感じている．昨年中国で発売されたJatco CVT7（日本製）搭載の新型サニーは大評判で，JGZでも既に2名の社員が購入している．（Photo 1）この購入者にCVTの感想

Photo 1 JGZ employee Ms. Choi and her new newly purchased Dongfeng Nissan Sunny

Photo 2 Overall view of JGZ

1. Introduction

JATCO Guangzhou Automatic Transmission Ltd. (JGZ) began producing the midsize JF011E CVT in April 2009. Two years later, JGZ was scheduled to launch production of the newest small CVT, the Jatco CVT7. This article describes the difficulties and joys involved in preparing the monozukuri processes for the Jatco CVT7.

At the time JGZ was founded in 2007, only two employees commuted to work by car. The number has increased rapidly to 15 employees at present, providing a first-hand impression of the rapid spread of vehicles in China. The new Sunny model, made in Japan and fitted with the Jatco CVT7, has been immensely popular in China since sales were launched in January 2011. Already two JGZ employees have purchased a new Sunny (Photo 1). When asked about their impressions of the CVT, they gave it high marks for its smoothness and exceptionally good fuel economy. Considering that vehicle ownership will continue to rise in China in the coming years, there is the feeling that the possibilities for our CVT products are unlimited. In addition, conveying our experiences accurately to future generations will help contribute to JATCO's global growth that transcends national boundaries. With that thought in mind, the following sections describe the efforts made to localize production of the Jatco CVT7 in China.

2. Production Preparations for Jatco CVT7

2.1. Review of JF011E launch

The JATCO Headquarters in Japan and JGZ began studies of the production preparations in the summer of 2009 for launching Jatco CVT7 production at JGZ in April 2010. Unfortunately, the launch of the

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を聞くと「スムーズ」さと「燃費が非常に良い」と高評価で，更に中国での車の保有率が上がっていくことを考えると，我々の商品であるCVTの可能性が無限にあると感じられ，また，私たちの経験をきちんと後世に伝えることが，民族の垣根を越えてジヤトコがグローバルに成長していくことなるとの思いで以下に記述する．

2. Jatco CVT7生産準備

2.1. JF011Eの振り返り

2010年4月のJatco CVT7の立ち上げに向け，2009年夏から，日本本社（以下，JHQと記）とJGZにて生産準備の検討に入った．残念ながら，同年4月に立ち上がったJF011Eは，決して順調な立ち上がりとは言えず，ドタバタ劇の立ち上げになってしまっていたため，「このままでは生き残れない！Jatco CVT7ではなんとしても，品質トラブルゼロの結果を出さなければいけない！」との思いからJF011Eの振り返りを実施した．要約するとTable 1のようになる．

数々の反省点があるとはいえ，生産に携わる中国人のほとんどが新卒者で，なおかつ車の免許も持たJF011E that went into production in April of that year had not gone smoothly. Because of the circus-like atmosphere surrounding the launch, there was a strong feeling that: "We'll never survive at this rate. We must achieve zero quality troubles for the Jatco CVT7 no matter what." Based on that realization, a thoroughgoing review was made of the JF011E launch. The results are summarized in Table 1.

While there were many points requiring serious reflection, most of the Chinese employees involved in the JF011E production launch were recent graduates and did not even possess a driver's license. Considering that production was launched by a team of amateurs, the fact that they were able to build the same JF011E model as in Japan, thanks to the cooperation of everyone involved, should be seen on the whole as a success.

However, with the expansion of production to include the Jatco CVT7, the level of results attained at that point was not sufficient. Preparations to produce the Jatco CVT7 were initiated with the enthusiastic goal of becoming No. 1 in quality worldwide by learning from the JF011E launch. While the JF011E was launched mainly by Japanese employees, the Jatco CVT7 was to be launched through the

Table 1 Results of JF011E launch review

JF011E review	Opinions of Japanese	Opinions of Chinese
Process	Basic information concerning theproduction line in Japan was not conveyed.	● Not included in the technical studies done at the launch stage. ● Documents were hard to understand because they were written only in Japanese and English. ● Did not know the structures of the equipment.
Quality	Anxiety about whether quality assurance procedures that depend on people were properly in place.	● Could not follow the conversations of Japanese employees when a problem occurred. ● Employees' awareness of quality did not improve.
Production by Chinese employees	● Manufacturing concurrently with Chinese employee training was not successful. ● Documents were not translated into Chinese.	Received training concerning machining, CVT assembly, etc., but production began without understanding the work operations.
Shop floor management	Production began without fully conveying the essentials of shop floor management.	Work sheets, standards, etc. were too complex and production began without understanding them.

ない素人チームによる生産であったことを思えば，関係者の協力により日本と同じJF011Eの生産が出来たことは，まずは成功だったと思う．

しかし，今後の拡大を考えると現状の結果で良いということはなく，この振り返りから，品質でグローバルNo.1になるんだ!という意気込みで，Jatco CVT7の生産準備に入った．準備を開始するにあたり，JF011Eの立上げは日本人中心で行ったのに対し，Jatco CVT7では日本人と中国人が一緒に協同で立ち上げるべく「齐心协力　达成目标!」(心を合わせて協力し，目標を達成する!)と言うスローガンを決めてキックオフした．

2.2. キーマン制度の充実・強化

まず，最初の改善点は，キーマン制度の育成・強化である．すなわち，JF011Eラインで貴重な成功体験や失敗体験をした若い人財を，Jatco CVT7立上げのキーマンとして選抜し，この選抜したキーマン(組立・加工・保全各3名)を日本の研修(技能，技術)に送り出し，JGZでの経験に加えて日本のモノ造りづくりを体験させたことが，キーマンの育成に大いに貢献したといえる．

JGZでは，創立当初から人材確保とその育成を最優先課題として取り組んできた．その苦悩はなかなか書き表すのは難しいのだが，まずモノづくりで欠かせない「現場管理」手法の習得を目指し，教育資料をいち早く中国語化し，更に中国人講師の育成を推進してきた．これは日本人が一生懸命「日本語」を使って教えてもなかなか伝わらないことから現地講師を育成することにしたものである．

Jatco CVT7においても彼ら現地講師による現場管理教育が行われている．
製造現場では当初，

正しい仕事をつくる．(標準作業を設定する)
→正しい仕事を部下に徹底する．
(標準作業を守らせる)
→より良い仕事を研究する．
(標準作業を改善する)

というサイクルの習得を狙っていたが，

「理解はすれど，実行できない」と言うもどかしさ

cooperative efforts of Japanese and Chinese employees working together. The preparations were kicked off under the slogan of "achieving our goal through cooperation with a unified spirit."

2.2. Improvement and strengthening of key men system

One area targeted initially for improvement was to further develop and strengthen the key men system. From among the young employees who gained valuable experience from both the successes and failures of the JF011E production line, key individuals were selected for launching the Jatco CVT7. Three employees each in the machining, assembly and maintenance processes were chosen as key men and sent to Japan for training in technical skills and technologies. In addition to the experience already gained at JGZ, their first-hand contact with monozukuri processes in Japan contributed greatly to the development of their abilities as key personnel.

From the time JGZ was established, employee recruitment and training have been vigorously promoted as top priority tasks. It is not easy to describe the various troubles encountered in this regard. The first aim was to teach employees the methods of shop floor management ("genba kanri"), which are indispensable to monozukuri operations. The training materials were translated into Chinese as quickly as possible and efforts were also made to develop Chinese instructors. It was decided to develop Chinese instructors because work procedures were not communicated well to the Chinese employees when Japanese trainers explained things diligently in Japanese.

Chinese instructors have also been conducting training in genba kanri for the Jatco CVT7. The aim is to have production line workers acquire genba kanri methods in the following cycle:

Create correct work procedures.
(Define standard work procedures.)
→Teach the correct work procedures to subordinates thoroughly.
(Observe standard work procedures.)
→Research ways of doing work better.
(Improve standard work procedures.)

There was a frustrating battle with the fact that JGZ

と戦いながら，結局自己流の標準作業となってしまい，検査不合格品の発生･災害等に繋がることになってしまっていた．

また，作業者に聞き込むといつも「没問題」（意味は，「問題無い」）が決まり文句，結局仮説に仮説を重ねての対策を強いられ，この先どうなるのかと落ち込む毎日だった．それでも工夫を重ねながら，教育→実践→失敗→振り返りを繰り返し行い，この絶え間ない繰り返しの過程で，製造ラインは，突然驚くような成長をしたり，また戻ったりを繰り返しながら成長していった．まさに，諦めずに真摯にOJTを繰り返してきた先人達の成果である．と確信している．

今回のキーマンは，こうした背景で育ってきた成長期のメンバーであり，日本人サイマルメンバーと，日本で一つの「チーム」としての意識を強く築き，Jatco CVT7の立上げへの準備も，少しずつだが，日本人と一緒に動けるまでに成長してきた．

事実Jatco CVT7の立上げのため，国慶節の休みを返上して日本人と共に設備調整や技術的な対策に没頭した中国メンバーもいたほどである．

2.3. 工程設定上の改善

工程設定においては，JF011Eでの振り返りと今後のグローバル･組立ラインのあり方を考慮し下記の点を織り込んだ．

〈組付部品のマーシャリング化〉

JF011E組立ラインで実施した組立方式で，ユニット1台分の部品をあらかじめ部品トレイに準備し，組立ラインではそのトレイから部品を取り出して組立てていく方法．JF011Eが組立てのメイン前半工程のみに採用したのに対し，Jatco CVT7ではさらに範囲をサブラインとメイン後半ラインにまで広げ，マーシャリング方式の弱点である部品取りの不効率も，トレイの小型化に成功したおかげで，効率を45%向上させた（Photo 3）．更にラインの長さをJF011Eに比べ約半分に短縮することができた．

employees understood the work procedures but could not execute them. So they ended up performing the standard work procedures in their own way. That led to the occurrence of products which failed the final inspection, accidents and other incidents.

When queried, the employees' standard response was always "no problem." In short, we were forced to implement corrective measures based upon one hypothesis piled on another. Every day was depressing, worrying about how things would turn out. Yet, improvements were steadily made by repeating the cycle of education → practice → failure → review. In the course of continuously repeating this cycle, the manufacturing line evolved through a repetition of sudden amazing advances, regression and then further advances. Undoubtedly, that progress resulted from the dedicated efforts of those who had earlier undergone repeated on-the-job (OJT) training without giving up.

The key men selected for the Jatco CVT7 were personnel who had honed their abilities during that period of growth against a backdrop of repeated difficulties. They had formed a strong awareness of working as one united team with the Japanese employees involved in simultaneous engineering. As the preparations for the Jatco CVT7 launch moved ahead gradually, those personnel reached a level where they were able to work effectively alongside the Japanese employees.

In fact, for the sake of the Jatco CVT7 launch, there were even Chinese employees who gave up their National Day holiday in order to concentrate on calibrating the equipment and dealing with technical issues together with the Japanese employees.

2.3. Process improvements

The following improvements were incorporated in the production processes based on the review of the JF011E launch and consideration of how world-class assembly lines should be configured.

<Marshalling of CVT parts>

The assembly method implemented on the JF011E production line was to prepare all the parts for one CVT on parts trays in advance; on the assembly line, the parts were then taken from the trays to build the unit. This method was adopted only in the processes

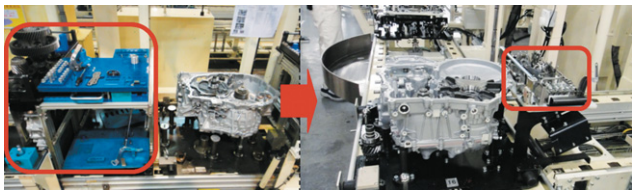

Photo 3 Downsizing of parts marshalling trays

〈FFM（フレキシブル ファイナル モジュール）の採用〉

ファイナルテスト工程においては，JF011E･Jatco CVT7双方の機種が流せるように設備を工夫した上，本工程を1箇所に集中させた．これは投資を抑えながら且つ予測の難しい中国生産受注の振れに柔軟に対処できる工程を実現している．

〈根を生やさないメインライン〉

先を見据え，メインラインを中心に改造の難しい専用機に対し，改造がフレキシブルに出来る汎用機の比率を11%向上させた．その為，ライン内には柱を立てない仕様にするなど工夫を行なっている（Photo 4）．

Photo 4 Machines without any inflexible pillars

Jatco CVT7の設備で最も苦労したのが現地LCCメーカーの採用だった．納期概念の欠如やジヤトコ設備仕様の理解不足等事前準備～設置～品質確認に至るまで，担当者は東奔西走する日々だった．中国人スタッフもJF011Eでは叶わなかった設備メーカー立会い，安全立会い，品質確認等の各フェーズで参画し，時にはLCCメーカーとのつなぎ役やメーカー合同ミーティングの取り仕切りなど，様々な場面で活躍した．安全立会いや品確などは日中合同で実施したため，通訳に時間を要し納期遅れも発生させたが，省略してはいけないプロセスだと考え協同で行なった．これらの努力の結果，LCCメーカ設備を，順調に稼働させることができた．

また，設備投資削減の方策の一つとしてCASE加

comprising the first half of the JF011E main assembly line. For the Jatco CVT7, the scope of this method was expanded further to include the sub-assembly lines and the latter half of the main line. One drawback of this marshalling system is that the action of taking parts from the trays is inefficient. That weak point was successfully overcome by reducing the tray size, resulting in a 45% improvement of work efficiency (Photo 3). Furthermore, the length of the production line was shortened by approximately one-half compared with that of the JF011E.

<Adoption of a flexible final module (FFM)>

The equipment of the final test process was improved so that both the JF011E and the Jatco CVT7 can be tested and inspected in the same process, which has been concentrated in one location. This was done to hold down capital investment and also to create a process that can flexibly accommodate the hard-to-predict fluctuations in production order volumes in China.

<Improved main line flexibility>

The proportion of general-purpose machines was increased by 11% primarily on the main line to allow more flexible conversion and reconfiguration in anticipation of future needs. Special-purpose machines are difficult to convert or remodel. One of the improvements devised here was the adoption of equipment specifications without inflexible pillars within the line (Photo 4).

One of the biggest difficulties we had regarding the production facilities for the Jatco CVT7 concerned procurement from local LCC suppliers. The people in charge of procuring the equipment were busily running around every day trying to complete advance preparations, get the equipment installed and confirm quality. Their job was complicated by the lack of a concept of delivery deadlines and an insufficient understanding of the specifications of JATCO's equipment, among other things.

The Chinese employees were also actively involved in every phase, including inspecting equipment manufacturers that had not met the requirements for the JF011E, witnessing safety trials and confirming quality. At times they liaised with LCC suppliers, presided over joint meetings of manufacturers and

工ラインを，日本から転用設置した．当初，オーバーホールを日本で行う計画だったが，時間がなく中国で行うこととなったためだが，人財育成で悩んでいた保全部隊では，この機会を保全員育成のチャンスと捉えることで技能習熟の早期化を図ることができた．

Photo 6 Jatco CVT7 assembly line

2.4. 生産直前の活動

こうした全社員の検討虚しく，やはり計画通りに進まないのが海外での難しさかもしれない．デイリーミーティングでは課題が溜まるばかり‥‥‥ため息の出る毎日だった．

そこで，JGZにも必要だと感じたのが「改善班」の力である．日本の工務部（GKPT）の力を借り，中国人に自ら現場を変えていく改善の力を見せながら，改善のスピード感と自律心を植えつけつつ，山積みの課題の解決を図ることにした．

まず，作業者はSOP後の生産量の拡大に合わせて月に数十名単位で増えていく計画をもっていたが，この様に新人が増えていく中，SQDC目標を達成する為に作業者の採用を前倒しして進めることとした．

JF011Eでの成功体験を活かしたパイロットラインをJatco CVT7でも製作し，新人は，二週間の修行をこのパイロットラインで行った後仮免を取得し，実ラインで作業を開始する．その後，実ラインでの経験を2ヵ月半経験した後，正式な作業員として認められることとなる．

品質ではJF011Eの反省を活かし，机上のFMEAから，現場の活きたFMEAにする為の現場･現物での確認会や，同じ図面の部品でも産地が違えばモノは違うというLCC部品の怖さを極力避けるため，日本の組立ベテラン者の技術支援を受け「組付け性B／M」を実施し，事前の灰汁出しを行った．

このように，さまざまな準備を経て日々挫折と達成感を味わいながら，生産を迎えることになった．

were active in a wide range of situations. The witnessing of safety trials, confirmation of quality and other activities were carried out jointly by Japanese and Chinese employees. Because time was needed for interpreting, there were cases where delivery deadlines were not met. However, this work was done collaboratively because it was felt that the process must not be omitted. As a result of those efforts, the facilities of the LCC suppliers also began to operate smoothly.

As one measure for reducing capital investment in facilities, the case/housing machining line was outfitted with equipment transferred from Japan. Initially, it was planned to overhaul the machines in Japan, but it was later decided to do it in China because of a lack of time. The maintenance team, which had been hard pressed to develop suitable personnel, saw it as a chance to educate and train maintenance employees. It thus provided a good opportunity for these employees to acquire technical skills at an earlier stage.

2.4. Activities just before production launch

Despite all the employees being involved in these activities, the launch plan did not proceed on schedule, which probably attests to the difficulties involved in launching production overseas. Issues kept piling up in the daily meetings, causing sighs of concern every day. At that point, it was realized that what JGZ needed was the support of an improvement team. Borrowing strength from JATCO's Production Administration Department (GKPT) in Japan, the Chinese employees began to show the ability to improve and change the shop floor by themselves. Imbued with self-discipline and an awareness of the need for speedy improvement, they set about solving the many issues to be addressed.

The original plan was to increase the number of workers after the start of production (SOP) by several tens of employees every month so as to match the expansion of the production volume. It was decided to move up the hiring of new employees in order to accomplish the safety, quality, deliver and cost (SQDC) targets while increasing the number of new production line workers.

Drawing upon the successful experience gained with the JF011E, a pilot line was also built for the

3. 生産開始とその結果

Jatco CVT7の立ち上げは，JF011Eの倍のスピードで増産していく計画（Fig. 1）で，それぞれ万全の準備で迎えた訳だが，3月の先行生産から4月の本格生産も工場内では決して順調な立ち上がりではなかった．しかし，品質表彰制度を大いに奨励した結果，今までなかなか浸透しにくかった，「止める！呼ぶ！待つ！」が当たり前となり，検査不合格品の発生を抑制できるようになった．

Fig. 2で示す品質表彰の件数の大幅な増加は，彼らの成長と，意識の向上とを現しているのだと感じている．

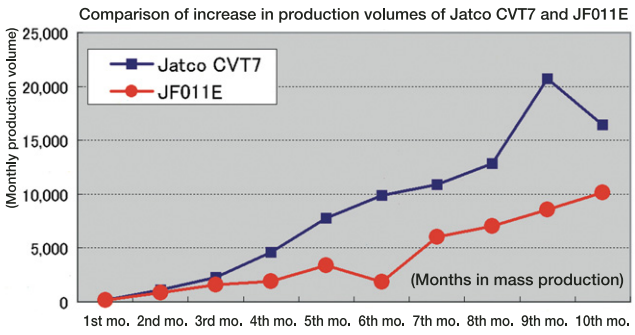

Fig. 1 Comparison of launch speed of JF011E and Jatco CVT7

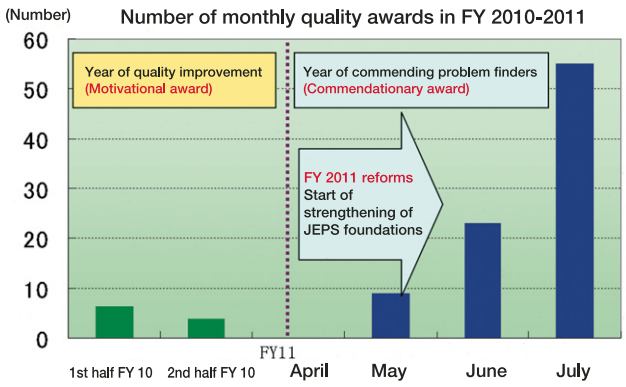

Fig. 2 Increase in number of quality awards

4. 継続的改善

Jatco CVT7の立ち上げと共にJEPS･基盤強化 活動を大幅に強化した．現在行っている工場拡張工事の中で，生産能力増強，内製部品の拡大などを進めているが，JGZにとってこの拡大スピードについていけるかどうかが，大きな課題である（Fig. 3）．

人も設備もモノも方法も全て懸念がないとは言えな

Jatco CVT7. New employees first undergo two weeks of training on this line to obtain provisional approval before starting to work on the actual production line. Then, after accumulating 2.5 months of experience working on the actual line, they are recognized as regular employees.

