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ジヤトコの進化

トランスミッションはクルマの「キープレーヤー」になる.

JATCO's Evolution

The transmission will be the “key player” in vehicles.

社長・最高経営責任者　中塚　晃章

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ダーウィンの進化論では,「生物は不変ではなく，長い時間をかけて次第に変化してきた」とされています．私たちジヤトコの AT，CVT も，世代を経て少しずつ進化してきました．この進化は，どこに向うのでしょうか.

各国の自動車に対する燃費規制は年々厳しくなっています．その対応策として，ハイブリッド車（HEV），電気自動車（EV），燃料電池車（FCV）等，最新の環境対応技術が投入されていますが，どれも明日から主役になるような状況ではありません．2020 年の EV のグローバルシェアは 1% 程度と予想されていますし，FCV も本格的な普及に向けては，水素供給インフラの整備や車両価格の問題等，解決すべき課題が山積しています.

このような状況で燃費の良い高機能なクルマへのニーズが高まる中，トランスミッションには何が求められるのでしょう?私は，クルマというシステム全体の中で，トランスミッションが「キープレーヤー」になることによって，今以上の大きな価値をお客さまに提供できると確信しています．何故なら，トランスミッションは「駆動力を伝える」という，クルマにとって最も基本的で重要な役割を担っているからです．その時々の運転状況を的確に判断し，エンジンやモーター，ブレーキ等のコンポーネントを繋いで，最適な駆動力，制動力をタイムリーに伝えるという，クルマの走行の中心となるポジションに存在するからです.

「キープレーヤー」になるということは，トランスミッションだけではなく，クルマの総合制御へ積極的に参画することを意味します．クルマ全体のシステムをどの様に構築するかというシステムエンジニアリングの考え方の中で，トランスミッションがより重要な役割を果たすようになるということです.

益々厳しくなる燃費規制に対応するため，システムエンジニアリングの中で特に重要となるのは「エネルギーマネジメント」です．駆動伝達のエネルギー損失の抑制，回収等を，全体でマネジメントすることによって，効率のよいシステムを構築することができます．トランスミッションの役割は重要です．トランスミッションの効率を上げることはもちろん，フライホイールなどの装置を巧みに組み合わせたエネルギー回生方法も考えられます.

日本の携帯電話業界の失敗からガラパゴスという言葉が流行しました．ガラパゴス島のように孤立した世界では，次世代に続く優れた技術・商品への進化は望めません．クルマにおけるトランスミッションも同様です．クルマ全体のシステムの中で，そしてエネルギーマネジメントの世界で「キープレーヤー」に．2020 年，更には 2030 年，2040 年に向けて，クルマ文化・社会へ大いなる価値を提供するためには，トランスミッションの枠を超えて，クルマ全体のシステムをどのように進化させるか．自動車メーカーと共に考え，最適解を見出し，実現することこそが，進化するトランスミッションメーカーの「ミッション」でしょう.

「最も強い者が生き残るのではなく，最も賢い者が生き延びるのでもない．唯一生き残るのは，変化できる者である」，ダーウィンの言葉です.

私たちジヤトコも変化を恐れず，モノづくりを極めて，クルマづくりの「キープレーヤー」へと進化して行きます.

According to Darwin's theory of evolution, “species are not immutable; they have changed gradually over many millennia.” JATCO's automatic transmissions (ATs) and continuously variable transmissions (CVTs) have also evolved little by little through successive generations. Where is this evolution headed now?

Regulations on vehicle fuel economy are becoming increasingly tighter every year in countries around the world. The latest environmental technologies are being deployed as measures to comply with these tighter requirements, including the development of hybrid electric vehicles (HEVs), electric vehicles (EVs) and fuel cell vehicles (FCVs), among other things. However, none of them seems ready to play a leading role starting tomorrow. As per the forecast global market share of EVs will only be around 1% even in 2020. There are also numerous issues that must be resolved in order to promote full-scale diffusion of FCVs, such as the implementation of the necessary hydrogen supply infrastructure and reduction of the vehicle price, among other issues.

In this situation where there are rising needs for high-performance vehicles with excellent fuel economy, what is required of the transmission? I am convinced that the transmission can provide customers with even greater value than at present by becoming the “key player” in the overall vehicle system. The reason is that the transmission is responsible for transmitting driving force, which is one of the most fundamental and critical roles that must be fulfilled in a vehicle. It is also because the transmission occupies a core position in the operation of a vehicle in that it delivers the optimum driving force and braking force in a timely manner by accurately judging the ever-changing driving conditions and linking with the engine, drive motor, brakes and other vehicle components.

Becoming the key player means active participation in the overall control of the vehicle, not only that of the transmission itself. This means that the transmission will play a much more important role in the context of systems engineering concepts about how to configure the entire vehicle system.

In order to comply with increasingly tighter fuel economy regulations, what is especially important in the context of systems engineering is energy management. A highly efficient system can be constructed through total energy management, including suppressing energy losses in the transferring of driving force and recovering kinetic energy. The transmission can play a key role here. Besides improving the efficiency of the transmission, of course, there are various conceivable approaches to energy regeneration such as by skillfully combining the transmission with a device like a flywheel storage system.

Galapagos is a word that has become popular due to the failure of Japan's mobile phone industry. In an isolated world like that of the Galapagos Islands, one cannot hope for evolution toward outstanding technologies and products that will be continued in succeeding generations. The same can be said for the automotive transmission. It must serve as the key player in the overall vehicle system and in the area of energy management. In order to provide more significant value to automotive culture and to society at large, as we move toward 2020 or further toward 2030 or 2040, we must consider how to evolve the overall vehicle system in a way that transcends the framework of the transmission itself. In this regard, the mission of an evolving transmission manufacturer is to think together with the automakers, find the optimum solution and then turn it into a reality.

In Darwin's words, “It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change”.

At JATCO, we intend to evolve into a “key player” in automotive engineering by attaining the best “monozukuri” operations without being afraid of change.