In the area of quality, the lessons learned from the JF011E launch were utilized to transform Failure Mode and Effect Analysis (FMEA) from a theoretical tool to FMEA that is actually used on the shop floor. That was done by holding workshops to practice confirming the actual location of a problem using actual parts. In addition, concerted efforts were made to avoid the pitfalls of LCC supplier parts by instilling in line workers the recognition that parts from different producers vary even though they are made from the same design drawings. In this regard, we obtained technical support from experienced assembly line employees in Japan and implemented assembly ease benchmarks in an effort to eliminate unpleasant incidents in advance.

As described here, we geared up for production by completing the various preparations while experiencing frustration and a sense of accomplishment every day.

3. Production Launch and Results

The schedule for the Jatco CVT7 launch called for the production volume to be expanded twice as fast as that of the JF011E (Fig. 1). While all of the various preparations for the Jatco CVT7 were duly completed, the situation at the plant from advance production in March to the start of regular production in April was definitely not one of a smooth launch. However, as a result of being greatly encouraged by JATCO's quality award system, the practices of "Stop the line!", "Call the supervisor!" and "Wait!" are now done as a matter of course. In the past, it was not easy to instill these practices in the line employees. This has made it possible to suppress the occurrence of products that fail quality inspections.

As shown in Fig. 2, the number of monthly quality awards given has markedly increased, which is indicative of the progress of JGZ employees and their improved quality awareness.

いが，現在我々がやるべきことは，将来のJGZのモノづくりを支える人材や設備を作り上げることだと思っている．

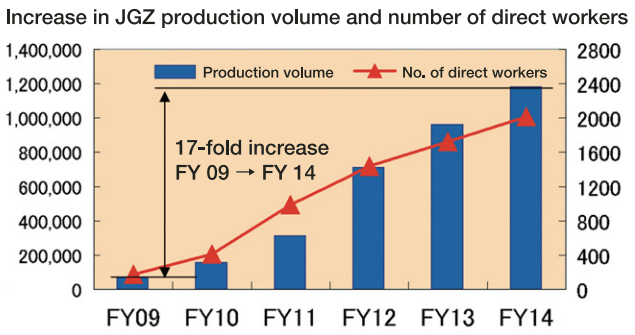

Fig. 3 Speed of future expansion

そのため，お客様に求められていることは何かを決め，課題を設定して取り組む範囲を，製造現場だけでなく検査･保全や技術まで広げ，世界一を目指して基盤づくりを行っている（Photo 5）．


Photo 5 Activities to strengthen JEPS foundations

5. 終わりに

まず，JF011Eでの苦労･苦悩が，入念な振り返りを行ったことで着実にJatco CVT7での効果に結びつけられたこと．これはやはり先人達のモノづくりにかける思いの成果であり，それを受け継いだ中国人と日本人が迷走しながらも，一つの方向に向けて真摯に取り組んできた結果だと思う．モノづくりは，図面を引く人，実際に作る人，工程を設定する人，様々な面からサポートする人などによって支えられていることを改めて実感することができた．

JGZは，お客様に本当に満足して頂ける為の必要な技術も，モノづくりの方法も，まだまだ成長過程ではある．しかしながらわたしたちは，しっかりとした

4. Continuous Improvements

Together with the launch of the Jatco CVT7, efforts were made to substantially strengthen various activities for enhancing the foundations of the Jatco Excellent Production System (JEPS). Work is now under way to enlarge the plant, including increasing the production capacity and expanding the parts manufactured in-house. A big issue for JGZ today is whether the plant can cope with the speed of this expansion (Fig. 3).

To be sure, there are concerns about every aspect involved, including the employees, facilities, materials and methods. What we must do at present is to put in place the human resources and equipment that will support JGZ's monozukuri activities in the future.

Toward that end, we must determine what our customers want, identify the issues that need to be addressed, and expand the scope of our activities beyond manufacturing workplaces to include quality control, maintenance and production engineering so as to build the foundations for being No. 1 in quality worldwide (Photo 5).

5. Conclusion

A thoroughgoing review of the troubles and difficulties experienced in launching the JF011E led to the steady attainment of results for the Jatco CVT7 launch. Without a doubt, this success resulted from the forerunners' dedication to monozukuri; it was also the result of the earnest efforts made by the current generation of Chinese and Japanese employees who have carried on that tradition in working together along a winding path toward a common goal. This launch project brought home once again the realization that monozukuri is supported by people involved in many different aspects—those who create the design drawings, those who actually build the products and those who design the manufacturing processes, among others.

JGZ is still in the process of acquiring the necessary technologies and monozukuri methods for producing products that truly satisfy customers. However, together with the JGZ employees who are making progress at a steady pace, we want to define

足取りで成長を始めたJGZ社員と共に，あるべき姿を掲げ，問題点を顕在化させ，中国の成長スピードに負けず，ここJGZを世界一のモノづくりの拠点にしていきたいと願っている．

our desired vision of the plant, identify any problems to be solved, and make JGZ into the world's best manufacturing center at a pace equal to the speed of China's growth.

■ Authors ■

Tomoaki YOSHINO

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付加価値を織り込んだファイナルテスト技術の開発

Development of Final Test Technologies for Embodying Added Value

千木良　英幸*
Hideyuki CHIGIRA

抄　録　Assemblyされた製品が意図通りに機能するかどうかを検査する工程において，昨今，単純な「テスト」のみならず「投資削減＋価値の付与」というニーズが高まってきている．新商品（Jatco CVT7）のテスト工程には製品に付加価値を与える技術を採用し，尚且つ付加価値を生んでいない時間を極端にカットした．本稿ではそのテスト工程の概要を紹介する．

Summary　The final test process is where assembled products are tested to see if they function as intended. Rather than simply testing products, there have been growing needs in recent years for the final test process to reduce capital investments and also impart added value. For the test process of the new Jatco CVT7, technologies were adopted to embody added value in the product, and work time that did not produce added value was cut dramatically. This article outlines the final test process and the technologies adopted.

1. はじめに

昨今，世界的な原油高騰，地球温暖化，お客様のニーズより，自動車のトランスミッションに求められる性能･コスト低減は一段と高いレベルのものになってきている．そのような要求を満足する為には種々の方策が考えられるが，その中で効果が大きいものが「ファイナルテスト（最終検査）工程におけるテスト機の機能向上」である．

ジヤトコのCVTは，組立ラインの最後で全数ファイナルテストを経て出荷されている．この工程では多岐にわたる検査を行っており，サイクルタイムが長く，ネック工程になり易い．また，必要な設備，治具も大掛かりなものになり，必要面積も大きく，投資･レイアウト上の制約条件になりやすい．

そのような状況の中，①製品性能向上の為の技術開発，②製品コスト削減の為の技術開発を行った．①についてはテスト工程において製品に付加価値を与えることで製品の初期性能を従来品に比べ飛躍的に向上させている．また，②については検査項目精査の結果，一部の検査項目はファイナルテストではなく別の方法･工程に置き換えて保証する事とし，ファイナルテストのサイクルタイムを削減して投資を抑

1. Introduction

Automotive transmissions have been required to achieve enhanced levels of performance and lower costs in recent years owing to sharply higher crude oil prices worldwide, global warming and customers' diversifying needs. While various methods can be considered for satisfying such requirements, improving the functionality of the test equipment used in the final test process is one approach that can provide significant benefits.

All JATCO CVTs undergo final tests at the end of the assembly line before they are shipped. Many different kinds of tests and inspections are conducted in this process, requiring long cycle times and often resulting in bottlenecks. Additionally, tests require the use of large-scale equipment and jigs, which need considerable floor space. The final test process is apt to incur limitations with respect capital investment and layout of facilities.

Given these conditions, we have been developing technologies for improving product functionality and technologies for reducing product costs. The former technologies have dramatically improved initial product performance over that of previous products by imparting added value to transmissions in the final

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える事に成功した．本稿ではその内容について概要を紹介する．

2. ファイナルテスト 副変速学習

2.1. 新商品 副変速機付きCVTの課題

新小型CVT（以下，Jatco CVT7と称す）の特徴として先ず挙げられるのは，「副変速機」である．本機構を有する事で軽量･小型化とワイドな変速比幅を実現したが，多段ATと同様の機構の為，変速ショックが発生する懸念がある．

従来のCVT（副変速機無し）ではその構造上，変速ショックが無く，滑らかに走行する事が可能である為，Jatco CVT7において従来のCVT同等の変速フィーリングを実現させる必要がある．

2.2. 解決の為の方策

ショックの要因として，大まかに以下の項目が挙げられる．

・油圧ばらつき
・クラッチクリアランスばらつき
・摩擦材ばらつき
・劣化ばらつき

部品単品レベルで個々の要因を潰し込もうとすると，莫大な工数が必要になってくる．また，部品の精度も著しく向上せざるを得ず，コストも格段に跳ね上がる．

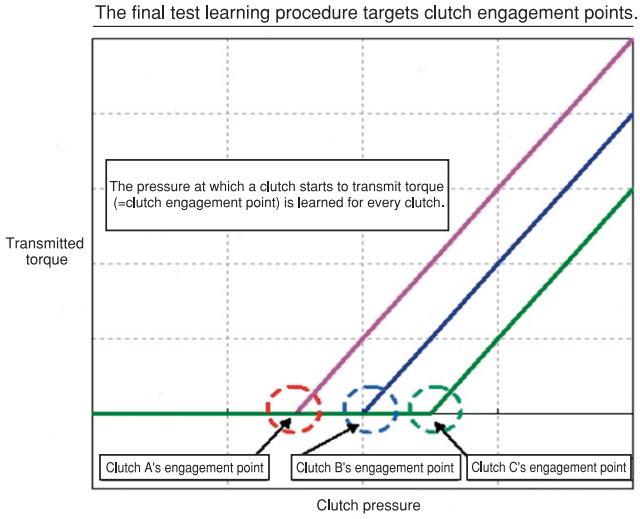

Fig. 1 Conceptual representation of clutch engagement points

test process. The latter technologies have successfully reduced cycle times in the final test process and held down investment costs. This has been accomplished by carefully reviewing test items and substituting other methods or processes, instead of the final test process, for some tests in order to assure product performance. This article outlines the technologies that have been developed in both areas.

2. Final Test Learning Procedure for Auxiliary Transmission

2.1. Issues in the new CVT featuring an auxiliary transmission

The first distinctive feature of the new small CVT (Jatco CVT7) is its auxiliary transmission. The adoption of this auxiliary transmission made it possible to achieve a smaller, lighter package together with wider ratio coverage. However, because it has the same shift mechanism as a stepped AT, there was concern that shift shock might occur.

A conventional CVT without this auxiliary transmission is built such that shift shock does not occur, so it delivers smooth driving performance. Therefore, it was necessary to ensure that the Jatco CVT7 would provide the same seamless shift feeling as a conventional CVT.

2.2. Possible solutions

Shift shock is generally caused by the following factors:

- Hydraulic pressure variation
- Clutch clearance variation
- Variation in friction material characteristics
- Variation due to deterioration

Trying to eliminate each of these factors at the individual part level would take enormous amounts of time and manpower. It would also be necessary to improve part accuracy markedly, causing costs to jump dramatically.

The following procedure was adopted to resolve this issue at the present level of part accuracy. The engagement point of each clutch in an assembled transmission is investigated, and that information is memorized for each clutch (Fig. 1). Engagement point refers to the moment at which a clutch first has enough capacity to transmit torque.

そこで，現状の部品精度のまま，この課題を解決する為，「トランスミッションASSY状態でクラッチのミートポイント（伝達トルク容量を持ち始める点）を個体毎に調査し，その情報をその個体に記憶させる」 という手法を導入した（Fig. 1）.

トランスミッションASSY状態でクラッチのミートポイントを調べる為には，大掛かりな設備が必要である. エンジン相当のモーターや出力軸を止める為のブレーキ，トランスミッションに油圧指令を与える為のコンピュータ等を有する“ファイナルテスター”にて行う．それ故，本手法は「ファイナルテスト副変速学習」と呼ばれている．従来，ファイナルテストでは品質保証の為の全数検査のみ行っていたが，今回，品質保証に加え副変速学習を織り込むことで部品単品のコストアップを抑えつつ，製品初期品質を向上させる事が可能になった.

2.3. ファイナルテスト学習の効果

Fig. 2に示す様に，学習無し状態では個々のばらつきの積み上げが大きく，変速ショック発生の懸念がある．が，ファイナルテストで学習を行い，ばらつきを吸収する事で製品の初期性能を向上させている. 残りのばらつきは車両になった後に自己学習を行う事で吸収し，製品性能を向上させる.

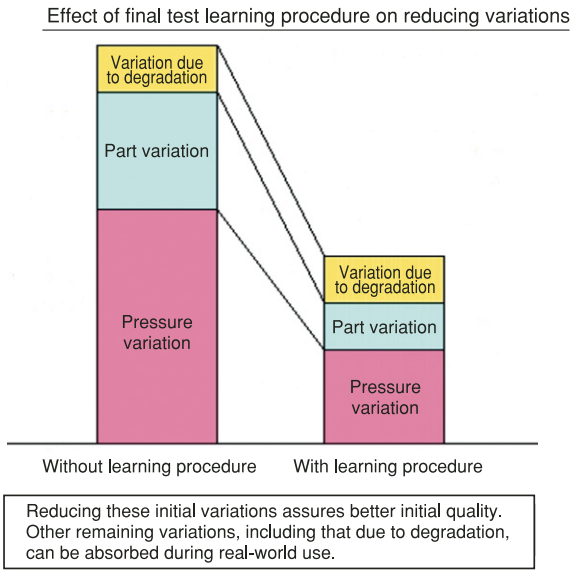

Fig. 2 Effect of final test learning procedure

また，この手法によるミートポイント学習結果は1速→2速または2速→1速の変速時だけではなく，アイドルニュートラル制御にも適応され，車両の性能に大きく関わってくるパラメータである.

Investigating clutch engagement points in an assembled transmission requires large testing equipment. This is done using a final tester comprising a motor corresponding to the engine, a brake for stopping the output shaft, and a computer for applying pressure commands to the transmission, among other components. This method is therefore called the "final test learning procedure for the auxiliary transmission." Previously, all transmissions were tested in the final test process only for the purpose of assuring quality. The new method applies a learning procedure to the auxiliary transmission in addition to assuring its quality. This approach makes it possible to improve initial product quality while holding down individual part costs.

2.3. Effects of final test learning procedure

As shown in Fig. 2, without any learning procedure individual variations accumulate substantially, giving rise to concern about shift shock. However, using the learning procedure in the final test process absorbs these variations to enhance initial product performance. Remaining variations are later absorbed through a self-learning procedure after installation in the vehicle, which also improves product performance.

The results of the engagement point learning procedure are applied not only to 1st-2nd and 2nd-1st shifts of the auxiliary transmission, but also to idle neutral control, thus constituting a parameter that has a major impact on vehicle performance.

3. テスト項目適正化活動

3.1. 保証工程見直し

製品に付加価値を与えるファイナルテスト副変速学習とは対照的に，品質保証確認の為のテスト項目について，

・その項目はファイナルテスト工程で保証するべき項目か?

・他の方法で精度良く保証できないか?

という観点で見直しを行った．

今までの製品保証の考え方は，製品を組み上げてから，最後に多項目にわたる検査をして出荷する，というものであった．しかし，本来，正しい部品を全数正しく組み付ければ，その後の検査は行わなくても良いはずである．

何でもファイナルテスト工程で保証するのではなく，組み付け工程内で保証する項目を増やす事で，同じ保証度でファイナルテスト項目を減らす事ができた．

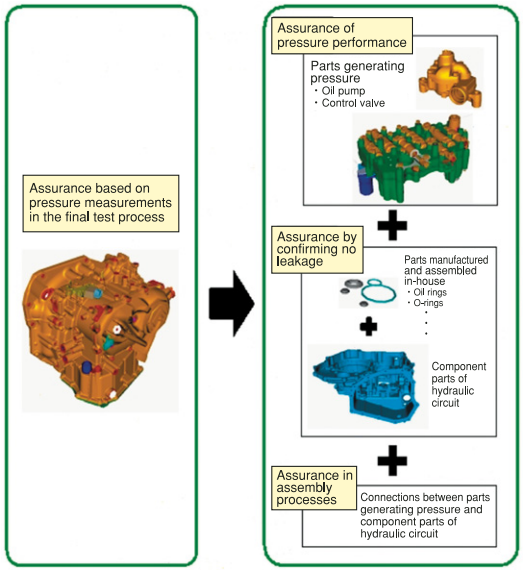

Fig. 3 Assurance of oil pressure

Fig. 3はその一例である．例えば，以前はファイナルテストで油圧計測を行っていたが，今回は行っていない．その廃止に至るロジックとしては

①油圧を吐き出すオイルポンプの性能

②油圧を調節するコントロールバルブの性能

③ ランスミッション内のオイルポンプから各作動デバイス迄の油路にリークが無い事

④油圧に関する各部品が確実に組み付けられている事

この4つ全てを保証することで初めてファイナルテスト項目から外す事が出来る，とした．

3. Activity to Optimize Test Items

3.1. Review of quality assurance process

As explained above, a learning procedure is applied to the auxiliary transmission in the final test process to impart added value to the product. In contrast to that, a review was made of test items for verifying quality assurance from the following perspectives:

- Is the test item one that should be assured in the final test process?
- Can assurance be accomplished accurately with some other method?

The concept of product quality assurance so far has been to assemble the product and then conduct wide-ranging tests at the end before shipping it. However, if the correct parts are all properly assembled, it should be possible to dispense with some tests following the completion of product assembly.

Rather than assuring the quality of everything in the final test process, the number of items assured in assembly operations was increased, making it possible to reduce the number of final test items while still attaining the same level of quality assurance.

One example of this is shown in Fig. 3. Previously, pressure measurements were made in the final test process, but that is no longer done at present. The logic involved in the discontinuation of these measurements required assurance of the following four items.

(1) Performance of the oil pump in discharging the required pressure

(2) Performance of the control valves in regulating the pressure

(3) Absence of any leakage in the oil passages in the transmission from the oil pump to the hydraulically actuated devices

(4) Reliable assembly of pressure-related parts

Only if all of these items could be assured elsewhere would it be possible to remove the pressure measurements from the final inspection items.

3.2. Activity results

The number of final test items for the Jatco CVT7 has been reduced by approximately half compared with the previous number for conventional CVTs (Fig. 4). Because the cycle time per transmission has been halved, the number of final testers needed has

3.2. 活動の効果

従来のCVTのファイナルテスト項目数に比べ，Jatco CVT7のファイナルテスト項目数はほぼ半減している（Fig. 4参照）．

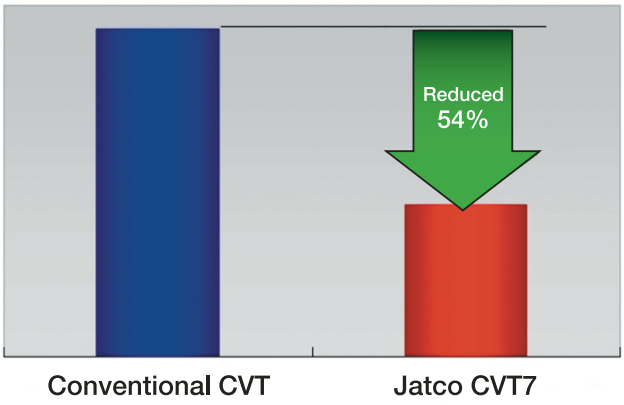

Fig. 4 Number of final test items

製品1台あたりのサイクルタイムが半減したので，必要となるファイナルテスターの台数も半減できた．

また，検査する項目が減ったので，検出機器も省くことが出来た．具体的なメリットとしては，

・設備仕様，治具仕様のミニマム化

・直行率の向上

が挙げられる．油圧検出を行わないので，検出機器，ホース，カプラ類の使用は省くことができ，コスト，保全面で非常に有利になった．また，従来，非常に難しい設備チューニングが必要なテスト項目があったが，その項目は他の工程で保証する事で検出精度向上，テスター直行率向上につながった．

Jatco CVT7でテスト項目適正化活動が始まったが，他の製品ラインに対しても同様に活動を行っている．その効果としてFig. 5を示す．横軸が年月，縦軸がジヤトコグローバルCVTファイナルテスター台数である．年月を追うに連れてCVTの生産台数が増え，その分必要なテスター台数も増加してきた．ピンク色の破線が，テスト項目適正化活動を行っていなかった場合のテスター台数，赤色の実線が，実際のテスター台数である．この活動は2009年下期あたりから効果を発揮し，現在ではテスター台数約20%減の実績を挙げている．

also been cut in half. Moreover, reducing the number of test items also made it possible to eliminate some of the test equipment. Specific examples of the benefits obtained as a result include:

- Minimization of equipment and jig specifications
- Improvement of first-time-through rate

The fact that pressure measurements are not made is very advantageous with respect to cost and maintenance because it eliminates the need to use various testers, hoses, and couplers. Additionally, there were some final test items before that required very complex tuning of the test equipment. Since those items are now assured in other processes, it has led to improvements in test accuracy and the first-time-through rate of testers.