“グローバルNo.1のモノづくり”を目指して

Aiming to establish “Global No. 1 Monozukuri”

最高執行責任者　本田　聖二
Chief Operating Officer (COO)　Seiji HONDA

自動車用変速機は，車のイージードライブ化に呼応して手動変速機から自動変速機への変革，さらに，自動変速機においても動力性能と燃費を両立させる多段化，また，走行パターンに相応しい変速比を得るために，きめ細かに制御する技術を取り込み進化してきた．この動力性能と燃費という両立困難な要求を達成する切り札として，CVT が登場し，現在，世界各国に拡大している．

ジヤトコは，軽自動車から大排気量乗用車用までのCVT を持つ世界唯一のグローバル・トランスミッション・サプライヤーである．CVT においても，絶えずお客様のニーズに対応するべく，開発，生産，調達，品質というモノづくり部門を中心に，改善・改革に取り組み，お客様にとって価値の高い商品をタイムリーに提供するため，現地での生産を可能とするグローバル化を急速に展開してきた．

このモノづくりのベースは，JEPS（JATCO Excellent Production System）活動にある．JEPS 活動の基本理念である「限りない課題の顕在化と改革」とは，モノづくりの改善・改革を推進する仕組みの構築とそれを支える人材の育成との両輪により支えられている．

モノづくりの人材育成においては，自ら課題に気付き，顕在化させ，対策を講じ，飛躍的な効果を引き出せる人を育てることであり，さらに，その教育が出来る人の育成も必要となる．そのため，モノづくりを実行する責任者として，自ら率先垂範でモノづくりの現場を確認する“JEPS 現場確認会”を実施することを通じて，モノづくりの基本理念の普及を図っている．また，製造現場の第一線である技能員の技能レベルをグローバルな視点で育成，強化するため，各生産拠点からリーダーとなる実習生を，グローバル・トレーニング・センターや改善道場に受け入れ，教育・訓練を行なっている．実習生は，帰国後，自職場で学んだことを実践することで，各生産拠点の JEPS 推進役と各生産拠点の製造リーダーとして多くの人々が活躍中である．

グローバルに競争力のある商品を提供するには，他社の追従をゆるさない革新的なモノづくりが求められている．生産技術における工程数の半減やサイクルタイムの大幅短縮，開発分野におけるトータルエネルギーマネジメントという視点での効率向上などのチャレンジングな目標を掲げ，その目標を達成すべく技術開発にも全社を挙げて取り組んでいる．

地球環境問題に代表されるように，ますますグローバルな視点での企業活動が求められている．今後も環境性能に優れる CVT は，需要の拡大が続くと予想されており，グローバルに JEPS 活動の理念を定着させるべく種々の改善・改革活動を推進し，モノづくりの競争力の原点となる生産拠点の改善力・改革力の向上を図るとともに，技術開発においては，より一層の商品競争力の強化を果たすことで，“グローバル No.1 のモノづくり”を目指し進化させていきたい．

Automotive transmissions have progressed over the years from manuals to automatics in response to demands for driving ease. Further evolution has involved the addition of more speed ranges to automatic transmissions to reconcile power performance with fuel efficiency and also the adoption of fine-tuned control techniques to obtain gear ratios matching actual driving styles. Continuously Variable Transmissions (hereafter CVT) have been introduced as a decisive technology for achieving both power performance and fuel efficiency, two demands that are difficult to reconcile. The use of CVT is continuing to expand today in markets around the world.

JATCO is the only global transmission supplier with a full lineup of CVTs for use on minivehicles to passenger cars powered by large displacement engines. Our monozukuri divisions—specifically, product development, manufacturing, purchase and quality assurance—have continuous major role for constantly improving and innovating our CVTs to meet customer needs. We have also been globalizing our operations rapidly to facilitate local production in order to supply our customers with high-value products in a timely manner.

The basis of our monozukuri operations is the JATCO Excellent Production System (hereafter JEPS) program. The fundamental philosophy of the JEPS program is a “never-ending quest to identify issues and establish reconstructive solution.” This pursuit is supported by a two parallel approaches (like two wheel of a vehicle), which involves building systems for driving the improvement activity, innovation of monozukuri and the development of the human resources that support the systems.

The development of human resources for monozukuri involves cultivating employees capable of proactively noticing and identifying issues and implementing corrective measures that produce dramatic improvements. Moreover, it is also necessary to develop people capable of conducting such employee education. In order to cultivate employees, we are striving to instill the fundamental philosophy of monozukuri by holding workplace meetings to confirm the principles of JEPS. The persons responsible for carrying out monozukuri operations take the initiative to lead by example in checking how monozukuri activities are performed in their own workplaces. We also conduct education and training courses at our Global Training Center and Kaizen Dojo (Kaizen Center) in Japan for trainees from each assembly plant who will serve as leaders at their own facilities. This is done from a global perspective of developing and strengthening the technical skill levels of technical personnel working on the front lines of their manufacturing workplaces. Many such trainees are now active as manufacturing leaders at their own facilities where they also serve to promote JEPS by implementing in their own workplaces what they learned and brought home from Japan.

In order to supply products with high competitiveness globally, we must pursue innovative monozukuri that other companies cannot imitate. We have set challenging goals such as halving the number of processes in production engineering, substantially reducing cycle times, and improving efficiency from the perspective of total energy management in the area of product development. Company-wide efforts are also under way to advance technological development for the purpose of accomplishing these goals.

Corporate activities must increasingly be pursued from a global perspective today, as typified by global environmental issues. It is projected that demand for CVTs featuring outstanding environmental performance will continue to expand. We are driving ahead with various improvement and innovation activities to firmly instill the philosophy of the JEPS program in our global operations. Vigorous efforts are being made to enhance our capabilities for improvement and innovation at our production plants, which are the source of our competitiveness in monozukuri. We are also seeking to further strengthen our product competiveness in terms of technological development. Through these ongoing efforts, JATCO will continue to evolve with the aim to establish “Global No. 1 Monozukuri”.

ベルト式 CVT の起源と進化の歴史

Origin of the Belt-type CVT and History of Its Evolution

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Haruyoshi KUMURA　　Keiju ABO

抄　録　ジヤトコテクニカルレビューは 2000 年創刊であり，それ以前のことはあまり知られていない．本特集の機会をとらえ，CVT の起源と歴史を紹介したい．また，現在の CVT につながる Belt CVT 技術の基礎が種々築かれた時代とも言える，2000 年以前の研究時代も含む日産自動車(株)（以下日産）とジヤトコ(株)（以下ジヤトコ）における，初期 CVT の進化の歴史を紹介したい．

Summary　The JATCO Technical Review was first published in 2000, and the progression regarding CVTs before that time is not well known. In conjunction with this issue's special feature, this article describes the origin and history of the belt-type CVT. In the period before 2000, various fundamental technologies of the belt-type CVT were established that are succeeded to today's CVTs. This article traces the historical evolution of the initial CVTs developed by Nissan Motor Co., Ltd (hereafter Nissan) . and JATCO Ltd. (hereafter JATCO), including the period of basic research prior to 2000.

1. はじめに

Belt 式 CVT を搭載した自動車の始まりは 1958 年に遡り，Dr. Hub Van Doorne 氏の開発による Variomatic[※1] は，DAF 社および VOLVO 社の小型車に搭載され数百万台が販売された．

当時のベルトはゴム製であったが，その後，伝達トルク容量を上げて排気量 0.8L 以上の乗用車に CVT を普及させるため，より耐久信頼性に優れた金属ベルトが発明された．Fig. 1 は現在もオランダの DAF Museum に保管されている金属 Belt 式 CVT の起源とも言える歴史的な後輪駆動車向けの試作ユニットである．

1972 年に金属ベルトメーカ Van Doorne's Transmissie[※2] が設立され，その金属ベルトが活用されて大容量化技術が進められた．Belt 式 CVT の伝達トルク容量は，下記のように約 15 年で飛躍的に増大され，現在では Belt 式 CVT が 3.5L エンジン用まで実用化されている．

- 1987 年 1.2L 用 富士重工（株），Ford 社，Fiat 社
- 1997 年 2.0L 用（トルクコンバータ付き）　日産
- 2002 年 3.5L 用（トルクコンバータ付き）　ジヤトコ

そのような歴史の中で当社 CVT は 1980 年に日産で研究を開始した CVT を起源として，その進化が始まった．

1. Introduction

The first use of a belt-type CVT on an automobile dates back to 1958 when the Variomatic[*1] originally developed by Dr. Hub van Doorne was mounted on a small DAF and Volvo passenger car of which several million units were eventually sold. The belt at that time was made of rubber, but subsequently a metal belt possessing superior durability and reliability was invented with the aim of increasing the torque capacity and popularizing CVTs on passenger cars with engine displacements of 0.8L or larger. Fig. 1 shows a prototype unit designed for application to RWD vehicles and which might be said the origin of the metal-belt CVT. This historical CVT is still preserved today in the DAF Museum in the Netherlands.

In 1972, Van Doorne's Transmisie[*2] (hereafter VDT) was established as a metal belt manufacturer. Its metal belts were actively applied to various vehicles and progress was achieved in developing technologies for increasing the torque capacity. The torque capacity of belt-type CVTs increased dramatically over a period of approximately 15 years as noted below. Currently, a belt-type CVT is being adopted for 3.5L engine.

- 1987: CVTs for 1.2L engines developed by Fuji Heavy Industries, Ford and Fiat

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Product Marketing Strategy Office

以下，本文では当社 CVT 技術の基礎となった 2000 年以前の技術開発トピックスを紹介する．

※1：ドライベルト式 CVT，ジヤトコ Welcome Center に展示

※2：現 Bosch Transmission Technology 社（略称 VDT 社）

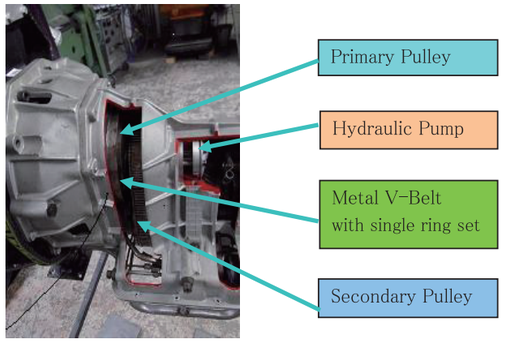

Fig. 1 The First Metal Belt-type CVT by VDT

2.Belt 式 CVT 技術進化の歴史

Fig. 2 に Belt 式 CVT 技術の進化の歴史を示す．大別すると，CVT ユニット技術と，CVT 向けのキー部品技術に分けられ,ユニット技術としては副変速機を設けないストレート型 CVT と副変速機を設けた CVT の 2 つの技術が進化してきた．それらに向けた変速制御技術も各型にあわせて種々開発されてきた．これら 2 つの領域の技術開発の集大成が Jatco CVT7，Jatco CVT8 である．

一方，CVT 向けのキー部品技術としては，トルク伝達のキーとなるプッシュ式ベルトやプル式チェーンとトルク伝達容量を確保するための CVT 用フルード技術，およびプーリのクランプ力を得るための高油圧オイルポンプ技術が重要であり，その性能向上のための開発が種々行われてきた．

ここで図中の薄緑色で背景を塗った部分が本稿で焦点を当てた 2000 年以前の，筆者らが今回定義したい CVT の進化の中の歴史的な領域である．以降，これら 3 つの技術領域において先人達が尽力し，新技術開発にチャレンジした技術トピックスをいくつか紹介したい．

- 1997: CVT equipped with a torque converter adopted by Nissan for use with a 2.0L engine
- 2002: CVT equipped with a torque converter developed by JATCO for use with a 3.5L engine

Amid this historical progression, the evolution of JATCO's CVTs today originated from a unit that Nissan began researching in 1980. This article describes various R&D highlights prior to 2000 that established the foundations of JATCO's current CVT technologies.

*1 A dry belt CVT that is displayed at JATCO's Welcome Center in Japan.

*2 Currently Bosch Transmission Technology B.V.

2. History of the Technological Evolution of Belt-type CVTs

Fig. 2 traces the history of the evolution of belt-type CVT technologies. This evolution is broadly divided into CVT technologies and technologies for the key parts of CVTs. The evolution of CVT technologies is further divided into two groups, namely, straight CVTs without an auxiliary transmission and CVTs with an auxiliary transmission. Various types of shift control technologies have also been developed to match individual CVT models. The Jatco CVT7 and the Jatco CVT8 embody grand sum of the technologies developed in these two categories over the years.

Important technologies for the key parts of CVTs include push belts and pull chains that are essential for transmitting torque, CVT fluids for obtaining the desired torque capacity, and high-pressure oil pumps for securing pulley clamping force. Vigorous development efforts have been made in various areas to improve the performance of these key parts.

The area highlighted with a light green background in the figure is the period before 2000 that is the focus of this article. We define this period this as a historical era in the evolution of CVTs. The following sections describe a number of new technologies that our predecessors undertook the challenge to develop in these three categories through their concerted efforts.