Activities for optimizing the final test items were initiated for the Jatco CVT7, and the same activities are now being carried out for other product lines as well. The results obtained are shown in Fig. 5. The horizontal axis indicates the month and year, and the vertical axis shows the number of JATCO's final testers in use worldwide. The CVT production volume has continued to increase with the passage of time, so the number of testers needed has also increased to a corresponding extent. The pink dashed line indicates the number of testers that would be needed if the activities to optimize the number of test items had not be undertaken, and the red solid line shows the actual number of testers being used. The effect of these activities began to appear from the second half of 2009, and the number of testers has been reduced by approximately 20% at present.

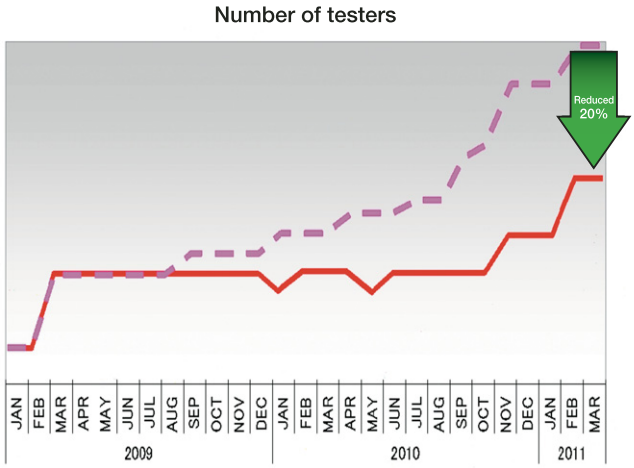

Fig. 5 Number of final testers

4．最後に

副変速学習は今までのジヤトコに無い新しい試みであり，軌道に載せるのは大変労力の要るものであった．意図通りに動かない，データの傾向変化にその都度対応していた，等の苦労はあったが開発･生産が一体になってクロスファンクショナルに活動してきた．今後の方向性としては，ラインで学習（部品バラツキを吸収するような制御）をすることでコスト･性能の両立を図る頻度が増えてくるであろう．

テスト項目削減活動では，検査すべき項目とそうでない項目を精査し，投資を抑える事ができた．検査項目は図面記載されるが，図面記載項目を事前に設計部署と何回も打ち合わせを重ねることにより両者納得の上，合意に至ったので，そのプロセスが非常に重要であると実感した．また，議論を重ねることで生産要件を明確にでき，図面記載の仕方も昔に比べ，変わってきたとの実感を得た．

今後もどのような工法が最適かを見極め，それをいかに早く安く確実に実現できるかが重要であると考える．お客様により良い製品をより安く提供する為に，常に生産ラインも変化し続け，走り続けたい．

4. Conclusion

The learning procedure for the auxiliary transmission was a new approach that JATCO had never attempted before, so a great deal of effort was needed to get it on track. Things did not always go as intended and changes in data tendencies were dealt with as they occurred. Those and other troubles were tackled through joint cross-functional activities by the R&D and production divisions. In the future, it is expected that efforts to reconcile cost and performance issues will be undertaken more frequently by applying this learning control procedure to other production lines for the purpose of absorbing part variations.

The activities undertaken to reduce the number of test items made it possible to hold down capital investments by carefully distinguishing between items that must be tested and those that do not require final testing. Test items are indicated on the design drawings. Prior discussions were held repeatedly with the design department concerning the items to be noted on the drawings, and an agreement was reached that was satisfying to both sides. Everyone involved came to realize how extremely valuable that joint process was. In addition, the repeated discussions made clear the production requirements, and people really felt that the manner of indicating them on the design drawings changed for the better compared with the previous way.

In the future, it will be essential to determine what sort of methods are the best and then to implement them as quickly, inexpensively and reliably as possible. We want to continue to make constant changes to the production lines in order to provide customers with even better products at lower cost.

■ Author ■

Hideyuki CHIGIRA

Jatco CVT7 Pulley 加工タクトタイム 1/2への取り組み

Efforts to Halve Machining Takt Time of Jatco CVT7 Pulleys

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抄　録　Jatco CVT7は，開発，生産技術の同席設計を開発初期から，積極的に実施したプロジェクトであった．Pulleyにおいても成果として，従来のCVTシリーズに対し加工タクトタイムの1/2を実現した．

本稿では，同席設計の取り組み内容について紹介する．

Summary　The Jatco CVT7 was developed in a project featuring vigorous collaborative design activities by the R&D division and production engineering division from the outset. One significant result achieved for the pulleys was that their machining takt time was halved compared with that of the existing CVT series pulleys.

This article describes the details of the collaborative design activities undertaken for Jatco CVT7 pulleys.

1. はじめに

Jatco CVT7は小型，軽量，低フリクションを追及し開発されたユニットであり，現在市場において高く評価されるユニットとなった．このユニットを開発する過程で，大変大きな成果を上げた取り組みが，同席設計である．CVTの基幹部品の一つである，Pulleyにおいても同席設計により大きな成果を上げる事が出来た．

Jatco CVT7は副変速機付きCVTであるが，その結果，Pulleyは従来に比べ大幅な小型化を実現した．生産部門としても，“部品の軽さ･小ささを活かしたライン造り”がコンセプトとなり，Pulleyにおいては，従来のCVTに対し，加工タクトタイム1/2にチャレンジすると言う方針を立て，開発，生産技術が同席設計に取り組んだ．

2. 活動の概要

加工タクトタイム1/2の取り組みは，以下の手順で進めた．

1）現状把握と課題の共有化

現状の各工程毎の加工タクトタイムを見える化し取り組むべき課題を全員で共有化した．

2）課題の即決

1. Introduction

The Jatco CVT7 was developed in pursuit of reductions in size, weight and friction, and it has received high praise from customers in markets everywhere. In the process of developing the CVT7, significant results were obtained through collaborative design activities. Collaborative design work achieved notable results for the pulleys, representing core parts of a CVT.

The Jatco CVT7 incorporates an auxiliary transmission that enabled the pulleys to be substantially downsized compared with those of conventional CVTs. The production division adopted the concept of building a production line that would take full advantage of the smaller, lighter parts. The challenge we set was to halve the machining takt time of CVT7 pulleys compared with their conventional CVT counterparts. That objective was pursued through collaborative design activities between the R&D division and the production engineering division.

2. Overview of Activities

Activities to halve the pulley machining takt time were undertaken according to the following procedure.

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Parts Process Engineering Department

・課題の推進責任者を明確にし，各課題の進捗を定期的に共有化した．
・進捗共有化の場には，判断出来る職位の人が必ず入り，早い意思決定による課題の推進を実行した．

3）生産技術の継続検討と達成

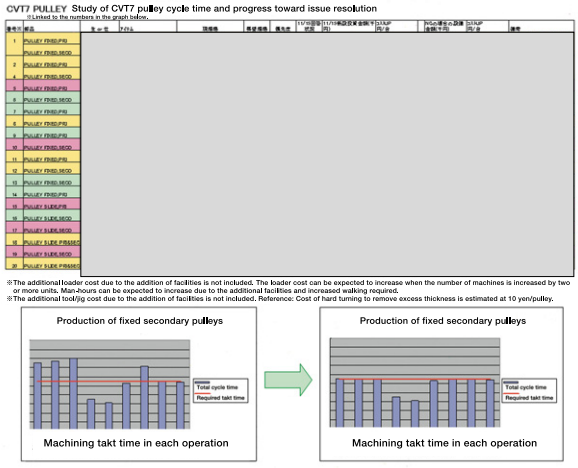
生産設備予算確定後は，技術課題を確実に実行に移すべく，新技術新工法でのレビュー等を経ながら，活動を進めた．

3. 現状把握

まず最初に，仮の図面ベースで，各工程の加工タクトタイムを予測する作業を実施した．この時，実際に加工タクトタイム予測用の加工プログラムを作成し，PC上で加工プログラムを走らせて，加工タクトタイムの予測を行った．この加工プログラムを使用することで，対策の検証についても精度良く迅速に確認する事が出来た．

Table 1は，加工タクトタイム削減アイテムリストと，加工タクトタイム検討結果である．各アイテムの効果を見える化し，達成進捗を共有化する事で，ショップを超えて一丸となった取り組みが出来た．

Table 1 List of measures for cycle time reduction and machining takt time in each operation



現状把握の結果，主として以下の課題に取り組むこととした．

1）シーブ裏面他 鍛造肌部拡大の検討
2）研削長さの最小化
3）加工条件の見直し

では次項より具体的な取り組みを説明する．

(1) Understanding the present situation and sharing of issues

The present machining takt time in each operation was visualized so that everyone could share the issues to be addressed.

(2) Quick decisions on issues

- The people responsible for addressing issues were made clear, and information on the progress achieved for each issue was regularly shared among everyone involved.
- Someone authorized to make decisions was always present when progress reports were shared. Quick decision-making advanced the work done to resolve each issue.

(3) Continuing and accomplishing production engineering

After securing a budget for production facilities, technical issues were then clearly addressed. Reviews were made of new technologies and methods in the process of proceeding with the activities.

3. Understanding the Present Situation

As the first step, the machining takt time in each operation was predicted based on provisional design drawings. A machining program was actually created for that purpose and was run on a PC to make a prediction of the machining takt time. The use of this machining program also made it possible to quickly and accurately confirm the effectiveness of measures devised for resolving issues.

Table 1 shows a list of measures for reducing machining takt time and the results of machining takt time studies. The effects of each measure were made visible and the progress attained was shared by everyone. This made it possible to transcend individual jobs and carry out activities as a united team.

After obtaining an understanding of the present situation, it was decided that the following main issues should be addressed.

(1) Study the possible expansion of forged surfaces, including the backside of sheaves and other parts
(2) Minimize the grinding length
(3) Review machining conditions

The specific activities that were undertaken are explained in the following sections.

4. 鍛造肌部　拡大の取り組み

生加工ラインの加工タクトタイム削減の方策として，シーブ裏面などの鍛造肌部の拡大による切削面積の削減に取り組んだ．

従来，切削加工であった部位を鍛造肌化することに対し，下記のような技術上の課題があった．

・切削加工に比べ，寸法精度が悪い

・マクレキズやバリが発生しやすい

これらの課題を解決する為の，主な取り組みを挙げる．

4.1. 鍛造肌部　寸法精度の向上

Pulley-Fixのシーブ裏面部は，ほぼ全面が鍛造肌化となったが，従来のPulleyに比べシーブ部が非常に薄肉になっている為，熱間鍛造時の反りやうねりなどの変形が問題となった（Fig. 1）．

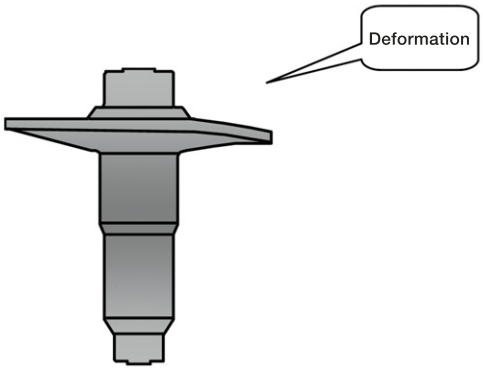


Fig. 1 Example of sheave deformation

対策として，熱間鍛造後にホットコイニングと呼ばれる矯正加工を実施することにより，必要な精度を確保できた（Fig. 2）．

また，既存のトリミングプレスを活用しホットコイニング工程とすることで，設備投資費をアップさせずに対策できた．

4.2. バリやキズの対策

鍛造時に発生するバリやキズは，完成部品の強度低下や，CVTユニット内でのバリの剥離による夾雑物となる危険性がある為，対策が必要であった．

バリ，キズの発生する工程を調査した結果，軸部の押出し成形工程におけるパンチとダイスの隙間（クリアランス）に差し込むバリ起因のものが多いことがわかった（Fig. 3）．

4. Effort to Expand Forged Surfaces

One approach taken to reduce machining takt time on the raw forging machining line was to expand forged surfaces, including the backside of sheaves and other parts, so as to reduce the area machined.

The forging of pulley parts that had previously been machined involved the following technical issues:

- Dimensional accuracy is worse than in machining operations.
- Scratches and burrs are more likely to occur.

The main efforts that were made to solve these issues are explained below.

4.1. Improvement of dimensional accuracy of forged surfaces

The backside of the fixed pulley sheave became almost entirely a forged surface, but the sheave was exceptionally thin compared with that of conventional CVT pulleys. As a result, warping, undulation and other forms of deformation presented problems in the hot forging process (Fig. 1).

This issue was resolved by performing a corrective machining process, called hot coining, after hot forging to ensure the necessary dimensional accuracy (Fig. 2). In addition, the existing trimming press is used in the hot coining process, making it possible to implement this measure without requiring any additional capital investment in equipment.

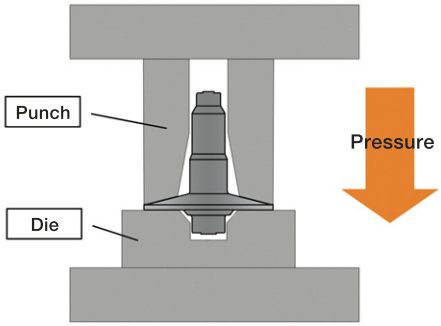


Fig. 2 Hot coining process

4.2. Measures against burrs and scratches

Burrs and scratches occurring in the forging operation reduce the strength of the finished product. If burrs come off inside a CVT, there is the risk they might come contaminants that affect performance. For these reasons, measures must be taken to deal with them.

この対策として，パンチの形状を工夫することにより，バリの差込みを抑制し，発生率の低減ができた．

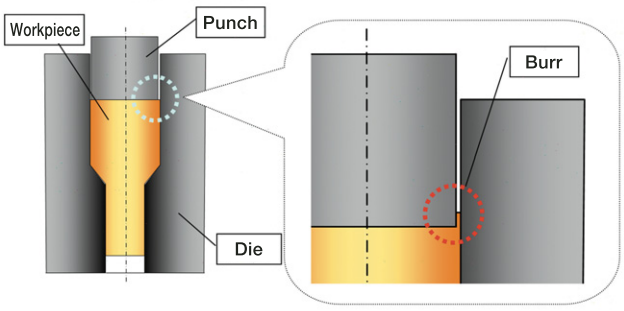


Fig. 3 Occurrence of burrs

以上のような取り組みや，開発部署との同席設計による部品規格緩和活動により，下図に示すような広範囲における鍛造肌面積を達成することができた（Fig. 4）．

効果としては，従来部品に対し，切削面積を約30%削減することができた．

5. 研削範囲最小化の取り組み

仕上げ加工工程での主要な取り組みの一つとして，外径研削工程の研削範囲最小化が挙げられる．

5.1. 研削長さ目標値の決定

研削条件と目標加工タクトから算出される，研削長さを開発へフィードバックし，詳細部品設計時の前提条件として設計検討を実施した．設計検討時点で，生産設計を同時に実施したので，設計検討の手戻りも少なく，早い段階での意思決定が可能であった．

5.2. 不要な部品仕様の見直し

本来，部品の要求精度としては不要であるはずの部位で，指示寸法を満たす為，加工している部位がある．今回は，そういった部位について，同席で議論し，加工レスとする方策を検討して行った．

以下は，その一例である．研削加工廃止を可能にする要求寸法を生産側から提案し，同席で検討することで，本来加工精度を必要としない，スプライン圧入案内部の研削加工を廃止した（Fig. 5）．

An investigation was made of the operations where burrs and scratches occurred. The results revealed that most originate from burrs sandwiched in the clearance between the punch and the die in the extrusion forming process of the shaft. This issue was dealt with by modifying the punch geometry so that burrs do not become sandwiched in the clearance. This effectively reduced the incidence of burrs (Fig. 3).

In addition to the foregoing measures, collaborative design activities were undertaken with the R&D division to relax certain part specifications. As a result, the combined area of forged surfaces was considerably expanded as shown in the diagram in Fig. 4.

The machined area was reduced as a result by approximately 30% compared with previous pulleys.

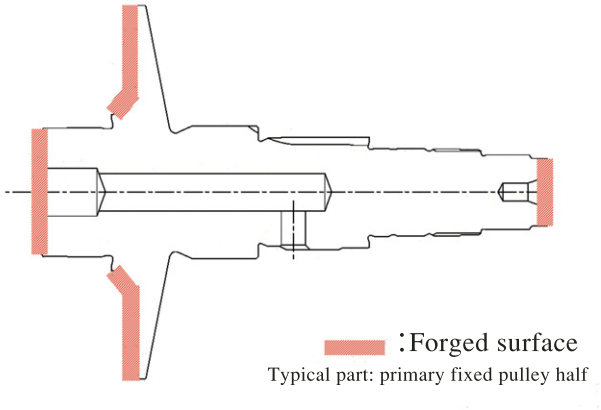


Fig. 4 Forged surface locations

5. Efforts to Minimize the Grinding Area

One of the principal activities undertaken in the finish machining process was to minimize the area ground in the outer diameter grinding process.

5.1. Determination of grinding length target

A target grinding length was calculated from the grinding conditions and the target machining takt time. That information was fed back to the R&D division and used as a prerequisite condition in studying the detailed part design. A production design was also executed concomitant with the design study. This allowed decisions to be made at an early stage with a minimal amount of reworking of the design study.

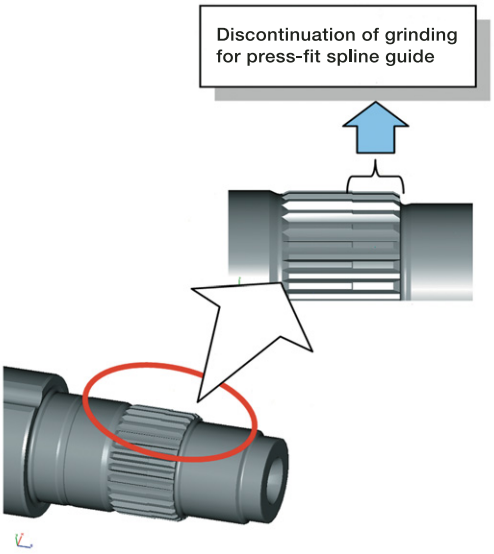


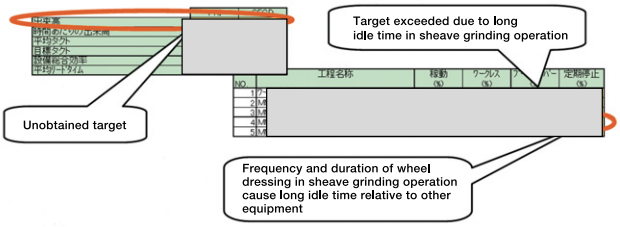
Fig. 5 Discontinuation of grinding for press-fit spline guide

6.ドレス時間短縮の取り組み

6.1. 背景

加工タクトタイム1/2へ向けて取り組む中で，開発との同席設計アイテムだけでは無く，本項で紹介するような，加工条件や工法に対する，チャレンジアイテムへの取り組みも行った．

Table 2 Worksheet for uptime rate simulation



今回の加工タクトタイム1/2への取り組みにおいて，成果を確認する為，稼働率シミュレーションを活用した．この稼働率シミュレーションを実施した結果，シーブ面研削工程の停止時間がネックになっている事が判った．この停止時間とは，ドレス時間と砥石交換時間である．

シーブ面研削工程のドレス時間を短縮するには，以下の2つのアイテムがある．

① ドレス時間そのものの短縮

② ドレスインターバルの延長

②については，当時の現行ラインでも取り組んでおり，今回のラインにも織り込む前提であった．しかし，それでも，目標の加工タクトタイム1/2は達成でき

5.2. Review of unnecessary part specifications

Ordinarily, unnecessary portions are machined so as to satisfy the specified dimensions and meet the required part accuracy. For Jatco CVT7 pulleys, discussions were held with everyone concerned regarding such areas and ways of achieving the required accuracy without machining were examined.

One example is explained here. The production division proposed dimension requirements that would allow grinding operations to be discontinued. As a result of a joint examination of this proposal, it was decided to discontinue the grinding operation for the press-fit spline guide, which originally did not have any required machining accuracy anyway (Fig. 5).