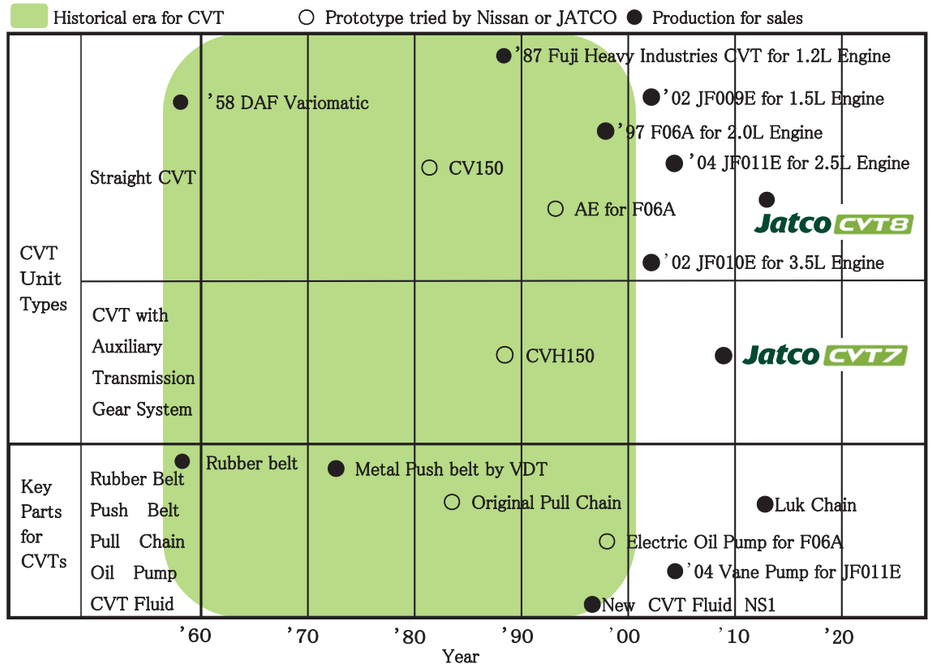

Fig. 2 Historical era for CVTs

3. 各技術領域における技術開発トピックス

3.1. ストレート型　Belt 式 CVT　ユニット技術

1980 年代は，小型自動車の前輪駆動化を背景に日産テクニカルセンターでは，油圧制御式 3 速 AT の開発を進めていた時代であったが，同社の中央研究所では，将来の電子制御トランスミッション時代を先取りするねらいで電子変速制御 CVT の研究が立ち上がった．当時は金属ベルト技術が生み出された直後であり，1.0L 以上のエンジンへの CVT の適用は遠い先と考えられていた時代であった．しかし，CVT 普及のキーは大容量化にあるというコンセプトのもと，150Nm エンジンへの適用を目指して CV150 プロジェクトという名で CVT 容量拡大のための，以下のような基礎研究が種々実施された．

1）伝達トルクと必要プーリ推力の明確化（次式ベース）

$$T=2\,\mu\,RF/\cos\theta$$

T：伝達トルク μ：摩擦係数 R：走行半径 F：プーリ推力 θ：シーブ角

2）変速比と入出力プーリ油圧バランス特性の明確化

3）変速比フィードバックリンクによる変速安定性向上

4）ステップモータ式電子変速制御の検証

3. Highlights of Technological Developments in Each Category

3.1. Technologies for straight belt-type CVTs

The decade of the 1980s was a time when a hydraulically controlled 3-speed AT was being developed at the Nissan Technical Center with the backdrop of adopting FWD systems in small cars. At Nissan's Central Engineering Laboratories, meanwhile, research was launched on a CVT with electronic shift control with the aim of anticipating a future era of electronically controlled transmissions. That happened soon after the development of metal belt technology, and at that time it was thought that the application of CVTs to engines larger than 1.0L displacement was still far off in the distant future. However, a project with the code name of CV150 was initiated to expand the torque capacity of CVTs for application to 150-Nm engines, based on the concept that larger torque capacity was the key to the popularization of CVTs. Various basic research activities were undertaken in that project such as those noted below.

(1) Clarification of the relationship between transmitted torque and required pulley thrust based on the following equation

$$T=2\,\mu\,RF/\cos\theta$$

T: transmitted torque; μ : friction coefficient; R: belt running radius; F: pulley thrust force; θ : sheave angle

(2) Clarification of the relationship between ratio and pressure balance characteristics of the input/output pulleys

(3) Improvement of shift stability by means of a ratio feedback link

(4) Verification of electronic shift control using a stepper motor

(5) Verification of fuel economy and power performance in actual vehicles

Fig. 3 shows a cross-sectional view of the CV150 research model that was mounted in a test vehicle. In addition to ensuring the smooth driving ease of an automatic transmission, the pleasure of shifting was also pursued jointly. The internal structure of the CV150 in Fig. 3 is still the standard configuration of today's CVTs. It is noteworthy that this optimum layout designed for FWD vehicles was achieved at such an early stage.

Based on the fundamental technologies built for the CV150, advance engineering was undertaken to develop a mass-produced CVT. That work created the technologies related to the quality design and the major unit specifications needed to achieve a CVT for practical application. The following is a list of the principal items for which technologies were developed at that time.

(1) Technology for designing the push belt usage
- Alignment accuracy of the fixed input/output pulley halves
- Ball spline accuracy of the input/output pulleys
- Parallelism of the input/output pulley shafts
- Stiffness and Strength of input/output pulley
- Stability of speed ratio during belt operating in high speed
- Stiffness design of case parts supporting the pulleys

(2) Technology for analyzing push belt failure modes
- Excessive pulley thrust force mode
- Pulley misalignment mode
- Excessive belt speed mode
- Belt overheating mode (including non-lubricated condition)

(3) Design technology for major unit specifications/ principal parts and control technology
- Necessary center distance between pulley shafts
- High-efficiency high-pressure oil pump

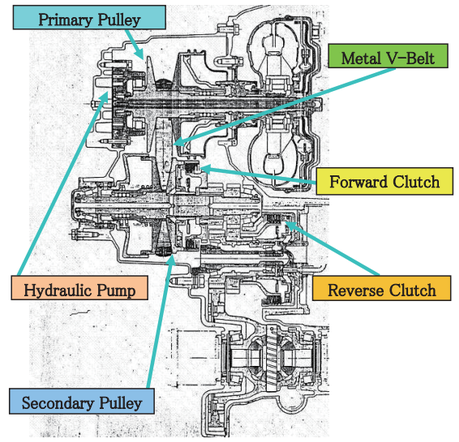

Fig. 3 Cross-sectional View of CV150 Research Unit

5）実車による燃費動力性能の検証

また Fig. 3 に示すような試作ユニット CV150 を車両搭載し，自動変速機としてのスムーズなイージードライブに加えて，シフトする楽しさを追及した．Fig. 3 のような CVT 内部構成は，現在でこそ CVT 構成のスタンダードとなっているが，前輪駆動車向けに最適なレイアウト構成をこのような早い時期から実現できていたことは特筆に価する．

CV150 で構築された基盤技術をベースに，量産 CVT の先行開発が進められた．CVT の実用化に必要な品質設計やユニット主要仕様に関する技術が構築された．ここで開発された主たる技術は以下の項目である．

1）Push Belt の環境設計技術
- ●入出力固定プーリのアライメント精度
- ●入出力プーリのボールスプライン精度
- ●入出力プーリ軸の平行度
- ●入出力プーリの剛性，強度
- ●ベルト高速走行時の変速比安定性
- ●プーリを支持する箱物部品の剛性設計

2）Push Belt の破損モード解析技術
- ●プーリの過推力モード
- ●プーリのミスアライメントモード
- ●ベルトの過速度モード
- ●ベルトの過熱モード（無潤滑状態を含む）

3）ユニット主要仕様，部品の設計技術と制御の技術
- ●必要なプーリ軸間距離の設計技術
- ●高油圧高効率オイルポンプ技術

●変速制御　―　安定性および応答性の確立技術
●最適ライン圧制御技術
●滑らかロックアップ制御技術

Fig. 4 に先行開発 CVT の主断面図を示す．また Fig. 5 にその変速制御システムを示す．ステップモーターとメカニカルプーリー位置センサーを活用した変速制御の根幹が，この先行開発によって確立された．ステップモーターによる直線的な変位によって変速制御バルブが移動すると，油圧のフィードバック作用によってプーリが所定の変速比位置に制御される，ロバスト性に優れた機構である．ユニットの成立性に必須となる CVT 変速の安定性と応答性を両立する重要技術がこれによって確立でき，量産 CVT の制御システムへとつながっていった．当社の JF009E，JF010E，JF011E にも継承された重要な変速制御機構である．この制御システムの確立によって CVT を搭載した実験試作車を用いた種々の機能評価，運転性評価，信頼性評価をすることが可能となった．

またこの先行開発 CVT では，Fig. 4 のように，発進要素としてフルードカップリングが搭載されており，車両実験を通じて発進加速性能も多々評価された．その結果，良好な発進加速を得るためにはトルク増幅機能を有するトルクコンバーターが必要であることもこの開発によって明確化され，後の量産 CVT として立ち上がった F06A ではトルクコンバーターを採用する決心に至った．

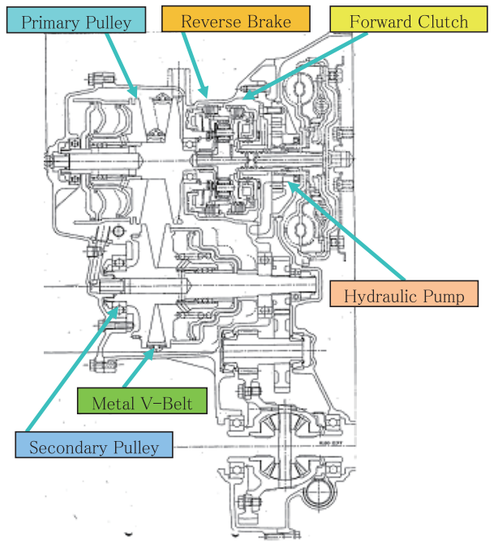

Fig. 4 Cross-sectional View of Advance Engineering CVT

● Shift control- Technology to obtain good stability and response
● Optimum line pressure control
● Smooth lock-up control

Fig. 4 shows a main cross-sectional view of the advance engineered CVT, and Fig. 5 shows its electronic shift control system. The foundations of shift control using a stepper motor and a mechanical pulley position sensor were established with the development of this CVT. When the shift control valve was moved by the linear movement of the stepper motor, the hydraulic pressure was fed back to control the pulleys to the desired position for the specified ratio. This control system had good robustness, and it established the key technology for securing both CVT shifting stability and responsiveness, qualities essential to the viability of a CVT. That technology led to the development of the control system for mass-produced CVTs. As a key shift control system, it was continued by JATCO's JF009E, JF011E and JF010E models. The establishment of this shift control system made it possible to conduct various types of functionality, driveability and reliability evaluations using experimental prototype vehicles mounted with CVT.

As shown in Fig. 4, this advance engineered CVT was built with a fluid coupling used as the start-off element. Extensive vehicle testing was conducted in which start-off acceleration performance was also thoroughly evaluated. As a result, it was also made clear by this advance engineering work that a torque converter with a torque multiplication function would be necessary to obtain satisfactory start-off acceleration. That led to a decision to adopt a torque converter for the F06A that was subsequently launched as a mass-produced CVT.

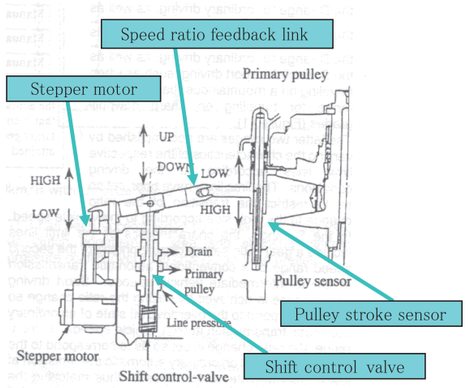

Fig. 5 Electronic Shift Control Mechanism of CVT

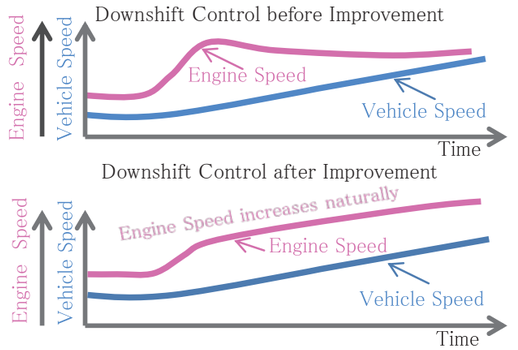

Fig. 6 Improved Shift Control to obtain Better Shift Feel

一方，研究段階の CV150 の時代から，CVT 制御の改良も種々行われていた．踏み込み加速時にエンジンの吹き上がりを抑えて人間の感性に合う加速感のある変速の研究も当時種々トライされ，今のリニアーモードにつながるコンセプトの基礎が形成されていった．（Fig. 6）また，任意の固定変速比を自由に選べるマニュアルシフト CVT 制御も実験車で研究され，現在ではマニュアルシフト機能は多くの CVT 車に普及している．Fig. 7 に当時試作された 7 速マニュアルシフトの事例を示す．