6. Efforts to Shorten Dressing Time

6.1. Background

The design measures devised jointly with the R&D division were not the only approaches taken to halve the pulley machining takt time (Table 2). Independent efforts were also made to achieve our own challenges regarding the machining conditions and methods, as explained in this article.

An uptime rate simulation was used to confirm the effectiveness of the measures devised for halving the machining takt time. As a result of running this simulation, it was found that idle time in the sheave face grinding process was a problem. This idle time was being used to dress or replace grinding wheels.

The following two measures were taken to shorten the wheel dressing time in the sheave face grinding process.

(1) Shortening the dressing time itself

(2) Lengthening the dressing interval

Efforts were already under way to implement the second measure on existing production lines at that time. It was a precondition that was incorporated in the line for Jatco CVT7 pulleys. However, that measure alone did not achieve the goal of halving the machining takt time. Therefore, it was necessary to tackle the first issue of shortening the wheel dressing time itself. Specifically, it was decided to adopt a universal rotary dresser as a solution to this issue.

6.2. Adoption of a universal rotary dresser

As shown in Fig. 6, the existing long-life dresser

ていなかった為，①のドレス時間そのものの短縮に取り組む必要があった．具体的な解決策として，総型ロータリードレッサーを採用する事とした．

6.2. 総型ロータリードレッサーの採用

Fig. 6のように，現状のLLドレッサーでは，砥石表面をトレースして，砥石表面の目立てと，砥石形状の再成形を実施しているが，総型ロータリードレッサーは，砥石に押し当てるだけで，目立てと成形を実施するものである．

これによって，ドレス時間は，大幅に短縮され，OEE（設備総合効率）も，稼働率シミュレーション上大幅に向上する見込みが立った．

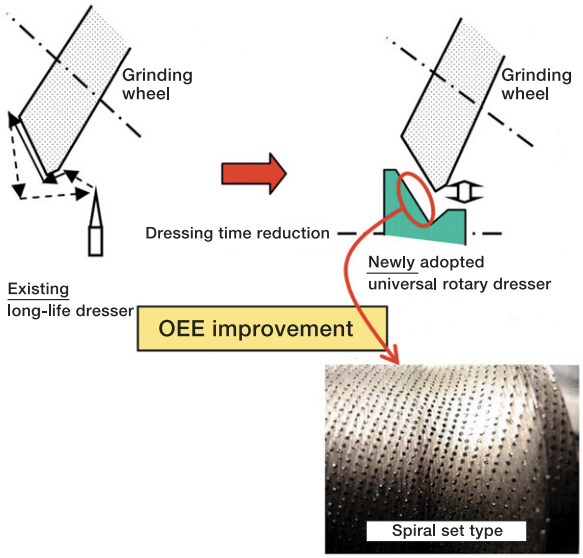


Fig. 6 Comparison of existing dresser and universal rotary dresser

7. 加工設備半減の取り組み

Pulleyは，プライマリー（PRI）軸とセカンダリー（SECD）軸の対で，構成されているので，PRIとSECDの類似2部品が存在する．通常は，PRIとSECDにそれぞれ，専用の加工ラインを構築するが，投資リスク回避の観点から，極力，小単位での投資が要求される．

そこで，今回は，開発当初から，元々相似形のライン構成である，PRIとSECDの段取り性を，向上させて，投資単位の1/2化にも取り組んだ．

具体的には，Fig. 7のように，部品の詳細設計段階で，各工程の治具構成による制約条件を提示し，治具段取りレス化に取り組んだ．

sharpened the cutting edges of the wheel and trued the wheel shape in the process of dressing the wheel face. The universal rotary dresser sharpens the cutting edges and trues the wheel shape simply by pressing the dresser against the wheel.

An uptime rate simulation indicated that the adoption of this dresser would substantially shorten the wheel dressing time and also significantly improve overall equipment efficiency (OEE) as well.

7. Efforts to Halve the Number of Machining Facilities

A CVT is built with a pair of shafts called the primary and secondary shafts, on which there are two similar pulleys called the primary and secondary pulleys. Usually, separate dedicated machining lines are built for the primary and secondary pulleys. However, from the standpoint of avoiding capital investment risks, it is necessary to keep investments in equipment to the smallest possible level.

Therefore, from the start of the Jatco CVT7 development project, efforts were made to improve the setup work for the primary and secondary pulleys, for which the machining line configurations were similar from the beginning. The aim was to halve the level of capital investment in equipment as well.

Specifically, at the stage of executing the detailed pulley design, constraints due to the jig configuration in each operation were identified and efforts were made to eliminate jig setup work, as illustrated in Fig. 7.

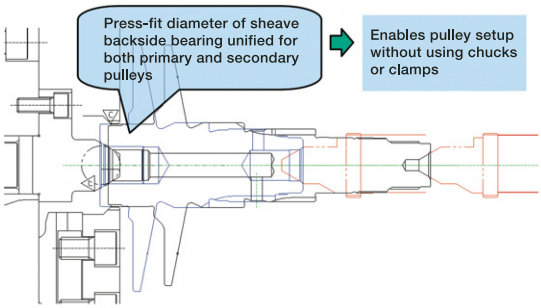


Fig. 7 Pulley design for improved setup work

8. Results

The results and effects obtained through the activities described here are summarized below.

Machining takt time:

Reduced by one-half compared with an existing CVT

8. 結果

本件の取り組みを通じて，得られた結果及び効果は以下の通り
加工タクトタイム ：1/2（従来ユニット比）達成
投資削減効果：約▲50%（従来ユニット比）
展開エリア面積：約▲50%（従来ユニット比）

9. まとめ

Jatco CVT7プロジェクトは，開発的にも，小型，軽量，低フリクション，ワイドレシオと多くの挑戦をしたプロジェクトであるが，その挑戦の初期段階から，同席設計として，生産技術部隊も積極的に参加し，様々な生産設計アイテムに取り組み，高いコスト目標にチャレンジしたプロジェクトであった．この，Jatco CVT7プロジェクトの開発初期段階の活動を振り返ってみて，改めて，同席設計の意義を確認する事が出来たと思う．今後の新規プロジェクトにおいても，是非，開発と生産が共に活動できる様尽力していきたい．

最後に，本稿は，生産技術の視点で述べた物ですが，開発関係者の方々の生産設計に対する理解と努力が有ってはじめて成果の得られる取り組みとなった事をお伝えし，ここに深く感謝致します．

Reduction of capital investment:
Reduced by approximately 50% compared with an existing CVT
Line layout area:
Reduced by approximately 50% compared with an existing CVT

9. Conclusion

The Jatco CVT7 project presented numerous development challenges, including downsizing, weight reduction, friction reduction and attainment of wide ratio coverage. Those challenges were tackled from the initial development stage through collaborative design activities. A production engineering team also actively participated in these activities and a wide range of production design measures were pursued. Achieving high cost performance was another challenge undertaken in this project. Looking back now on the activities undertaken from the initial stage of the Jatco CVT7 development project reaffirms the significance of collaborative design work. Every effort will be made in new development projects in the future as well to enable the R&D division and the production division to pursue joint activities effectively.

This article has described the Jatco CVT7 development project from the perspective of production engineering, but the results presented here were obtained only because of the understanding and efforts by the R&D division people with regard to production design. In conclusion, the authors especially want to note this point and express their profound gratitude to everyone involved.

■ Authors ■

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ジヤトコの部品・材料の現地化，LCC化に関する取り組み

JATCO'S Efforts to Procure Parts/Materials Locally and from LCC Suppliers

増田　茂*
Shigeru MASUDA

抄　録　円高が続き，また経済の座標軸が先進国から新興国にシフトしつつある現在，自動車業界のみならず多くの業種が，海外生産及びLCC（Leading Competitive Country）からの製品，材料，構成部品，設備等の調達推進を加速している．

自動車用自動変速機を製造，販売しているジヤトコ株式会社（以下 ジヤトコと略す）での部品の現地調達及びLCCからの部品調達活動の取り組みについて紹介する．

ユニット生産の海外展開とリンクしたこの取り組みは競合他社より一歩先んずる活動だと考えるが，同時に顕在化した品質レベル･技術レベルの向上を早急に図ることがジヤトコの競争力の更なる維持向上に直結すると考える．

Summary　Companies in many different industries besides the automotive sector are accelerating their overseas production activities and procurement of products, materials, component parts, equipment and other items from suppliers in leading competitive countries (LCCs). This is taking place in the face of the continued high yen and the ongoing shift of the coordinate axes of the world economy from the developed countries to emerging economies. This article describes the activities JATCO is undertaking to procure parts locally and from LCC suppliers for its business of manufacturing and marketing automotive automatic transmissions. JATCO has been one step ahead of its competitors in these procurement activities, which are linked to the company's expansion of overseas production operations. Improvement of the quality and technical levels of suppliers has emerged as an issue that must be addressed urgently, as it is directly related to JATCO's efforts to maintain and further improve its competitiveness.

1. はじめに

世界の4輪自動車の全需台数はリーマンショックの影響で2008年，2009年に大きく台数が落ち込んだものの，2010年以降は回復から成長にSHIFTしている．具体的には，全需台数は2010年の約7,000万台から2016年には主として中国とNAFTAでの台数増により，約9,000万台まで増大するものと予想されている．日本全需は横ばいの見込みである．

一方，為替は2年前の1ドル＝100円から現在の約77円まで，23％変動しており，急激な円高となっている．この円高の環境下で最大の株主である日産自動車株式会社は日本市場向け小型車マーチをタイで生産している．また，トヨタ自動車株式会社がインドでの新車現地生産にあたり，現地取引先を20

1. Introduction

The collapse of Lehman Brothers caused the total demand for four-wheeled vehicles to plummet worldwide in 2008 and 2009, but vehicle demand began to recover again in 2010 and has since shifted to a growth trend. In terms of specific figures, vehicle demand totaled approximately 70 million units in 2010 and is projected to increase to some 90 million units by 2016. That growth will mainly be due to increased vehicle demand in China and the three NAFTA (North American Free Trade Agreement) countries. Total vehicle demand in Japan is expected to be flat.

Meanwhile, the yen has appreciated sharply against the dollar, rising from an exchange rate of US$1 = 100 yen two years ago to approximately 77 yen at

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社採用し，今後，エンジン，変速機の生産開始に向けて，更に現地での部品調達率を向上させる計画との報道があった．こうした動きは日産自動車株式会社，トヨタ自動車株式会社のみならず，他自動車メーカー，変速機メーカー，部品メーカーも同様である．

目的は言うまでもなく，需要のある地域での生産により，急激な円高による為替差損リスクの回避及び最終顧客までの物流費含めた製品のコスト低減による商品価格競争力向上と新興国の需要の取り込みにある．

2ペダルトランスミッション業界の中で海外生産が先行したジヤトコは，LCCメーカーのコスト競争力に着目し，早くからLCCメーカーからの部品調達の開始，自動変速機の海外生産及び構成部品の現地調達を全社を挙げて推進し，ジヤトコ自動変速機の価格競争力向上に大きく貢献している．

2. LCCからの部品調達の歴史

ジヤトコが海外からの部品調達を開始したのは1990年後半であったが，極一部の部品に留まっていた．当時の為替は1$＝120円であり，2001年の1$＝130円から今日までの超円高が始まったスターティングポイントである．

ジヤトコは，国内の自動車メーカーの車両の海外生産化に対応し，2005年に当社の戦略的変速機であるJatco CVT7（以下，CVT7と略す）のメキシコ生産を開始した．以降，海外，LCCからの部品調達推進のアクセルペダルが一気に踏みこまれた．CVTのメキシコ生産にあたり，構成部品のNAFTAサプライヤー又はLCCサプライヤーからの調達を検討したが，厳しい部品加工精度を要求し，投資額も大きなCVT部品の生産，品質保証が可能なサプライヤーはBig3のサプライヤーも含めてほとんど存在しなかった．同時に，日本部品メーカーの海外展開が旺盛な時期ではなく，設計，生産，品質保証が難しい部品は，日本，欧州からの輸入とせざるを得ない部品も多くあった．

変速機の部品はサプライヤーへの設計仕様提示方法で2つに大別される（Table 1）．

present, a jump of 23%. In this high yen environment, Nissan Motor Co., Ltd., JATCO's largest shareholder, is building its March small car in Thailand for sale in the Japanese market. There are also media reports that Toyota Motor Corporation selected 20 Indian suppliers in connection with the local production launch of a new model in India. Toyota reportedly plans to increase its local parts procurement rate further for launching engine and transmission production in the future. These moves are not limited to Nissan and Toyota, as other automakers, transmission manufacturers and parts makers are also taking similar steps.

One purpose for producing in areas where there is strong demand is clearly to avoid exchange loss risks due to the sharp appreciation of the yen. Other reasons are to enhance the price competitiveness of products by reducing related costs, including the cost of distribution to the end user, and to capture demand in emerging economies.

In the two-pedal transmission industry, JATCO has been a pioneer in launching overseas production. JATCO was quick to notice the cost competitiveness of manufacturers in leading competitive countries (LCCs) and began early on to procure parts from LCC suppliers. Company-wide efforts have been made to promote overseas production of automatic transmissions and to localize procurement of component parts. Those efforts have contributed significantly to improving the cost competitiveness of JATCO automatic transmissions.

2. History of Parts Procurement from LCC Suppliers

JATCO began procuring parts from overseas suppliers in the latter half of the 1990s, but procurement was limited to just a few parts. The exchange rate at that time was US$1=120 yen. The starting point of today's extremely high yen was in 2001 when the exchange rate was US$1=130 yen.

To cope with the transfer of production overseas by Japanese automakers, JATCO began producing the CVT7, one of the company's strategic transmissions, in Mexico in 2005. Since then, JATCO has been pushing the accelerator pedal hard to advance the procurement of parts from LCC suppliers overseas. For CVT production in Mexico, JATCO considering

Table 1 Methods of conveying design specifications to suppliers

Parts category	Responsible for design	Share of purchase value
Specification-indicated parts	Indication of required specs J*	60%
	Creation of design drawings S*	
	Approval of specs S*	
Drawing-provided parts	Creation of design drawings J*	40%

*J: JATCO *S: supplier

仕様提示部品は購入品全体額の60%を占める部品で，ジヤトコが提示する機能，性能，サイズを満足する様，サプライヤーが設計，生産する部品であり，部品の開発機能を有するサプライヤーがキャンディデイトとなる．

一方，部品図部品は，購入額比40%で，ジヤトコ設計部門が作成した図面に基づきサプライヤーが生産する部品であり，LCCサプライヤー含め，キャンディデイトの門戸は広がる．

仕様提示部品は，変速機の性能，品質に大きく係わる部品であり，現状では，設計，生産で実績のある日系又はグローバルサプライヤーへの依存度を高くせざるを得ないため，短期的にコスト競争力を確保するためには，仕様提示部品のLCC生産と，

部品図部品をコスト競争力の高いLCCサプライヤーから購入出来るかがKEYとなる．

その後，2008年に中国広州でCVTを生産開始し，Jatco CVT7の海外生産が本格化したことを受け，必然的こ部品の現地，LCCサプライヤーからの調達ニーズが高くなった．

3. LCCサプライヤーからの部品調達の課題

ジヤトコに限らず，自動車，2輪，その他産業でも海外生産進出，LCCサプライヤーからの部品等の調達が進んでいる．家電，衣服産業はその代表格と考えるが，ジヤトコは同業種他社と比較し，CVT用を代表する高精密加工部品の多くをLCCから調達している点で，一歩進んでいる．

ジヤトコの海外生産変速機の部品現地化，LCC化率90%に対し，ジヤトコの競合他社は，各種情報から推定するに，部品の現地，LCC調達率は50%以下であり，多くの部品を日本から輸出しているものと思われる．

procuring component parts from NAFTA suppliers and LCC suppliers. However, there were virtually no suppliers, including those of the Big Three U.S. automakers, which were capable of producing and assuring the quality of CVT parts that require stringent machining accuracy and large capital investments. Moreover, Japanese parts makers were not actively setting up operations overseas at that time, so many of the parts that had difficult design, manufacturing and quality assurance requirements had to be imported from Japan or Europe.

There are two principal ways in which the design specifications of transmission parts are conveyed to suppliers (Table 1). Parts for which the specifications are indicated by JATCO account for 60% of the total value of purchased parts. These are parts that suppliers design and manufacture so as to satisfy the functionality, performance and size requirements specified by JATCO. Companies possessing parts development capabilities are candidate suppliers for these parts.

Parts for which JATCO provides the design drawings account for the remaining 40% of the total. These are parts that suppliers manufacture based on design drawings created by JATCO's design division. The door for supplying these parts is open wide to many candidates, including LCC suppliers.

Specification-indicated parts play a large role in transmission performance and quality. For these parts, JATCO is currently highly dependent on Japanese-affiliated companies or global suppliers that have a proven track record for design and manufacturing. A key factor in ensuring near-term cost competiveness is to have LCC suppliers produce specification-indicated parts and to purchase drawing-provided parts from LCC suppliers having high cost competiveness.

JATCO subsequently launched CVT production in Guangzhou, China in 2008. The start of full-scale

他方，先行してのLCC部品採用の課題は次のものと考える．

部品に対し，高い加工精度，品質を求めるが故に，変速機部品又は自動車部品の生産の経験を有する日系サプライヤー又は，高い技術力，品質力を有する海外サプライヤー企業からの部品調達の依存度が高いこと，つまり，コスト安のLCCサプライヤーからの調達部品が制限されることである．

Fig. 1は，過去3年間のジヤトコと取引きのあるアジアのある国のサプライヤーと日本のサプライヤーの平均品質実績（納入不良個数率）を示したものである．品質レベルの差がある．

ここ数年は急激な円高が進行中であるが，この国のサプライヤーからの部品調達額は，大きな増加には至っていない．

次項ではLCCサプライヤーの品質，技術レベルの向上に関する施策について述べる．

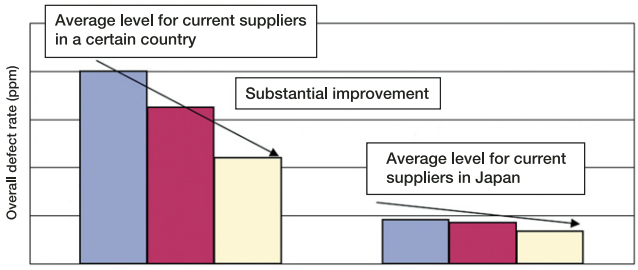

Fig. 1 Average quality levels

4. LCCサプライヤーの品質，技術向上策について

この課題に対しジヤトコが取り組んでいる活動を次に紹介する．

一つ目は，発注サプライヤーの決定プロセスの改善である．

ジヤトコでは，主として新規開発変速機や新海外拠点で生産する変速機用の部品発注先を決定する場は，PSSC（Purchasing Suppliers Sourcing Committee）という会議体である．メンバーは，チェアマンである調達，開発役員，提案者の調達，設計，そして審議メンバーである品質，技術，生産管理，原価管理部門で構成されている．コスト競争力のみではなく，品質，技術，開発力の評価，課題有無，その対応についてPSSCで合意の上，全社で透明性を

production of the Jatco CVT7 overseas necessarily increased the need to procure parts locally and from LCC suppliers.

3. Issues in Procuring Parts from LCC Suppliers

Not only JATCO but also automakers, two-wheeled vehicle manufacturers and companies in other industries are setting up production operations overseas and proceeding with the procurement of parts from LCC suppliers. The consumer electronics and apparel industries are often considered to be typical examples in this regard. Compared with other automotive transmission manufacturers, JATCO is one step ahead with respect to the procurement of many high-precision machined parts from LCC suppliers, including components for CVTs.

Currently, 90% of the parts used in the overseas production of JATCO transmissions are either procured locally or from LCC suppliers. By comparison, the corresponding rate estimated from various information sources for our Japanese competitors is less than 50%, and presumably they export many parts from Japan for use in overseas production.

The following are some of the issues JATCO has faced in taking the lead in adopting parts procured from LCC suppliers. There is a high degree of dependence on Japanese-affiliated suppliers and overseas suppliers possessing excellent engineering and quality capabilities and which have experience in manufacturing transmission and automotive parts. This is because transmission parts require high levels of machining accuracy and quality. In other words, parts that can be procured from low-cost LCC suppliers are limited.

Figure 1 shows the average quality levels (defect rate of delivered parts) over the past three years for suppliers in a certain Asian country and Japanese suppliers, with which JATCO has business dealings. The level of quality between the two groups clearly differs. Despite the steep appreciation of the yen these last few years, the monetary value of parts JATCO procures from suppliers in this Asian country has not increased significantly. The following section describes measures JATCO is taking to improve the quality and technical levels of LCC suppliers.