また，学術界との連携によってハイブリッド化の検討も行われた．CVT を活用してエネルギー回生車を研究していた米国 CA 州立大学 Frank 研究室との共同で，1998 年頃から数年間，量産 CVT を用いて 1 モーター 2 クラッチ式ハイブリッドパワートレーンの研究も行い，当社社員も留学して種々の最新制御技術の習熟も推進した．

Fig. 8 はその当時の HYBRID パワートレーンの写真である．これを搭載した研究車によって，同研究室は Future Car 競技会で，燃費部門他で全米チャンピオンとなるというような輝かしい歴史も残っている．ここで研究した技術には，更なる高効率 CVT を実現する技術として今後も活用が期待できる技術アイテムが残っている．

Various improvements were also being made to CVT shift control from the research stage of the CV150. Different attempts were made at that time to research a shift control for achieving a feeling of acceleration matching human sensibility by controlling engine speed flare during power-on acceleration. The basis of the concept that led to today's linear mode was formed at that time (Fig. 6). In addition, a CVT control for a manual shift mode that allowed the driver to freely select arbitrary fixed ratios was also being researched in test vehicles. Nowadays, a manual shift mode is commonly found on many CVT-equipped car models. Fig. 7 shows an example of a 7-speed manual shift gate pattern that was being researched in those days for CVT application.

Studies of hybrid systems were also conducted in cooperation with the academic community. Professor Andrew Frank at the University of California, Davis who were conducting the research on energy regeneration function using CVT, a joint research project for several years from around 1998 was started, also to research one-motor two-clutch hybrid powertrain using our mass production CVT. JATCO employees also went to the university to study and were vigorously engaged in acquiring various new control techniques. Fig. 8 is a photo of the hybrid powertrain being researched at that time. Dr. Frank's department entered a research vehicle mounted with this powertrain in the Future Car Contest and it created a brilliant record of becoming the U.S. champion in the fuel economy category. Among the technologies researched in that project, there are still various technical items that are expected to be utilized in the future as a means of achieving even more efficient CVTs.

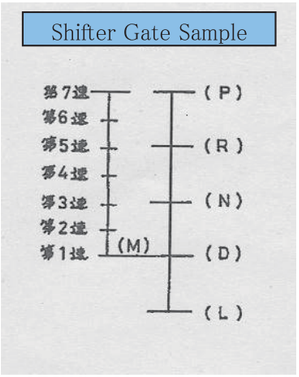

Fig. 7 Gate Pattern of CVT Manual Shift Mode

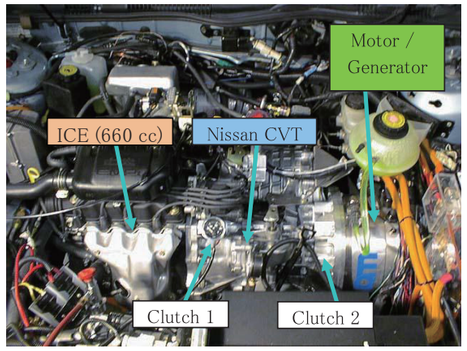

Fig. 8 Hybrid Powertrain with Nissan CVT

3.2. 副変速機つき　Belt 式 CVT ユニット技術

副変速機と CVT を組み合わせることによって，CVT 機構を組み込んだトランスミッション全体のシステムとして，CVT 単独で構成したミッションと比較して大幅にトルク伝達容量を増大したり，変速の幅を大幅に拡大することが可能となる．それによって小型車の小エンジンコンパートメントに搭載可能な，コンパクトながらワイドレンジの CVT が実現できるため，この領域の技術開発も各社で盛んに研究されていた．Jatco CVT7 はその技術を　世界で始めて量産化に成功した革新ユニットである．この技術領域においても日産の研究時代から研究開発が重ねられていた．

Fig. 9 は 1980 年代後半に研究開発されていた副変速機構つき CVH150 の主断面図である．

ストレート型 Belt 式 CVT“CV150”の伝達トルク容量は 150Nm であったが，同じ 24mm 幅ベルトを使用して，副変速機と組み合わせることによって 250Nm のトルク容量を持たせることを目標に CVH150 が開発された．発進直後の Low 側の変速比は副変速機によるギヤ駆動によって実現し，発進後に副変速機が変速することにより CVT 機構を通したトルク伝達に切り換わる．CVT 変速機構はプーリの最小巻きつき半径を大きく設定することによって，大トルク伝達時の負荷を抑制できるようにしたシステムであり，ワイドな変速比の一部を副変速機に持たせるコンセプトの原型とも言える機構である．

当時の前輪駆動車である，最大トルク 230Nm のエンジンを持つ日産ブルーバードに CVH150 を搭載して，追浜プルービンググランドにて優れた動力性能と低燃費を実証した．ストレート型の CV150 で 150Nm の伝達トルクを実証し，更にこの CVH150 の開発で 230Nm の伝達トルクを検証できたことにより，3.5L エンジン適用 CVT の開発への弾みをつけていった時期であった．

3.2. Technologies for belt-type CVTs with an auxiliary transmission

Combining an auxiliary transmission with a CVT enables the overall transmission system with the CVT mechanism to greatly expand both torque capacity and the range of ratio coverage compared with a transmission consisting of a CVT mechanism alone. As a result, that makes it possible to build a CVT that is mountable in the small engine compartment of small cars and provides wide ratio coverage despite its compact size. For that reason, companies were engaged in vigorous research efforts to develop technologies in this area. The JATCO CVT7 is a revolutionary unit that was the world's first to successfully embody the required technology in a mass-produced CVT. The research this technical category was also undertaken at Nissan research center.