持ったサプライヤー決定している．

このPSSCでサプライヤー提案をするにあたり，次のプロセスを置いている．

サプライヤー提案前に，調達，品質，技術，開発部門にて，部品の技術難易度，候補サプライヤーの品質･技術レベル，カントリーリスク有無等を考慮し，最適なサプライヤーを検討する．PSSC自体は従来からの会議体であるが，過去に発生したLCCサプライヤー問題，具体的には，サプライヤーの技術力以上の加工難易度が高い部品を発注し，部品の量産開始時期の遵守，品質確保にかなり苦労したこと，過激な労働争議による部品供給の停止を経験したこと，を二度と繰り返さない為，社内関係部門での問題振り返りにより，PSSC提案プロセスとPSSCメンバーの充実を図った．

二つ目はLCCサプライヤーの指導･育成である．

発注先選定時，候補サプライヤーがジヤトコとの取引きが新規となる場合，又は新規拠点での生産，新規工法の採用の場合には，ジヤトコ PSSCメンバーの各部門がそのサプライヤーの事前監査を実施し，発注先として問題無いかの評価を行なう．

この監査により，品質･技術力が弱いと評価されたサプライヤーは，発注不可と判定される訳だが，この評価は必ずしもLCCサプライヤーを採用しない為の評価ではなく，採用せざるを得ない理由がある場合には，採用する場合の課題を洗い出し，対処を決める仕組みでもある．

変速機のコスト競争力確保の観点から，RISKサプライヤーの活用が必要と判断された場合には，そのサプライヤーが課題の改善可能なレベルであることを条件に，品質，技術と調達部門内のモノづくりサポートチームが中心となり，そのサプライヤーの工程設計，品質改善，現場管理力改善，モノづくり改善を指導し，判定されたRISKを解消する取り組みを実施し，品質をないがしろにすることなく，コスト競争力を確保する活動を実施中である．

このサプライヤーサポート活動は，国内外で実施している活動であり，サプライヤーからも品質向上とモノづくり力向上が実現でき，好評を頂いているサポートプログラムである．

このサポートプログラムの一環として昨年より韓国のKOTRA（Korea Trade-investment Promotion

4. Measures for Improving Quality/Technical Levels of LCC Suppliers

The section describes some of the activities JATCO is undertaking to address this issue. The first point concerns improvement of the process for selecting suppliers from which parts are purchased.

JATCO has a Purchasing Suppliers Sourcing Committee (PSSC) that mainly determines the suppliers from which JATCO procures parts for newly developed transmissions or transmissions manufactured at overseas production plants. The members of the PSSC include the company officer responsible for purchasing and product development, who serves as the committee chairman, purchasing and design representatives who present proposals, and representatives of the quality assurance, engineering, production control and cost planning departments who examine the proposals. Candidate suppliers are selected in a process that is transparent to the entire company, based on a consensus by the PSSC regarding not only cost competitiveness but also an evaluation of supplier quality, technical and development capabilities, existence of any issues of concern and ability to deal with them.

The following process is adhered to in proposing a supplier to the PSSC. Before proposing a supplier, the purchasing, quality assurance, engineering, and development departments conduct a study of the optimum supplier, taking into account the technical difficulty of the part in question, quality/technical levels of candidate suppliers, existence of country risks and other factors. While the PSSC still has its original committee structure, steps have been taken to improve the PSSC proposal process and PSSC members based on a review by the relevant internal departments of problems that occurred with LCC suppliers previously. Specifically, exceptionally difficult-to-machine parts were outsourced to certain suppliers that exceeded their technical capabilities, so they had considerable trouble keeping the deadline for the start of mass production of the parts and assuring the required quality. In other cases, fierce labor-management strife caused the supply of parts to be suspended. The improvements made are intended to prevent such bad experiences from being repeated again.

Agency）と連携の上，実行準備中のプログラムがある．次にこのプログラムの紹介をする．

5. KOTRAとの活動

KOTRAの役割は，1）海外グローバル企業と韓国サプライヤーの戦略的な提携支援を通ずる韓国サプライヤーの輸出拡大の支援，2）外資／高度外国人人材の誘致である．

1）の目的は，海外グローバルサプライヤーへの韓国サプライヤー紹介，R&D費用の支援である．

ジヤトコは韓国にR＆D会社を設立しており，KOTRAと韓国でのR&D事業の推進において強固な協力関係を構築済みである．

このコミュニケーションルートを活用し，韓国サプライヤーがグローバルプレイヤーになるための課題とジャトコ支援策をKOTRAに提示した．

1）ジヤトコは韓国サプライヤーからの調達を年々増加させている．今後，更なる調達拡大の可能性があること，2）これを実現させる為には韓国サプライヤーの品質･技術レベル向上が必要であること，3）ジヤトコはこの為のサポートをする用意があること，4）その結果，韓国サプライヤーは技術･品質レベル向上が図れ他のグローバル企業とのビジネス拡大が期待出来ること．

こうして昨年末にKOTRAとジヤトコはMOU（Memorandum of Understanding）を締結した．ポイントは以下である．

ジヤトコは，1）韓国サプライヤーの品質向上を通じたグローバル競争力向上の支援を実施する．一方，KOTRAは1）当社の次世代CVT構成部品のサプライヤー選定活動支援2）ジヤトコの韓国サプライヤーの技術･品質向上サポート活動の推進支援である．

現在，KOTRA，サポート実施サプライヤーと支援実施についての最終調整中であり，年内には最終合意見通しである．

このKOTRA支援による韓国サプライヤーのサポート活動により，ジヤトコの韓国からの調達部品の品質向上，QCDDが優れた部品の韓国からの調達拡大の実現とともに，現在，部品図部品のみの韓国，LCCサプライヤーからの輸入の実態を回避すべく，

The second point concerns efforts to advise and develop LCC suppliers. Before the selection of a supplier is finalized, the PSSC members from the JATCO departments involved conduct a prior audit of the company and evaluate whether it might have any problems as a supplier. This is done in cases where a candidate supplier will do business with JATCO for the first time, production is being launched at a new location or a new manufacturing method has been adopted. If this audit rates a company as having poor quality/technical levels, it will not be approved as a supplier, but this evaluation does not necessarily mean that an LCC supplier will not be adopted. In cases where there is a reason why the company must be used as a supplier, the audit provides a mechanism for identifying issues that first must be addressed and for determining ways of resolving them.

When it is deemed that a potentially risky supplier must be used for the sake of ensuring transmission cost competitiveness, the quality assurance, engineering and purchasing departments form the core of a monozukuri support team on the condition that the supplier's issues are at a resolvable level. This support team advises the supplier on ways of improving its process design, quality levels, shop floor management system and monozukuri capabilities and on the implementation of measures for eliminating identified risks. Activities are undertaken to ensure the supplier's cost competitiveness without sacrificing quality.

These supplier support activities are carried out both in Japan and overseas, and this support program has been highly acclaimed by suppliers for enabling them to improve both their quality levels and monozukuri capabilities. As one part of these support activities, JATCO has been working with the Korea Trade-Investment Promotion Agency (KOTRA) since last year to prepare a supplier support program for implementation, which is described in the following section.

5. Activities with KOTRA

The roles of KOTRA are (1) to support the expansion of exports by Korean companies through the facilitation of strategic cooperation between overseas global firms and Korean suppliers and (2) to attract foreign investment and highly educated

仕様提示部品の韓国サプライヤーでの開発，調達の実現を目指している．

6. Jatco CVT7 でのLCCからの部品調達状況

調達部門はジャトコ海外展開の計画の主要サプライヤーとの共有化･海外進出の誘導，あらゆる情報ソースを活用したLCCサプライヤーのーの発掘･評価に取り組んできた．

現在のジヤトコの最量産CVTであるJatco CVT7の中国，MEXでの部品の現地化／LCC調達率は90%（対購入額全体）であり，設計，品質，技術，生産管理部門との全社活動により，高いQCDDを満足する部品調達網が整備出来た．

また，昨年外部発表済みの2013年のタイでのCVT生産に対応し，ASEAN地域からの部品調達推進中であるが，これまでの取り組みにより，LCCからの部品調達率はほぼ100%，ASEANからの調達は約95%を達成する見込みである．

7. まとめ

部品の現地／LCCサプライヤー調達はかなり進んでいるが，更なるQCDD競争力向上の為の課題は，LCCサプライヤーの品質･技術力向上に，加えて，ジヤトコの図面規格緩和の可能性確認，各ジヤトコ海外拠点での調達部品の実質現地化率（購入価格に占める現地付加価値コストの割合）の向上である．

材料は品質保証上重要なファクターである．一方，部品コストの約30%を占めており価格低減の大きなポイントでもある．

中国，韓国の材料メーカーの品質レベルが急激に向上していることからジヤトコ開発部門とサプライヤーと連携し，材料の現地化／LCC調達を強力に推進中である．

また，先に述べた様に，NAFTAは中国とともに，将来の自動車需要の増大オポチュニティーは大であり，今後益々QCD競争力に優れた変速機の需要が

増大するものと考えられる．現在のメキシコ生産CVT部品の調達は，NAFTA圏サプライヤーに加え，LCCアジアからの部品送達で価格競争力を向上させているが，物流費含めたコスト低減，更なるコスト

international human resources to Korea. To accomplish its first objective, KOTRA introduces Korean suppliers to overseas global companies and provides support for R&D expenses.

JATCO established an R&D company in Korea and has forged strong cooperative ties with KOTRA for the promotion of R&D activities in that country. Through this communication channel, JATCO has presented various issues to KOTRA that should be addressed to enable Korean suppliers to become global players and has proposed the support measures noted below.

(1) JATCO is increasing its procurement from Korean suppliers every year and may further expand the scope of its procurement in the coming years.
(2) To accomplish that, the quality and technical levels of Korean suppliers must be improved.
(3) JATCO is ready to provide support toward that end.
(4) As a result of improving their quality and technical levels, Korean suppliers can expect to expand their business dealings with other global companies.

Toward the end of 2011, KOTRA and JATCO concluded a memorandum of understanding (MOU), the key points of which are outlined below.

(1) JATCO will provide support for improving the global competitiveness of Korean suppliers through the enhancement of their quality levels.
(2) For its part, KOTRA will support JATCO's activities to select Korean suppliers for the component parts of JATCO's next-generation CVTs and support the promotion of activities to improve the quality and technical levels of JATCO's Korean suppliers.

Discussions are currently under way with KOTRA to work out the final details of the suppliers to be supported under this MOU and the specific support measures, and a final agreement is expected to be reached in 2012. The Korean supplier support activities to be carried out with KOTRA's assistance will improve the quality of the parts JATCO procures from Korean companies and expand the range of parts purchased from them that are superior with respect to quality, cost, delivery and development (QCDD) aspects. At present, JATCO imports from Korean and LCC suppliers only drawing-provided parts, but we

ト競争力UPの為，特に現地化推進が必要と考えている．

競合他社も海外生産進出を加速しており，今後間違い無く，現地，LCCからの部品調達を大幅に拡大するものと考えられる．

ジヤトコも価格競争力において，安穏としていられる状況ではない．

海外進出されている他業種，自動車メーカー，部品サプライヤーもお手本にし，更なるグローバルでのQCDD向上活動を推進していきたい．

aim to overcome this situation and procure specification-indicated parts that have been developed by Korean suppliers.

6. Jatco CVT7 Parts Procured from LCC Suppliers

The purchasing division has been working to use principal suppliers in common for the company's plan to expand overseas production operations and to invite Japanese suppliers to set up production facilities overseas. Various information sources have also been used to discover and evaluate LCC suppliers.

The Jatco CVT7 currently has the highest production volume of the company's CVT models, and 90% of the parts used in producing this unit in China and Mexico are procured locally or from LCC suppliers. (That figure is the percentage of the total value of purchased parts.) Thanks to the company-wide activities undertaken by the design, quality assurance, engineering and production control departments, we have built a network for procuring parts that satisfy our high QCDD requirements.

In December 2011, JATCO announced a plan to launch CVT7 production in Thailand around the middle of fiscal 2013, and efforts are now under way to procure parts from the ASEAN region. Building on the activities carried out so far, it is expected that the parts procurement rate from LCC suppliers will reach nearly 100% and that approximately 95% of the parts will be procured from the ASEAN region.

7. Conclusion

Considerable progress has been made in procuring parts locally and from LCC suppliers, but various issues must be tackled to improve QCDD competiveness further. These include improving the quality levels and technical capabilities of LCC suppliers, confirming the possibility of relaxing JATCO's design drawing specifications and increasing the real local parts procurement rate (i.e., the share of the local value-added cost as a percentage of the purchase price) at each of the company's overseas production centers.

Materials represent a crucial factor with respect to quality assurance. At the same time, since materials account for approximately 30% of the total cost of

parts, they are a key factor in reducing prices. Because the quality level of Chinese and Korean materials manufacturers has improved dramatically, JATCO's R&D division is working with parts suppliers to strongly promote the procurement of materials locally and from LCC suppliers.

As mentioned earlier, along with China the NAFTA region has a large potential for higher vehicle demand in the coming years. It is expected that demand for transmissions with even more outstanding QCDD competitiveness will increase in the future. In addition to procuring parts for CVT production in Mexico from NAFTA region suppliers at present, parts are also being shipped from Asian LCCs for the purpose of increasing price competitiveness. However, there is an especially strong need to promote further local procurement in order to reduce costs, including logistics expenses, and further improve cost competitiveness.

Our competitors are also accelerating their overseas production activities and will undoubtedly expand their procurement of parts locally and from LCC suppliers substantially in the years ahead. JATCO is not in a position to be complacent about price competitiveness. We want to move ahead with activities to improve our global QCDD levels further, learning from companies in other industries, automakers and parts suppliers that are operating overseas.

■ Author ■

Shigeru MASUDA

品質・サービスの取り組みについて

Efforts to Improve Product Quality and Service

森　隆直*
Takanao MORI

抄　録　本稿では 最近の商品，ジヤトコを取り巻く環境が大きく変化したことに対して品質サービスの取り組んできたこと，これから必要な視点を考察する．

Summary　This article explains efforts that have been made to improve product quality and service in relation to large changes in the business environment surrounding JATCO and its products in recent years. It also discusses perspectives that must be considered in future activities.

1. はじめに

ステップATが普及して約30年，それに対してCVTはここ10年足らずで飛躍的な市場保有台数（FY10時点で当社CVTがグローバル1,000万台を突破）になり，急激な成長を見せている．その中で商品品質とアフターサービスについては 構造の複雑化と同時にインターネットの普及による情報伝達の劇的なスピードアップによって，要求品質の高まり，保証期間後の品質サービス要求の高まりなど，過去に経験したことのないレベルでの質･規模･スピードが求められている．最量販のCVT専門メーカーにとって，商品品質とアフターサービスへの要求に対処することに対する重要性はたいへん大きく，品質･サービスで如何にCVTのプレゼンスを向上･維持するかが最大の使命である．最新機種であるJatco CVT7は これらの環境が大きく変化した以降で，品質への取り組みを見直しし改善した最初のユニットである．

2. 取り巻く環境と課題

対応すべき具体的な環境変化と重要なポイントを以下に述べる．

① 品質不具合を『早く見つけて 早く直す』

例えば 最量販のJatco CVT7は グローバルで月産約10万台であり，一日でもアクションが遅れれば約5000台の改善チャンスが無くなってしまう可能性を考えることが必要である．一方で従来からの不具合現

1. Introduction

It took stepped ATs approximately 30 years to penetrate the market, but the number of CVTs installed on production vehicles has grown dramatically in less than ten years. As of end-March 2011, JATCO CVTs were installed on more than 10 million vehicles worldwide. During this time, demands for higher product quality and after-sales service have increasingly risen due in part to the complex structure of CVTs. Another factor here is the dramatic speed at which information is transmitted today owing to the spread of the Internet. The requirements for higher quality and service after the expiration of the warranty period have thus increased. Quality, scale of service and speed are being demanded today at levels never experienced in the past. As a high-volume CVT specialist manufacturer, it is extremely important that we meet customers' demands for product quality and after-sales service. Our biggest mission is to enhance and maintain the market presence of CVTs by providing the highest possible quality and service. The Jatco CVT7 is the company's latest CVT model and the first unit to be released since we reviewed and improved our quality activities following these momentous changes in the business environment.

2. Surrounding Business Environment and Issues

Specific examples of business environment changes that must be met and the key points involved are described below.

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Quality Assurance Department

品の回収を待っているだけでは1ヶ月～3ヶ月はかかってしまう．そこで各種情報を総合的に分類分析して仮説を立て，検証するプロセスが重要である（Fig. 1）．

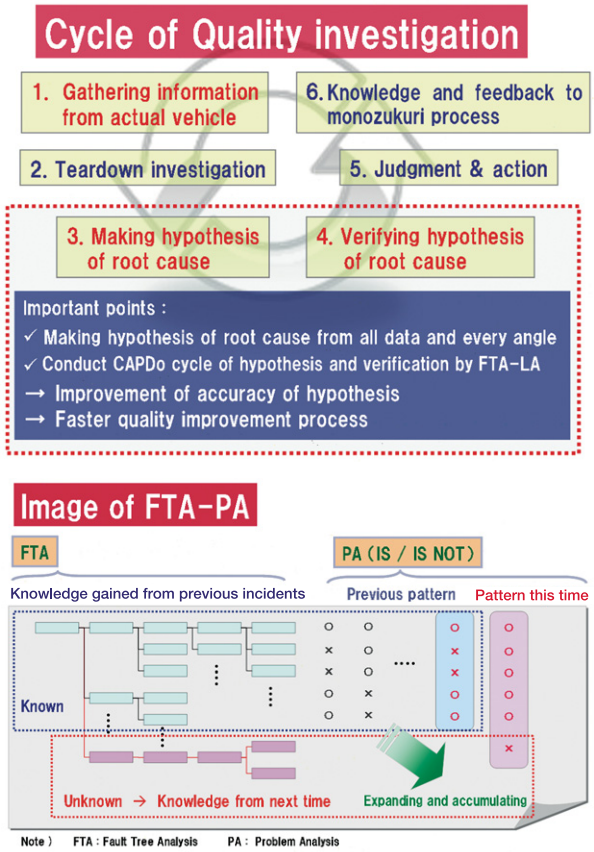


Fig. 1 Diagram of hypothesis verification process

仮説検証のプロセスもさることながら，それをサポートするシステムを2011年4月から正式導入し，運用中である．このシステムは社内にスタンドアローンで点在するデータベースをユーザーPC上でバーチャルに連結できることが最大のポイントである．品質で例えれば市場不具合と工程管理データ，4M変化点デー

(1) Finding and fixing quality problems quickly

The Jacto CVT7 is the company's highest-volume unit with a global monthly production volume of approximately 100,000 units. It is necessary to consider that if action on a quality problem is delayed even one day, we may lose a chance to improve some 5,000 units. On the other hand, it may take 1-3 months if we just wait for defective products to be recovered from the market in the conventional way. For that reason, it is vital to have a process for organizing and analyzing all sorts of data comprehensively, formulating a hypothesis about the root cause of a problem and then verifying it (Fig. 1).

More than just having a process for verifying hypotheses, a system for supporting it was officially implemented in April 2011 and is now in operation. The most significant feature of this system is that it enables stand-alone databases scattered throughout the company to be linked virtually on employees' PCs. With regard to quality, for example, product defects in the field, process control data and data on 4M (manpower, material, method, machine) changes can be visualized in one chart or graph, making it possible to dramatically improve the accuracy and speed of judgment and action (Fig. 2). Similarly, for durability problems as well, a key point is to predict and take action against potential durability issues before a CVT accumulates high mileage over long-term use. Activities are undertaken to investigate and statistically process large volumes of quantitative data, including cumulative mileage, wear levels and other details for parts besides specific defective ones recovered from the market (Fig. 3).

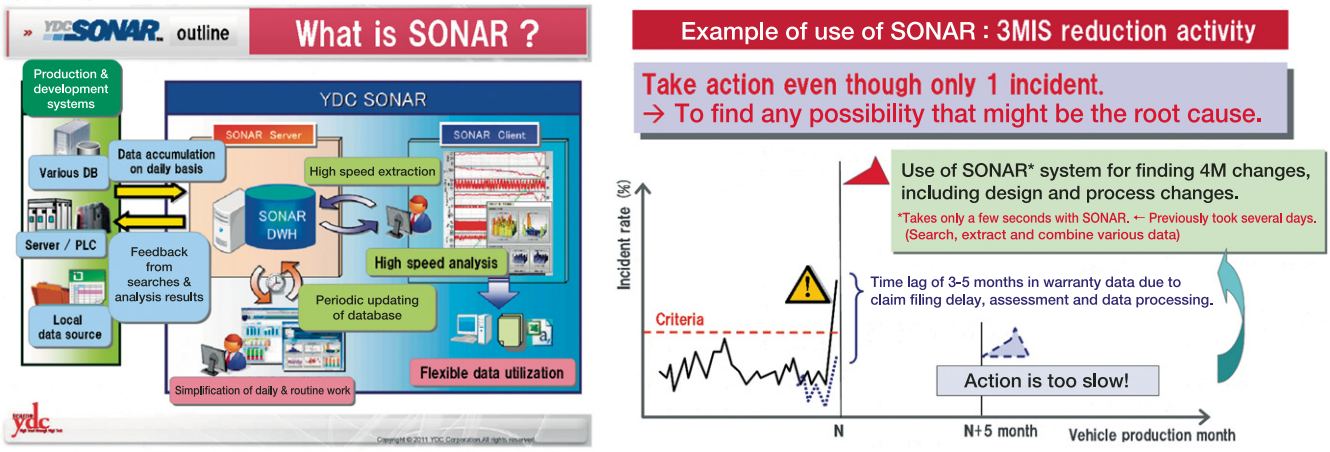


Fig. 2 Conceptual overview of SONAR

タをひとつのチャートやグラフ上で可視化でき，判断アクションまでの精度，スピードを飛躍的に向上させることができる（Fig. 2）．また耐久性不具合も同様に長期間走り込む前に耐久性不具合の予兆を掴んでアクションするかがキーとなり，特定の不具合回収品でも不具合部位以外の走行距離と部品の摩耗量などの定量データを数多く調査して統計処理する活動も行っている（Fig. 3）．

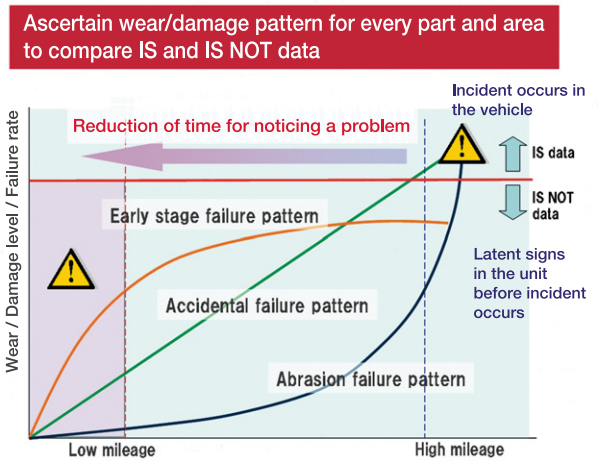


Fig. 3 Conceptual diagram of the process for predicting product durability

② 品質情報収集とアクションの先取り

他社事例も含めてインターネットによる情報伝播は1週間で激変するリスクがある．特に風評リスクは保有台数の大きな市場，新興国において顕著である．従って現地語による状態監視と素早いアクションが重要である（Fig. 4）．

③ 品質のアフターサービス

先進国の品質保証期間は通常5年10万kmであるが，競合他社との比較で新興国も含めて長くなる傾向にある．また，保証期間が切れた後のエンドユーザーの負担も重要なファクターとなる．特にCVTはユニット交換費用がステップATに比べ高額であることと，品質要求特性が厳しく市場での分解修理，部品交換が難しいため，早くステップAT並にすることが急務な課題である（Fig. 5）．

(2) Collection of quality-related information and proactive action

Based on our own experience and examples at other companies, there is a risk that information conveyed via the Internet can change radically within a week. The risk of rumors is particularly high in markets where many JATCO CVTs are in use and in emerging economies. It is essential to monitor the situation in the local language concerned and to take action promptly (Fig. 4).

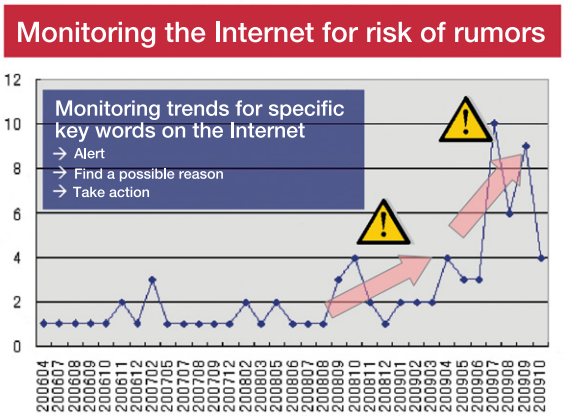


Fig. 4 Monitoring of risks to the company

(3) After-sales service for quality issues

The warranty period for automotive parts in developed countries is usually five years or 100,000 km. Compared with competitors, the warranty period has tended to become longer even in emerging economies. Another important factor is the repair cost for end users after the warranty period expires. There is an urgent need to achieve the same level of service for CVTs as for stepped ATs as quickly as possible. One notable reason is that a CVT is more expensive to replace than a stepped AT. Another reason is that in markets with rigorous quality requirements, it is difficult to overhaul and repair or replace CVT parts (Fig. 5).

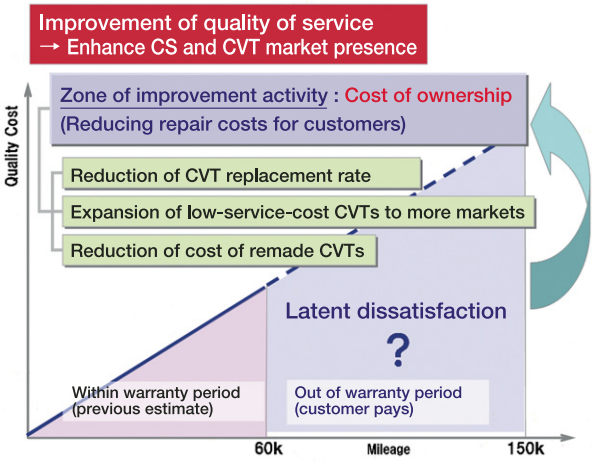


Fig. 5 Improvement of quality of service

3. 目指す姿

いままでに述べたように現行商品の品質改善とアフターサービスは たいへん重要であるが，これらの経験･知見を類似部品や工程，新規商品開発にフィードバックし再発防止を行うこと＝モノづくりへのフィードバックがジヤトコ全社をあげて取り組む課題である．もちろん，個々の不具合においては原因の掘り下げと再発防止，水平展開活動を実施してきているが，急速なグローバルへの拡大と新規イベント（＝大きな変化点）において類似の品質不具合を『所変え，品を変え発生』させないために，振り返りの視点と展開方法を改善して取り組む必要がある．特にグローバル展開にあたっては 失敗学の視点で シンプルに判りやすく，暗黙知を形式化し受け取った人が自責で考えられ，応用が効くように実施していく（Fig. 6）．

3. Desired System

As explained here, it is vital to improve the quality of current products and to provide thoroughgoing after-sales service. Experience and knowledge gained from previous incidents are fed back to prevent the recurrence of problems with similar parts or processes as well as in the development of new products. The entire company is engaged in the crucial task of feeding back information to the monozukuri process. Naturally, we isolate the causes of individual defects and take steps to prevent their recurrence by deploying parallel activities for other products throughout the company. The rapid expansion of production on a global scale and the undertaking of new events mean large changes are taking place. It is necessary to reflect carefully on previous incidents and improve our action deployment methods so that similar quality problems do not occur for other products at other places. In the course of promoting global expansion of production in particular, we need to learn lessons from past mistakes and express the resultant tacit knowledge in simple, easy-to-under formulas so that recipients can think about it for themselves and apply it effectively (Fig. 6).

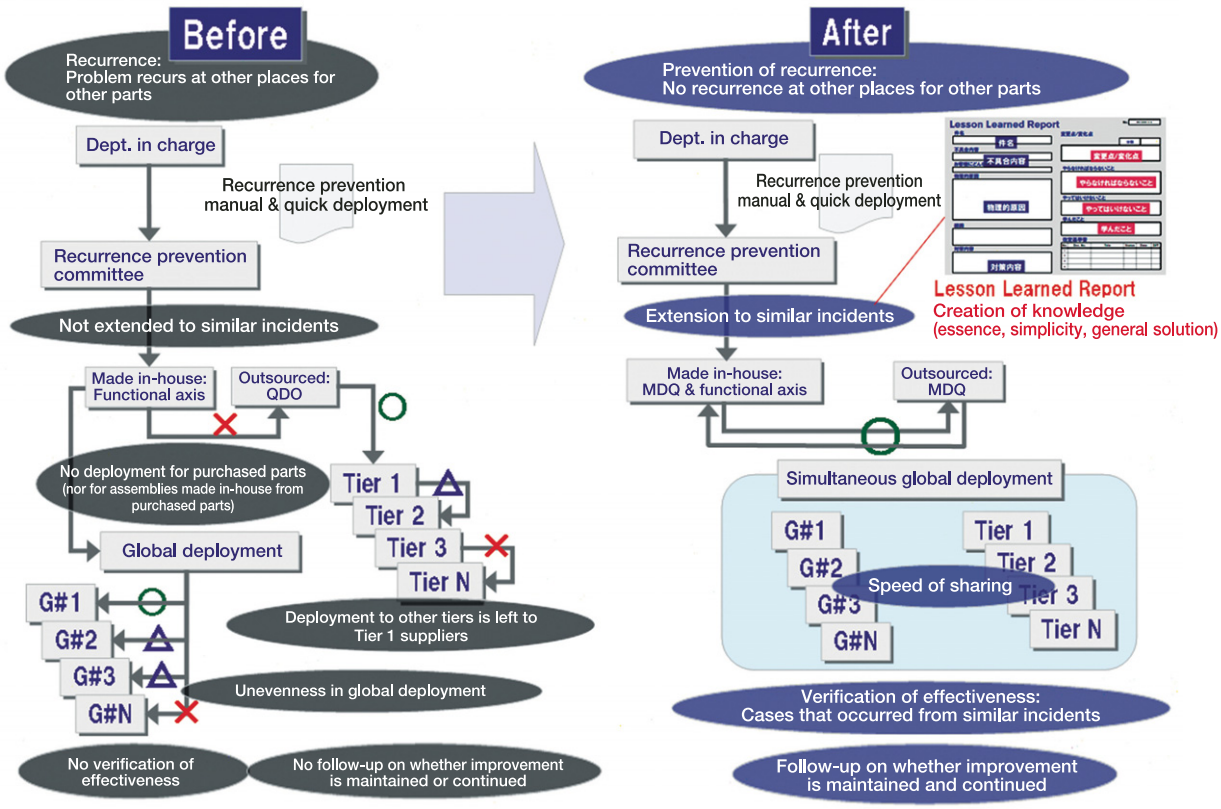


Fig. 6 Improvement of the process for preventing incident recurrence and deploying parallel activities

4. おわりに

自動車部品の品質保証業務に30年関わってきた者としての所感を述べたい.

・きちんと心配して品質確認しているところからは品質不具合は発生しない
　→ 各節目や変化点での判断を，抜け漏れのないように確認できる仕組みが重要
・これからの品質改善活動はデータによる仮説と検証の質･スピードを上げることが重要
　→ 多種多様膨大な品質データを多角的に定常的に分析し,仮説を立ててアクションにつなげる
・不完全な情報を疑う前に，自前で『(不具合を)仕込んでいるかも知れない』というマインドで即点検
　→ サプライヤーも含めて,この『前向きに心配する』マインドが必要である

今後も商品の品質保証については 品質保証サービス(市場)や実験部門(開発)，検査部門(工場)がリーダーシップを取っていくことに変わりはないが,モノづくりのプロセスに関わっている全ての関係者がこのような視点で少しずつレベルを上げて後戻りしないことが当社商品を世界一品質にする唯一の方法であり，近道でもあると思う．今後ともお客さまにとっての世界一品質を目指して活動を積み重ねていきたい.

4. Conclusion

The following are the personal views of one who has spent 30 years working to assure the quality of automotive parts.

- Quality problems do not occur in places where people are concerned about and confirm quality properly.
  → A system is necessary for confirming judgments made at every juncture and for every change so that nothing is omitted or overlooked.
- In future quality improvement activities, it will be essential to enhance the quality and speed of making and verifying hypotheses on the basis of quantitative data.
  → Large volumes of many different types of quality-related data need to be analyzed from multifaceted perspectives so that hypotheses can be formulated that lead to effective action.
- Before questioning the incompleteness of data, an inspection should be conducted immediately based on an awareness that one may be building in a defect in one's own process.
  → It is necessary for everyone, including suppliers, to have a mindset for positive thinking.

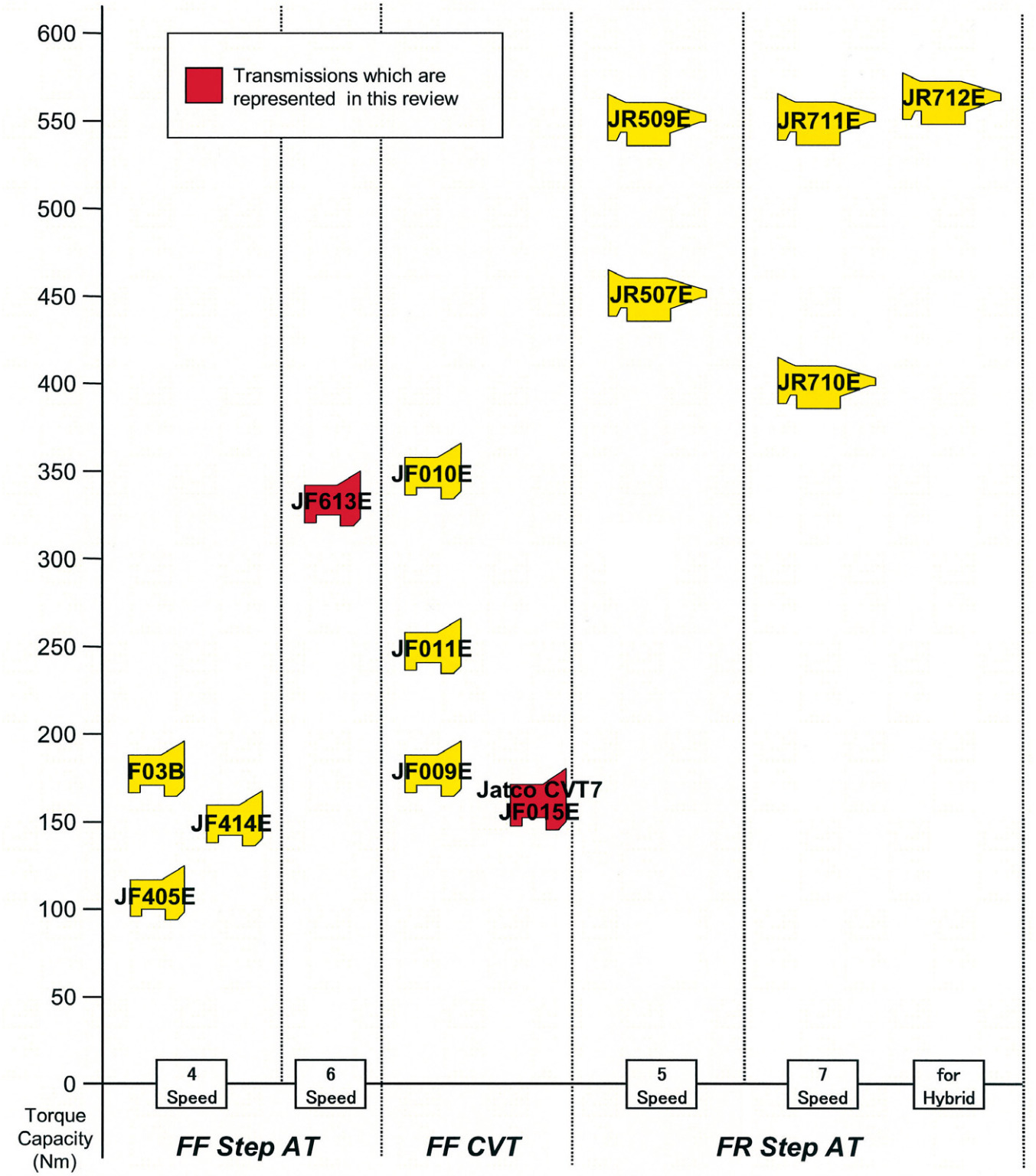
People involved in quality assurance activities in the field as well as employees in the experimental (R&D) and quality control (factory) departments will continue to exercise leadership in product quality assurance work in the future as well. However, everyone involved in monozukuri processes should strive to improve quality levels little by little from the perspectives noted above so that there is no backsliding on quality. This is the only way, and also the quickest way, to make our products number one in quality worldwide. We plan to redouble our efforts with the aim of providing our customers with the world's best quality.

■ Author ■

Takanao MORI

Product Line-up

Jatco



東風日産乗用車公司向け　FF車用CVT　Jatco CVT7の紹介

Introducing the Steel-belt Jatco CVT7 for Front-drive Compact Cars

2011年6月販売の東風日産乗用車公司（以下東風日産）の新型ティーダに搭載されたJatco CVT7は，従来のベルト式無段変速機＋遊星歯車を用いた副変速機を備えた独自の機構を採用することで世界一の変速比幅を実現し，ASC（アダプティブ･シフト･コントロール）によるレスポンスの良い発進，加速性能を確保しつつ，高速走行時の静粛性向上を実現させました．また，小型･軽量化と攪拌ロスの低減により，新型ティーダのアピールポイントでもある低燃費（2012年1月適用の中国第三段階燃費規制の規格6.9L/100Kmに対し，6.2L/100Km）達成に大きく貢献し，中国のお客様に好評を得ています．

2011年4月にはジヤトコ広州にてJatco CVT7の生産を開始し，国産化による原価低減にも寄与しています．

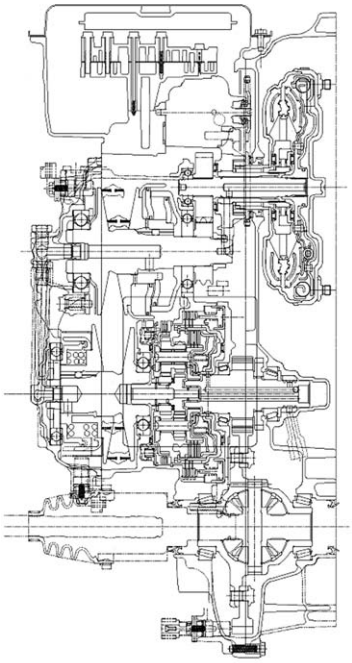


Fig. 1 Main cross-sectional view

■ Typical model fitted with the Jatco CVT7 ■

New TIIDA

The Jatco CVT7 was adopted on the new generation of the Tiida released in the Chinese market by Dongfeng Nissan Passenger Vehicle Co. (Dongfeng Nissan) in June 2011. The Jatco CVT7 features a unique architecture that combines a conventional belt-pulley system with a planetary auxiliary transmission to achieve the world's widest ratio coverage. It also incorporates Adaptive Shift Control (ASC) for quick start-off response and smooth acceleration performance combined with enhanced quietness in high-speed driving. Thanks to its smaller, lighter design and reduced fluid churning loss, the Jatco CVT7 greatly helps the new Tiida attain fuel economy of 6.2L/100 km to comply with the standard of 6.9L/100 km under China's Phase III fuel economy standards that came into effect in January 2012. Excellent fuel economy is one of the appealing features of the Tiida that has been highly popular among customers.

The Jatco CVT7 went into production at JATCO Guangzhou Automatic Transmission Ltd. in April 2011 and localization of production has contributed to significant cost reductions.