Fig. 9 is a main cross-sectional view of the CVH150 that was researched and developed with an auxiliary transmission in the latter half of the 1980s. The torque capacity of the straight belt-type CVT CV150 was 150 Nm. The CVH150 was developed with the aim of achieving a torque capacity of 250 Nm by combining the CVT with an auxiliary transmission while using the same 24-mm-width steel belt. The transmission ratio on the Low side right after vehicle launch was achieved with the gear drive of the auxiliary transmission. After the vehicle was launched, the shifting of the auxiliary transmission effected a change to torque transmission through the CVT shift mechanism. The CVT shift mechanism was designed with a large minimum running radius of the belt on the pulleys so as to hold down the load when transmitting large torque. This CVH150 can be regarded as the prototype of the concept of having the auxiliary transmission provide a portion of the wide ratio coverage.

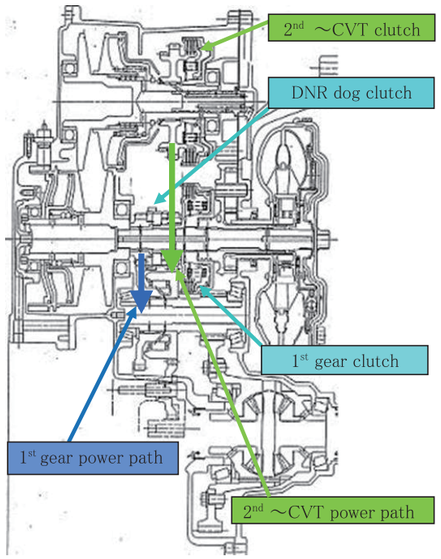

Fig. 9 Cross-sectional View of CHV150 with Auxiliary Transmission

The CVH150 was mounted on the Nissan Bluebird, a FWD model fitted with an engine that produced maximum torque of 230 Nm at that time. Tests conducted at the Oppama Proving Ground verified that the vehicle delivered outstanding power performance and excellent fuel economy. Torque capacity of 150 Nm was confirmed with the straight belt-type CV150 and that was further raised to 250 Nm with the development of the CVH150. The verification of that performance created the momentum at that time for the development of a CVT applicable to a 3.5L engine.

An indispensable technology in JATCO's current CVT7 is the close coordination between the CVT shift control and the auxiliary transmission shift control. Various methods of accomplishing such coordinated control were also being researched at the same period. For example, research was conducted on various techniques for switching from gear drive to CVT drive by shifting the auxiliary transmission and conversely for changing over from CVT drive to gear drive. Techniques were investigated for optimizing the timing of each shift control and the shifting speed so as to obtain the smoothest shift feel for the transmission as a whole. A technology was also established for obtaining the optimum shift feel by also controlling the lock-up clutch of the torque converter in a coordinated manner depending on the driving situation. The shift control system of the current Jatco CVT7 inherits that concept and DNA.

3.3. CVT のキー部品技術

先述のとおり，CVT のキー部品としてはベルト，チェイン，CVT フルード，高油圧オイルポンプであり，研究時代から種々の開発が行われてきた．

特にベルト，チェインはトルク伝達の要であり，その特性を知り尽くして活用することが極めて重要である．研究時代には CVT の重要機能を基礎研究し「ノウハウは手元に持つ」という当時の会社方針もあり，椿本チェイン（株）様と独自 CVT チェインの研究も行われた．Fig. 10 に，その独自開発チェインの概観写真を示す．写真のように，現在のプッシュベルトとプルチェーンの良特性を合わせ持ったような構造のベルトであり，今となっては貴重な技術開発の歴史を語りつぐような試作品の写真である．本チェインの研究では，動力伝達特性，NVH 特性について“Push Belt”と“Pull Chain”の特徴について種々研究された．

NVH 低減のため，Fig. 10 中に示されたロッカージョイントピンの接触凸 R のランダム化や，左右 2 列のチェインを 1/2 ピッチオフセットするアイデアにより，当時先行していた VDT 社の Push Belt と同等の音振レベルを達成できていた．この研究で得られたノウハウはチェイン式 CVT にも伝承されていった．

3.3. Technologies of key CVT parts

Efforts were undertaken from the period of basic research to develop various key CVT parts such as the aforementioned belt, CVT fluid and high-pressure oil pump. Because the belt in particular is the key element for transmitting torque, it is critical to have a thorough knowledge of its characteristics and to utilize them effectively.

Fundamental research was conducted on CVT functions during the research stage. Partly on account of the company's policy of possessing know-how in house,

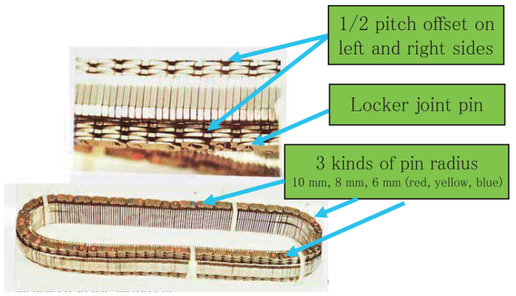

Fig. 10 Original J-Chain

CVT フルードについても世界最大のトルク容量を実現するための開発が種々行われた.学術会との連携も活用され，General Motor 社で CVT の研究経験のあった D.C. Sun 教授と，CVT のベルトとプーリ間の摩擦特性を表すストライベック線図に関する研究の交流も図られ，新 CVT フルードの開発にそこで得た知見が活用されていった.

また，現在ではベーンポンプが CVT 用高圧ポンプの主流になってきているが，1980 年代後半の 4 速 AT 時代には可変吐出流量ベーンポンプも多用していたため，ベーンポンプの経験，ノウハウも同時期に蓄積された.

並行して，大容量トルク伝達のキーとなったプーリ加工に関する生産技術も多々開発されたが，本稿ではその紹介にとどめ，詳細は割愛させていただく.

research was also conducted on an original CVT chain together with Tsubakimoto Chain Co. Figure 10 shows a photo of the appearance of the original chain that was developed. As shown in the photo, the structure of the chain combines the good features of today's push belt and pull chain. Today, the photo of this prototype is valuable in relating the history of the important R&D work that was done in the past. In researching this chain, various studies were conducted on the features of the push belt and pull chain with respect to power transmission characteristics and noise, vibration and harshness (hereafter NVH) characteristics.

The figure shows typical ideas incorporated in the chain for reducing NVH, including the random convex radius of contact of the locker joint pins and the one-half pitch offset of the right and left sides of the chain. These measures achieved a noise and vibration level equal to that of VDT's push belt that the most advanced product at that time. The know-how gained through the research done in those days is continued in today's chain-drive CVTs.