Table 1 Specifications of Jatco CVT7

Torque capacity	150 Nm
Control system	Electronic
Torque converter size	205 mm dia.
Counter gear ratio	0.967
Pulley ratio	Low: 2.2　High: 0.55
Ratio coverage	7.3
Planetary gear ratios	1st　Fwd: 1.821
	2nd Fwd: 1.000
	Rev: 1.714
Final gear ratio	3.882
No. of selector positions	5
Overall length	327.3 mm
Weight (wet)	67.3 kg (no IS figure)

北米日産向け　FF車用CVT　Jatco CVT7の紹介

Introducing the Steel-belt Jatco CVT7 for Front-drive Sedans

2011年8月販売の北米日産の新型グローバルセダン VERSAに搭載されたJatco CVT7は，副変速機を備えた独自の機構を採用することで世界一の変速比幅を実現し，ASC（アダプティブ･シフト･コントロール）によるレスポンスの良い発進，加速性能を確保しつつ，高速走行時の静粛性向上を実現させました．また，小型･軽量化と攪拌ロスの低減により，新型VERSAセダンのアピールポイントでもある低燃費（US 2016 CAFEに対し30city / 38hwy mpg）達成に大きく貢献し，北米のお客様に好評を得ています．更に，北米のお客様から求められる，再加速時のレスポンス向上についてもエンジンとの協調制御により目標達成いたしました．

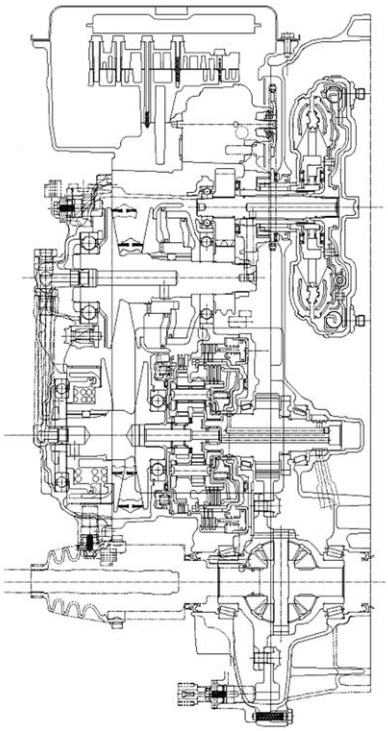


Fig. 1 Main cross-sectional view

The Jatco CVT7 was adopted on the Nissan Versa, a new global sedan that Nissan North America Inc. released in its market in August 2011. Incorporating a unique auxiliary transmission, the Jatco CVT7 achieves the world's widest ratio coverage. Adaptive Shift Control (ASC) is provided to ensure excellent start-off response and acceleration performance while also improving quietness during high-speed driving. This smaller, lighter CVT with reduced fluid churning loss contributes significantly to the Versa's excellent fuel economy figures of 30 city/38 highway mpg under the US 2016 CAFE test cycle. Outstanding fuel economy is one of the appealing features of the Versa sedan and has earned high praise from customers in North America. In addition, cooperative control between the engine and transmission achieves the target set for improved vehicle response when re-accelerating.

Table 1 Specifications of Jatco CVT7

Torque capacity	150 Nm
Control system	Electronic
Torque converter size	205 mm dia.
Counter gear ratio	0.967
Pulley ratio	Low: 2.2　High: 0.55
Ratio coverage	7.3
Planetary gear ratios	1st　Fwd: 1.821
	2nd Fwd: 1.000
	Rev: 1.714
Final gear ratio	3.882
No. of selector positions	5
Overall length	327.3 mm
Weight (wet)	67.3 kg (no IS figure)

■ Typical model fitted with the Jatco CVT7 ■

New Versa Sedan

ルノー三星自動車向け　FF車用6速AT　JF613Eの紹介

Introducing the JF613E 6-speed AT for Front-drive Cars

JF613Eは，2011年8月に発売されたルノー三星自動車株式会社の大型乗用車「All-New SM7」に搭載された．ONE WAY CLUTCH廃止仕様のGasoline Engineへの最初採用で，フリクション低減・Nアイドル制御の採用・ロックアップ領域の拡大による燃費向上及び，ASC（アダプティブシフトコントロール）機能により，走行環境や路面状況に応じた最適な変速を実現して，非常に高い評価を得ております．

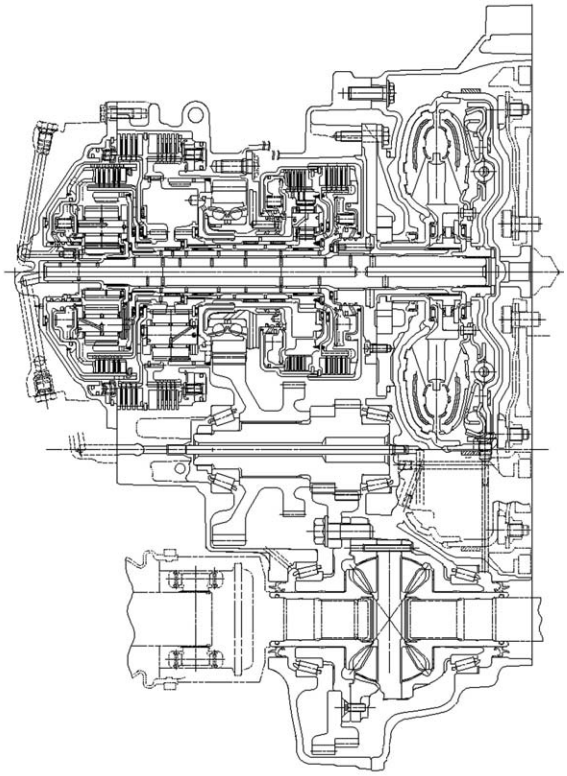


Fig. 1 Main cross-sectional view

The JF613E 6-speed AT was adopted on the all-new SM7 large passenger car released by Renault Samsung Motors in the South Korean market in August 2011. This was the first application to a gasoline engine of the version of this AT without a one-way clutch. Fuel economy has been improved by reducing internal friction, applying neutral idle control and expanding the region of lock-up operation. Adaptive Shift Control (ASC) is also provided for automatically selecting the optimum gear matching the driving environment and road surface conditions. These features have made this AT immensely popular with customers.

Table 1 Specifications of JF613E AT

Torque capacity		240 / 330 Nm
Control system		Electronic
Torque converter size		250 mm dia.
Gear ratios	1st	4.199
	2nd	2.405
	3rd	1.583
	4th	1.161
	5th	0.856
	6th	0.686
	Rev.	3.457
Final drive gear ratios		3.804 / 3.36
No. of selector positions		4（P, R, N, D）＋M-Mode
Overall length		385 mm
Center distance between engine and differential		197 mm
Wet weight		98 kg

■ Typical models fitted with the JF613E AT ■

New SM7

スズキ向け　FF車用CVT　Jatco CVT7の紹介

Introducing the Jatco CVT7 for Front-drive Cars

2009年9月に発売のスズキ株式会社のパレットに搭載されたJatco CVT7は，ワゴンR，ラパン，等に搭載車両が拡大されています．2010年12月には小型車のソリオにも搭載されました．副変速機構の採用により世界一の変速比幅を実現し低速時の加速性能と高速時の静粛性向上とENG回転を抑える事による低燃費を両立しました．

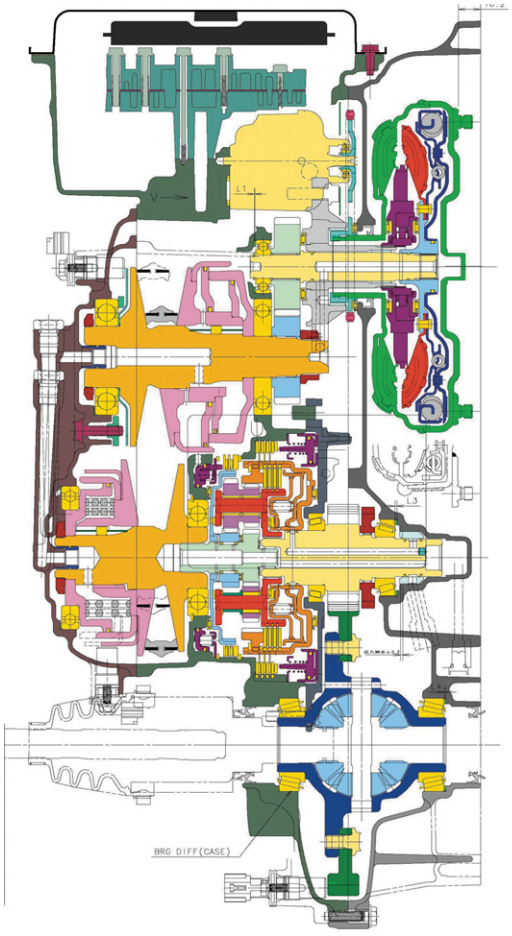


Fig. 1 Main cross-sectional view

The Jatco CVT7 steel-belt CVT was first adopted on the Palette released by Suzuki Motor Corporation in September 2009, and its application was subsequently expanded to Suzuki's Wagon R, Lapin and other models. It is also featured on the Sorio, a small car that Suzuki rolled out in December 2010. The Jatco CVT7 incorporates an auxiliary transmission to achieve one of the world's widest ratio coverages. This feature reconciles low-speed acceleration performance with improved quietness and low fuel consumption during high-speed driving by holding down the engine speed.

Table 1 Specifications of Jatco CVT7

Torque capacity	118 Nm
Control system	Electronic
Torque converter size	UUF 185 mm dia.
Pulley ratio	Low: 2.2　High: 0.55
Ratio coverage	7.3
Final gear ratio	3.757
No. of selector positions	5
Overall length	319.3 mm
Weight (wet)	64.2 kg

■ Typical models fitted with the Jatco CVT7 ■

Sorio

スズキ向け　FF車用CVT　Jatco CVT7の紹介

Introducing the Jatco CVT7 for Front-drive Cars

2009年9月に発売のスズキ株式会社のパレットに搭載されたJatco CVT7は，ワゴンR，ラパン等の軽自動車だけでなくスイフト，ソリオ等の小型車にも次々に搭載されています．2012年1月にはアルト低燃費車にも搭載されました．

アルト低燃費車は，燃費30km／l（JC08モード）を達成しており，Jatco CVT7の低フリクション化，コーストストップ技術追加が低燃費に貢献しています．

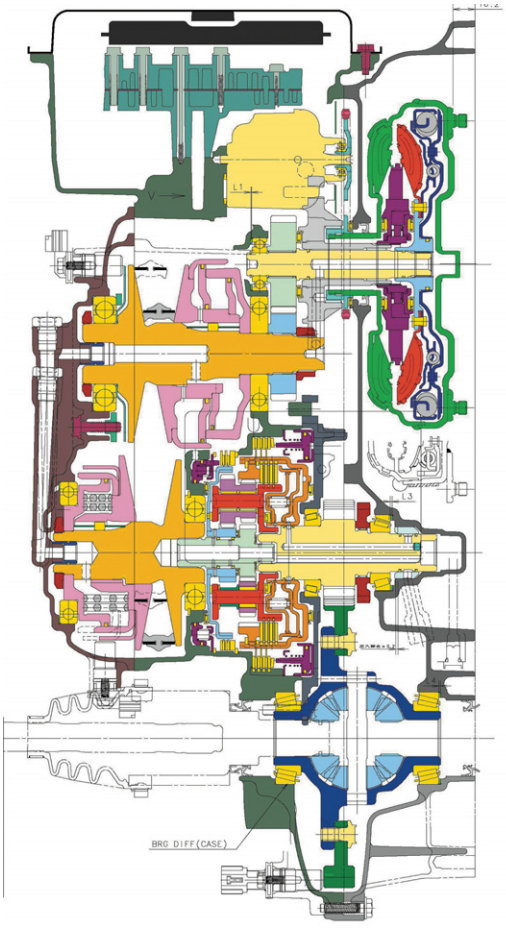


Fig. 1 Main cross-sectional view

The Jatco CVT7 has been adopted on a number of minicars produced by Suzuki Motor Corporation, including the Palette released in September 2009 as well as the Wagon R, Lapin and other models. Moreover, its application has also been steadily expanded to Suzuki's small cars such as the Swift, Sorio and others. The Jatco CVT7 was also fitted on Suzuki's Alto Eco car series in January 2012. The Alto Eco achieves impressive fuel economy of 30 km/L under Japan's JC08 test mode. The reduced friction level of the Jatco CVT7 and the addition of a control technique for executing a coasting downshift after the vehicle stops contribute significantly to this fuel economy performance.

Table 1 Specifications of Jatco CVT7

Torque capacity	63 Nm
Control system	Electronic
Torque converter size	UUF 185 mm dia.
Pulley ratio	Low: 2.2　High: 0.55
Ratio coverage	7.3
Final gear ratio	4.575
No. of selector positions	5
Overall length	319.3 mm
Weight (wet)	64.4 kg

■ Typical models fitted with the Jatco CVT7 ■

Alto Eco

ジヤトコ 一年間のトピックス

Highlights of the Past Year

1. 吉原工業高校 インターンシップを実施

9月7日（火）からの3日間，富士第一地区の技能塾･教育センターを中心に，吉原工業高校のインターンシップを実施した．これは，吉原工業高校の“実際の職場における就業体験を通して，職業観･就労観を養い，関連する教科の理解を深める．”という方針のもと吉原工業高校2年生全員が，地元各企業で就業体験するもの．ジヤトコも例年通り19名の生徒を受け入れた．

生徒たちは教育センターで，ピンボードの演習，ATの分解･組立やMCプログラムによる現物加工などを実際に体験を行なった．

2. 第3回ASIA FORGE MEETINGで講演

9月14日（火），上海のRenaissance Shanghai Zhongshan Park Hotelで開催された「第3回ASIA FORGE MEETINGにおいて，ジヤトコから“Eco Friendly CVT Pulley Forging”と題して，現在JGZで生産しているJF011Eの部品一体化の取り組みについて講演が行なわれた．これは日本鍛造協会からの講演要請を受けたもので，ジヤトコのCVTが軽量化･燃費向上で地球環境に貢献しており，それを鍛造部品での取り組みを通じてアピールした．

会場には，中国，インド，韓国，台湾，日本などのアジア諸国だけではなく，アメリカ，ヨーロッパか

1. Internship program for Yoshiwara Technical High School students

An internship program for Yoshiwara Technical High School students was conducted mainly at the Ginou Juku (Technical Skills School) and Educational Center in Fuji Area No. 1 over a three-day period beginning from Tuesday, September 7, 2010. The purpose was to foster the students' views of occupations and work through job experience in actual workplaces and deepen their understanding of related academic subjects.

All second-year students at Yoshiwara Technical High School personally experience working at local companies. As in the past, JATCO welcomed 19 students. At the Educational Center they gained first-hand experience in pinboard exercises, disassembling/assembling an AT, and machining actual workpieces using a machining center program, among other work operations.

2. Presentation at Third AsiaForge Meeting

A JATCO employee delivered a presentation at the Third AsiaForge Meeting at the Renaissance Shanghai Zhongshan Park Hotel in Shanghai, China on Tuesday, September 14, 2010. Entitled "Eco-friendly CVT Pulley Forging," the presentation described the activities undertaken to integrate the pulley parts of the JF011E CVT currently being produced at JATCO Guangzhou (JGZ). This presentation was given in response to a request from the Japan Forging Association. Presenting the efforts made to integrate the forged pulley parts provided an opportunity to publicize the contributions of JATCO's CVTs to the global environment through weight savings and improvement of vehicle fuel economy.

The meeting attracted a large number of people involved in forging, not only from China, India, Korea, Taiwan, Japan and other Asian countries, but also from the U.S. and Europe. Technical presentations were given by employees of three

らも多くの鍛造関係者が集い，日本からはジヤトコ，日産，トヨタの3社が技術講演を行なった．

3. 第40回記念 全日本選抜QCサークル大会で金賞受賞

11月9日（火），日比谷公会堂において「第40回記念 全日本選抜QCサークル大会」が行われ，地区予選を勝ち上がった弊社の2チームが金賞を受賞した．各地区予選会を勝ち抜き，この場に選抜された18チームのうち，金賞受賞はわずか7チーム．ジヤトコとしては初の栄誉となる．

4. アグアスカリエンテス州 Carlos Lozano 州知事来社

12月1日（水）に，JMEXのあるアグアスカリエンテス州ではCarlos Lozano（カルロス ロザーノ）氏が新たに州知事として着任．それに先立ち，10月21日（木），ロザーノ知事がジヤトコに来社され，社長との懇談や，富士第2地区第7工場の見学，JMEX出向者との意見交換会を行なった．

【ロザーノ州知事からのメッセージ】

今回の来日で，富士市の皆さんやメキシコ人出向者の皆さんが新しいプロジェクトで活躍している姿を見ることが出来て，とても感謝している．30年前，アグアスカリエンテス州に日産自動車を誘致したころには，メキシコ人が経営層やエンジニアとして（日本企業で）働くのは難しいと認識していたが，現在はジヤトコや日産に限らず，多くのメキシコ人が経営層やエンジニアとして活躍し，「メキシコ化」が進んでいることを嬉しく思っている．

ジヤトコはアグアスカリエンテス州ではまだ5年の歴

Japanese companies－Nissan Motor Co., Ltd., Toyota Motor Corporation and JATCO.

3. Gold Medal Recipients at the 40th All-Japan Select QC Circle Conference

The All-Japan Select QC Circle Conference was held at Hibiya Public Hall on Tuesday, November 9, 2010, celebrating the 40th anniversary of QC circles. Two JATCO teams that had won in the regional qualifying competition were awarded gold medals. Only seven of the 18 selected teams that had won in the regional qualifying rounds were given gold medals. This was the first time for JATCO to receive this honor.

4. Aguascalientes State Governor Carlos Lozano visits JATCO

On Wednesday, December 1, 2010, Carlos Lozano was newly sworn in as governor of Aguascalientes State where JATCO Mexico, S.A. de C.V. (JMEX) is located. Prior to that, Governor Lozano visited JATCO on Thursday, October 21 for an informal discussion with JATCO President Shigeo Ishida and toured plant No. 7 in Fuji Area No. 1, where he exchanged views with JMEX employees currently dispatched to Japan. The following is a summary of Governor Lozano's remarks on that occasion.

"On this visit to Japan, I am very grateful to have this opportunity to see the citizens of Fuji city and the Mexican employees dispatched to Japan actively engaged in new projects. Around thirty years ago when Aguascalientes State invited Nissan Motor Company to build a plant in our state, it was generally recognized that it was difficult for Mexicans to work

史しかないが，JMEXは生産効率が高く，エンジニアも優秀で，大きな可能性を持っていると確信している．今回の来日でとても良い会社だということが理解でき，とても有意義な時間を過ごすことが出来た．ありがとうございました．

5. Henkel主催のシンポジウムで講演

10月21日，ジヤトコは，上海のPudong Shangri-La Hotelで開催された，Henkel主催のシンポジウム『Henkel 2010 Asia-Pacific Powertrain Customer Symposium』にて講演を行なった．Henkel:液体ガスケットやアルミダイキャスト用離型剤を弊社に収めて頂いているサプライヤ．本社はドイツ．欧州･北米･南米･アジアに拠点を置くグローバル企業．

中国，インド，韓国，日本などのアジア諸国から，多くの自動車メーカー，部品メーカー，調査会社の社員が参加しており，そのうち10社がゲスト講演を行った．

日本からは，トヨタ，ホンダ，ジヤトコの3社が講演し，ジヤトコのビジネスにとって重要な市場である中国で，CVTの素晴らしさを訴求することができた．

at the managerial level or as engineers at Japanese companies. I am pleased to note that today many Mexicans are active as managers or engineers at various companies, not only JATCO and Nissan, as more and more Mexicans are being employed in such positions.

JATCO has been operating in Aguascalientes State for only five years now, but I am confident that JATCO Mexico has an enormous future potential, given its high production efficiency and outstanding engineering staff. This visit to Japan has enabled me to understand what an excellent company JATCO is, and my time spent here has been truly worthwhile. Thank you all very much."

5. Presentation at a symposium hosted by Henkel

A JATCO employee delivered a presentation at the Henkel 2010 Asia-Pacific Powertrain Customer Symposium hosted by Henkel AG & Co. KGaA at the Pudong-Shangri-La Hotel in Shanghai on October 21, 2010. Henkel supplies JATCO with fluid gaskets and aluminum die cast release agents. Headquartered in Dusseldorf, Germany, Henkel is a multinational company with business operations in Europe, North and South America and Asia.

Attendees included employees from many vehicle manufacturers, auto parts makers and research companies in various Asian countries, including China, India, Korea and Japan, among others. Participants from 10 companies gave guest speeches.

Attendees from three Japanese companies－Toyota, Honda and JATCO－delivered presentations. For JATCO, it was a good opportunity to publicize the remarkable benefits of CVTs in China, which is a key market for JATCO's business.

6. Support for Shizuoka Prefecture High School Students Eco-run Challenge

The 18th Shizuoka Prefecture High School Students Eco-run Challenge was held at the Shizuoka-ken Driving School in Shizuoka city on November 13, 2010. This event is organized for students of technical high schools in Shizuoka prefecture. The contest tests students' eco-driving skills using fuel-saving cars that they have designed and built

6. 静岡県高校生エコラン大会に協賛

11月13日，静岡県下の工業高校の生徒たちによる，第18回静岡県高校生エコラン大会が静岡市にある県自動車学校で開催された．これは，生徒達自らが設計･製作した省エネカーの低燃費運転の腕を競い合うもので，ジヤトコは昨年に引き続き協賛．【エコラン大会】

ガソリン自動車部門では25分間で10キロメートル走行時の燃費，また，電気自動車部門では同一容量（12ボルト3アンペア･アワー × 2個）バッテリーでの走行距離を競い，日頃の部活動や課題研究の成果を発表した．

7.『ものづくりイノベーションセミナー』で発表

11月18日，ケンタッキー州レキシントンで，JETRO（日本貿易振興機構）主催による，『ものづくりイノベーションセミナー』が開催された．このセミナーは，日本企業のものづくりの理念，商習慣を，米国企業が共有し，相互理解を促進することを目的とするもの．

当日は，部品メーカーを中心に約200名が集まり，ケンタッキー州知事，前州知事，ナッシュビル日本総領事など政府関係者が参加．

ジヤトコは，主催者並びに日本自動車部品工業会北米支部から要請を受け，“ジヤトコのメキシコにおけるものづくりの定着”というテーマで，設立後の取り組みなどについて講演を行なった．

themselves. JATCO again supported this year's event as it did last year. The following is an overview of the Eco-run Challenge.

In the gasoline-engine vehicle category, entrants vie for the best fuel economy in driving 10 kilometers in 25 minutes. In the electric vehicle category, entrants compete for the longest driving distance obtained with the same battery capacity using two 12-volt, 3-amphere-hour batteries. The students also present the results of their club activities and research projects.

7. Presentation at a monozukuri innovation seminar

The Japan External Trade Organization (JETRO) sponsored a seminar entitled "The Mindset of Monozukuri: Encouraging a Culture of Talent and Innovation in Manufacturing" in Lexington, Kentucky on November 18, 2010. The aim of this seminar was to share the monozukuri concepts and business practices of Japanese companies with their American counterparts and to promote better mutual understanding.

The seminar attracted approximately 200 attendees mainly from auto parts makers and included government-related participants such as the present and former governors of Kentucky and personnel from the Japanese Consulate-General in Nashville, Tennessee.

JATCO was asked by the sponsors and the North American office of the Japan Auto Parts Industries Association to make a presentation on the theme of "JATCO's Establishment of Monozukuri in Mexico." The presenter explained the monozukuri activities undertaken at JATCO Mexico since it was established.

8. CVT2010で基調講演

11月17日～19日オランダ･マーストリヒト市でCVT2010（The International Conference on Continuously Variable and Hybrid Transmissions）が開催され，ジヤトコは基調講演を行った．本国際会議は，大学，研究所，カーメーカー，部品メーカーなど世界的に著名なCVT関係者約170名が参加する大規模なもので，ジヤトコの他，BOSCH Transmission Technology B.V.，Politecnico di Bari（伊）が基調講演を行ない，36件もの個別の技術発表が行なわれた．

9.【JKE/JKS】2011年ソウルモーターショーに出展

4月1日～10日までの10日間，ソウル近郊のKINTEX（京畿道高陽市）で，2011年ソウルモーターショーが開催された．今回は“Evolution，Green Revolution On Wheels（進化，自動車のグリーン革命）”をテーマに，合計8カ国，139社が参加し，新車，コンセプトカーなど300台を超える車両の展示が行なわれた．韓国メーカーを始め各社が最先端の商品･技術を展示する中，ジヤトコもJKE/JKSの協力のもと，コーポレートカラーを基調にしたブースを設け，環境技術に対応する高い先進性と技術力をアピールした．

8. Keynote Presentation at CVT 2010

A JATCO employee delivered a keynote presentation at the International Conference on Continuously Variable and Hybrid Transmissions (CVT 2010) held in Maastricht, Netherlands on November 17-19, 2010. This large-scale international conference attracted approximately 170 globally prominent attendees involved with CVTs, including people from universities, research institutes, vehicle manufacturers, auto parts makers and others. Besides the keynote speaker from JATCO, other keynote presenters were from Bosch Transmission Technology B.V. of the Netherlands and Politecnico di Bari of Italy. In addition, 36 individual technical presentations were given.

9. JATCO exhibits at 2011 Seoul Motor Show with the cooperation of JKE/JSE

The 2011 Seoul Motor Show was held at the Korea International Exhibition Center (KINTEX) in Goyang city in the suburbs of Seoul over a ten-day period from April 1-10. Under the theme of "Evolution, Green Revolution on Wheels," 139 companies from eight countries took part in the show at which over 300 vehicles were displayed, including new models and concept cars. Beginning with the Korean automakers, exhibitors showed off their latest products and technologies. With the cooperation of JATCO Korea Engineering Corporation (JKE) and JATCO Korea Service Corporation (JKS), JATCO presented a booth decorated in the corporate colors and publicized the company's engineering strengths and advanced capabilities with respect to environmental technologies.

10.「人とくるまのテクノロジー展2011」に出展

5月18日（水）～20日（金）パシフィコ横浜で「人とくるまのテクノロジー展2011」（主催：（社）自動車技術会）が開催された．当社は「トランスミッションで世界のCO_2削減」をキーメッセージとして，CVTフルラインナップやハイブリッド車用トランスミッション，新興国向け新型4速トランスミッションなどを展示し，“環境にやさしいトランスミッション”をアピールした．また，環境技術として注目されるCVTに焦点をあて，技術的な優位性，開発の歴史などを改めて紹介した．

Jatco CVT7が「日本機械学会賞（技術）」と「日本自動車技術会 技術開発賞」を同時受賞．当社新開発の副変速機付ベルトCVT（ジヤトコ CVT7）が，2010年度 日本機械学会「日本機械学会賞（技術）」と，第61回 日本自動車技術会「技術開発賞」を同時受賞．（共同開発先である日産自動車と共願．）新技術審査と生産現場審査が行われ，先進技術・量産技術を総合したジヤトコの高い技術力が評価された．

【「日本機械学会賞（技術）」について】

“機械工業に関し，数年以内に完成した新技術，新製品，システムの開発”が対象となり，①独自性，新規性，②品質または性能の相対的優秀性，③生産性の向上を通して経済および社会への貢献，④機械工学・工業との関連性，⑤波及効果または実績の5つの評価項目で評価される．

【「技術開発賞」について】

自動車技術の発展に役立つ新製品または新技術を開発した個人会員及びその共同開発者に贈られる．

10. JATCO exhibits at 2011 Automotive Engineering Exposition

The 2011 Automotive Engineering Exposition, sponsored by the Society of Automotive Engineers of Japan, Inc. (JSAE), took place at Pacifico Yokohama from Wednesday-Friday, May 18-20, 2011. JATCO emphasized its eco-friendly transmissions, presenting the company's full CVT lineup under the banner message of "Fuel-efficient transmissions contributing to CO_2 reduction worldwide." The exhibits also included transmissions for hybrid vehicles and a new 4-speed AT intended for use in emerging economies.

The technological superiority, development history and other details of CVTs were once again showcased, as these transmissions have attracted attention as an effective environmental technology. A notable exhibit was the Jatco CVT7, a newly developed steel-belt CVT featuring an auxiliary transmission. The Jatco CVT7 was simultaneously awarded the JSME Medal for New Technology in fiscal 2010 by the Japan Society of Mechanical Engineers and the 61st JSAE Technology Development Award given by the Society of Automotive Engineers of Japan, Inc. (These awards were shared with Nissan Motor Co., Ltd., which jointly developed the CVT7.) JATCO's outstanding technological capabilities, combining advanced product technologies and mass production engineering, were highly rated based on evaluations of the new technologies and manufacturing workplaces.

[Overview of JSME Medal for New Technology]

This award is given in recognition of "the development of a new technology, product or system completed within a period of several years in machinery industries." Candidates are evaluated on the basis of five evaluation criteria: (1) originality and newness, (2) relative superiority in quality or performance, (3) contribution to the economy or society through improvement of productivity, (4) relationship to mechanical engineering and industry, and (5) ripple effects.

[Overview of JSAE Technology Development Award]

This award is given to individual JSAE members or to joint development partners for the development of a new product or technology that helps to advance automotive engineering.

11. SAE China主催の「2011 TM Symposium China」で講演

4月19日～21日の3日間，SAE China（Society of Automotive Engineers of China）が主催する「2011 TM Symposium China」が中国 上海で行われ，弊社から3名が講演を行なった，AT･CVTの優位性を強くアピールしたこれら講演に対して，割り当ての時間では足りないほどのQ&Aが出たり，後日メディアで，講演内容が取り上げられるなど中国国内におけるCVT，ATへの関心の高さを感じることができた．

12. CTIシンポジウムにて新開発4速ATについて発表

5月17日･18日の2日間，米国ミシガン州において，第5回CTI北米シンポジウムが開催され，トランスミッションに関する多くの論文発表が行われた．ジヤトコからは，新しい制御技術を取り入れ，既存ユニットと比べて，軽量，コンパクト，低コスト化を実現させた「新開発4速AT」について発表した．

また，プレゼン後の質疑応答で，CTI議長の

11. Presentations at 2011 TM Symposium China sponsored by SAE China

Three JATCO employees delivered presentations at the 2011 TM Symposium China held in Shanghai, China over a three-day period from April 19-21, 2011. This event was sponsored by the Society of Automotive Engineers of China (SAE China). The presentations strongly emphasized the superiority of CVTs and ATs and elicited so many questions that the allotted time was almost insufficient for answering all of them. The details of the presentations were also later given considerable coverage by local media. These are indications of the strong interest in CVTs and ATs in China.

12. Presentation on newly developed 4-speed AT at CTI Symposium

The 5th CTI Symposium & Exhibition-North America was held in Detroit, Michigan, USA over a two-day period on May 17-18, 2011. Many technical presentations concerning transmissions were given at this event. A JATCO employee delivered a presentation on the company's newly developed 4-speed AT that features new control technologies and is lighter, more compact and lower in cost than the previous unit.

In the Q&A session following the presentation, CIT Chairman Ernie J. DeVincent (Vice President-Product Development, GETRAG Transmissions Corporation) posed the question: "While other companies' presentations have been about 8-speed and 9-speed transmissions, why did you develop a 4-speed transmission now?" The JATCO presenter replied that: "Consumers are mainly concerned about cost. In emerging economies like India, A- and B-segment vehicles constitute the mainstream, so it is important to develop minimum-size ATs suitable for small-displacement engines." This answer drew the attention of many attendees because it emphasized that JATCO is putting importance on the development of ATs designed for global markets, in addition to CVTs.

DeVincent氏（GETRAGグループの副社長）から，「他社のプレゼンは8速や9速にも関わらず，なぜ今4速なのか」との質問をされ，それに対して，「消費者の最大の関心はコストである．インドのような新興国市場ではA·Bセグメント車がメインであるため，小型エンジンに対応する最小限サイズのAT開発が重要である」と回答したことで，ジヤトコがCVTのみならず，グローバル市場を視野にいれたATの開発にも力を入れていることがアピールでき，多くのシンポジウムの参加者の関心を得ることが出来た．

13. 自動車技術会フェローに認定

6月2日，自動車技術会関東支部総会において「2011年自動車技術会フェロー認定式」が開催され，弊社から2名の受賞者があった．自動車技術会フェロー制度とは，会の目的達成及び自動車に係る科学技術に関し，多大なる貢献をしている正会員に対して自動車技術会フェローの称号を授与することで，会員がフェローとしてのプライドを持って，さらに積極的に自ら事業に参画し，同会の活性化，自動車技術の発展への貢献を図ることを目的としたもの．弊社の受賞者はこれで累計8名となった．

14.【環境月間行事】“アユの稚魚放流”と“緑の配布”を実施

【アユの稚魚放流　6月17日】

富士市の私立いまいづみ幼稚園の園児とともに，アユの稚魚放流を実施した．当日はまず，清流の大切さを伝えるため，ジヤトコプラントテックの若手社員と保育士が協力して「川を大切にしよう!」と題した寸

13. JSAE Fellow Member honors

Two JATCO employees were granted JSAE Fellow Member status in 2011 at the annual general meeting of the JSAE Kanto Branch on June 2, 2011. The JSAE Fellow Member system confers this membership grade honor on regular members who have made notable contributions to the accomplishment of JSAE's objectives and to automotive science and engineering. It is intended to encourage recipients to take pride in being a Fellow Member and to vigorously participate in activities voluntarily so as to energize the Society and promote the further development of automotive engineering. To date, a total of eight JATCO employees have been granted Fellow Member status.

14. Releasing juvenile sweetfish and distributing greenery as Environment Month activities

Releasing juvenile sweetfish on June 17

Young employees of JATCO Plant Tec Ltd. joined the pupils of the privately operated Izumi Kindergarten in the city of Fuji in releasing juvenile sweetfish in a nearby river. The employees and the kindergarten teachers first cooperated in performing a play that day on the theme of "let's treasure rivers" in order to convey the importance of fresh, clean streams. After that, 350 juvenile sweetfish were released from buckets into the Tajuku River that flows through the Izumi area.

Distributing greenery on July 3

JATCO distributed 100 potted foliage plants, flowers and other greenery to local children around Koikegawa in the Kambara area.

劇を披露．その後，今泉地区を流れる田宿川へ，バケツに入ったアユの稚魚計350匹を放流した．

【緑の配布　7月3日】

蒲原地区の小池川周辺で，地元の子供たちに観葉植物や花の鉢植えなど100鉢の配布を行った．

15. 京都安全衛生大会にて八木･京都工場の安全活動が評価される

7月5日，京都市にて京都安全衛生大会が行われ，当社の八木･京都工場が「安全衛生管理に係る京都労働基準連合会長表彰」を受賞．表彰の対象は①京都府内の従業員50人以上の事業所，②過去に行政表彰を受けていない事業所，③過去2年間休業災害4日以上の災害のない事業所となり，八木･京都工場の日頃の安全活動が評価されたこととなる．今回の表彰を受け，本年度も災害ゼロを継続していく．

15. Commendation of Yagi and Kyoto plants' safety activities at Kyoto Safety and Sanitation Convention

The Kyoto Safety and Sanitation Convention was held in Kyoto on July 5, 2011. JATCO's Yagi and Kyoto plants received the Chairman's Prize given by the Kyoto Labor Standards Association for their excellent safety and sanitation management. This prize is given to places of business meeting the following criteria: (1) located in Kyoto prefecture and have 50 or more employees, (2) have not received any governmental commendation in the past, and (3) have not had any incidents causing a work stoppage for four or more days in the last two years. In winning this prize, the regular safety activities at the Yagi and Kyoto plants were highly evaluated. Having received this recognition, the plants intend to continue to operate without any incidents during the current fiscal year.

特　許　紹　介

Patents

1. 無段変速機及びその変速制御方法

（Fig. 1）

出　願：出願日　2008.9.25　特願2008-245752
登　録：登録日　2011.1.7　特許第4660583号
名　称：無段変速機及びその変速制御方法
発明者：鈴木英明，野々村良輔，井上真美子
田中寛康，井上拓市郎

1. Continuously variable transmission and Control method thereof

(Fig. 1)

Application Number: 2008-245752
Application Date: 9.25,20082
Patent Number: 4660583
Registration Date: 1.7,2011
Title: Continuously variable transmission and Control method thereof
Inventor: Hideaki Suzuki, Ryousuke Nonomura, Mamiko Inoue, Hiroyasu Tanaka, Takuichiro Inoue

【目的】

有段副変速機付き無段変速機において，高い動力性能と燃費性能を維持しつつ副変速機の変速ショックを抑制する．

【発明の構成】

変速制御手段は，バリエータ及び副変速機構の全体の変速比であるスルー変速比がモード切換変速比よりも小さな変速比に変化したときに副変速機構の変速段を第1変速段（Low）から第2変速段（High）に変更する．モード切換変速比は，バリエータの変速比が最High変速比で副変速機構の変速段が第1変速段であるときのスルー変速比に設定される．

また，副変速機の変速に伴い，バリエータを変速比が大きくなる方向へ変速する．

【作用・効果】

バリエータの変速比が最Highのときに副変速機が変速されるので，副変速機に入力されるトルクが最小となり，変速ショックが抑制される．

また，スルー変速比がモード切換変速比を跨いで変化すれば副変速機構の変速段が変更され，副変速機構の変速段の変更が必要以上に制限されることがないので，副変速機構を備えたことによる高い運動性能と燃費性能を享受することができる．

【SUMMARY OF THE INVENTION】

When a through speed ratio, which is an overall speed ratio of a variator and a subtransmission , varies from a larger speed ratio than a mode switch speed ratio to a smaller speed ratio than the mode switch speed ratio, a gear position of the subtransmission is changed from a frist gear position to a second gear position. The mode switch speed ratio is set at a through speed ratio obtained when the speed ratio of the variator is a highest speed ratio and the gear position of the subtransmission is the first gear position.

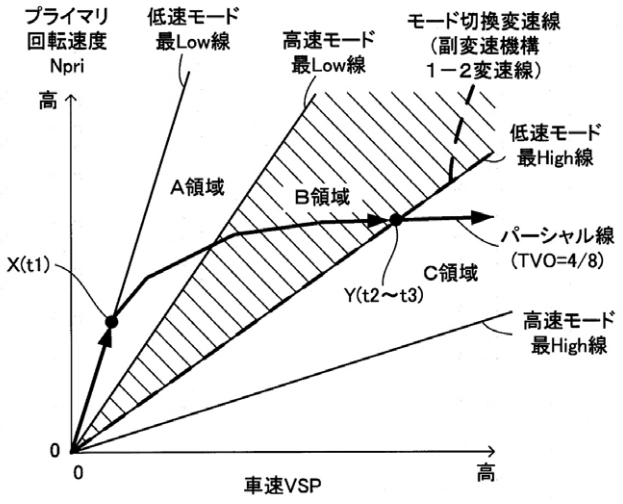


Fig. 1

2. 無段変速機及びその変速制御方法

（Fig. 2）

出　願：出願日　2009.3.27　特願2009-079646
登　録：登録日　2011.7.8　特許第4779030号
名　称：無段変速機及びその変速制御方法
発明者：城崎建機，鈴木英明，野々村良輔，
井上真美子（他5名）

2. Continuously variable transmission and Control method thereof

(Fig. 2)

Application Number: 2009-079646
Application Date: 3.27,2009
Patent Number: 4779030
Registration Date: 7.8,2011
Title: Continuously variable transmission and Control method thereof
Inventor: Tateki Jozaki, Hideaki Suzuki, Ryousuke Nonomura, Mamiko Inoue, et al.

【目的】

有段副変速機付き無段変速機において，副変速機の変速が禁止された場合でも，変速ショックを抑制する．

【発明の構成】

変速比設定手段は，副変速機構の変速が禁止されていると判定されたときは，到達スルー変速比をバリエータの変速のみで達成可能な変速比範囲に制限する．

【作用・効果】

到達スルー変速比がバリエータの変速のみで達成可能な変速比範囲外に設定されることにより，バリエータの変速限界において変速動作が急激に停止してショックが発生することを防止できる．

【SUMMARY OF THE INVENTION】

A continuously variable transmission includes a variator capable of varying a speed ratio continuously, and a subtransmission prvided in series with the variator. On the basis of an operating conditionof a vehicle, a transmission controller sets a destination through speed ratio, which is an overall speed ratio of the variator and the subtransmission to be realized in accordance with the operating condition, and controls the variator and the subtransmission on the basis thereof. When shifts are prohibited in the subtransmission, the destination through speed ratio is limited to a speed ratio range that can be realized only a shift in the variator.

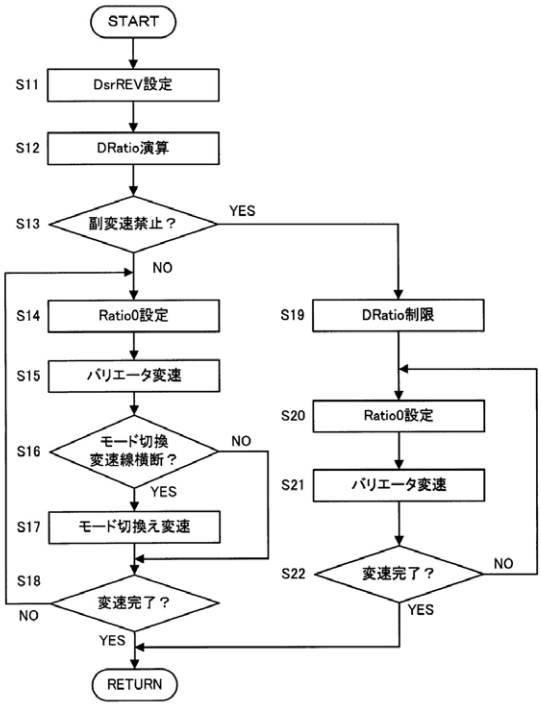


Fig. 2

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