Wide-ranging activities were also carried out to develop a CVT fluid that would obtain the highest level of torque capacity worldwide. Collaboration with the academic community was also actively utilized. Research findings concerning the Stribeck Curve that expresses the friction characteristics between the CVT belt and pulleys were exchanged with Dr. D.C. Sun, who had previously done research on CVTs at General Motors. The knowledge gained through such collaboration was used effectively in developing a new CVT fluid.

Vane pumps have currently become the mainstream high-pressure oil pumps for CVT application, but variable displacement vane pumps were also frequently used in the era of 4-speed automatic transmissions in the latter half of the 1980s. Accordingly, experience and know-how concerning vane pumps were also accumulated during that same time. In parallel with that, many production engineering techniques concerning the machining of pulleys were also developed, which have been a key factor in facilitating the transmission of large torque. This article simply notes this fact and does not go into the details of those techniques.

4. 終わりに

1981 年神奈川県横須賀市にあった日産中央研究所（現：日産総合研究所）で，CV150 が産声を上げてから 34 年が過ぎた.

手動変速機が主流であった時代に，小型車用電子制御 CVT の研究を立ち上げた諸先輩方，生産拡大に向けて多大なご尽力をいただいた部品メーカの皆様方や社内関連部門の方々に心より感謝する.

合わせて，CVT 発祥の地である欧州に金属ベルト会社を立ち上げ，CVT 車の普及に骨身を削り，プッシュベルトの開発，生産に努力を重ねられた方々に敬意を表す.

4. Conclusion and Acknowledgments

Thirty-four years have passed since the CV150 was first created at Nissan's Central Engineering Laboratories (currently the Nissan Research Center) in Yokosuka, Kanagawa, in 1981. We would like to express our heartfelt appreciation to our predecessors who launched research on an electronically controlled CVT for small car application at a time when manual transmissions were still the mainstream. We also would like to express our heartfelt appreciation to all the partner manufacturers and internal departments involved for their tremendous efforts in expanding CVT production. We also want to pay our deep respect to the people who founded a metal belt manufacturing company in Europe, birth place of CVT, and who made repeated efforts to develop and manufacture push belts as well as striving vigorously to popularize CVT-equipped vehicles.

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感性にマッチした CVT 新変速制御の開発

Development of a New CVT Shift Control Matching Drivers' Sensibilities

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太田　義和**　Yoshikazu OOTA

抄　録　CVT は低燃費で滑らかな走りを実現させ，多くのお客様から大変好評を得ている．今回は，欧州等で MT や AT に乗り慣れたお客様にも更に満足して頂くために，「Dynamic step shift control」（D-STEP 変速制御）と呼ばれる，感性にマッチした新しい変速制御を開発した．

本稿では，その技術内容を紹介する．

Summary　Continuously variable transmissions (CVTs) are evaluated highly by customers for delivering smooth driving performance with high fuel economy. New shift control software called “Dynamic step shift control” (D-STEP) that provides a shift feel matching drivers' intention have been developed recently. D-STEP was developed to give even drivers in Europe and other markets who are accustomed to driving vehicles with manual or step shift automatic transmissions(hereafter AT) a more satisfying driving experience. This article presents the technical details of D-STEP.

1. Dynamic Performance の進化

1.1. 背景

CVT は変速比を無段階に選択することが出来るため，例えば Fig. 1 の青線に示すように，発進加速において，エンジン回転を最も燃費に有利な領域に維持させることで，低燃費を実現させている．

また，無段変速により，変速時駆動力変動の無いスムーズで滑らかな走りを実現させている．

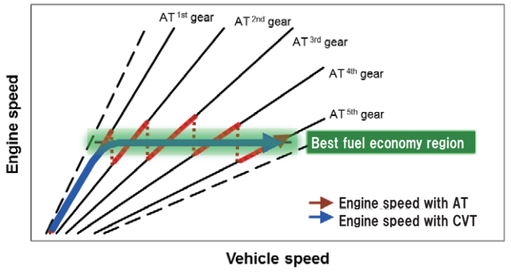

Fig. 1 Engine speed comparison between CVT and AT in start-off acceleration

しかし一方で，追い越し等のスポーティな加速を必要とするシーンにおいて，車速が上昇してもエンジン回転が殆ど変化しないような変速を行った場合には，有段のＭＴやＡＴに乗り慣れたお客さまには多少違和感を持たれることがあり，お客様やジャーナリストから，次のようなコメントを受けがちであった．

- Disconnected feeling (Rubber band feeling)
- Unnatural engine speed
- Noisy, Droning

これらのコメントから言える共通の改善課題は，車速上昇とエンジン回転上昇とを如何にリニアに関係させるかを，制御によって実現することである．

その観点で，初代 CVT の誕生以降，種々の改良制御が加えられ，CVT の変速性能が着実に進化してきた．

- ●初代 CVT 変速制御
  踏み込み量に応じたエンジン回転上昇
  中高開度踏み込み時のラバーバンドフィーリングが強い．
- ●第二世代 CVT 変速制御
  リニアモードの採用
  中高開度踏み込み直後のエンジン回転上昇を抑制し，その後有段 AT のような変速比固定を行うことにより，ラバーバンドフィーリングを低減．
- ●第三世代 CVT 変速制御
  新リニアモードの採用
  リニアモード適用領域を低開度に拡大．アクセル開度に応じエンジン回転上昇量を選択可能とし，更に感性に合う加速フィーリングを実現．

今回開発した新制御は，これらの進化の最先端と言える制御であり，CVT の自在変速の利点と，有段 AT のリニアで伸びのある加速フィーリングを融合させ，走行シーンに応じて最適な変速フィーリングが得られるようにすることを目指したものである．

我々はこの変速制御を「Dynamic step shift control」（以下 D-STEP 変速制御）と命名した．以下にこの新制御の詳細を紹介する．

1.2. D-STEP 変速制御コンセプト

D-STEP 変速制御のコンセプトは，前述のとおり，次のような CVT と AT のそれぞれの強みを融合させたものである．

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1. Evolution of Dynamic Performance

1.1. Background

CVT can select the transmission ratio in a stepless manner which help to achieve high fuel efficiency by adjusting engine speed to optimal operate condition for the best fuel economy during start-off acceleration, as shown, for example, by the blue line in Fig. 1. In addition, stepless shifting provides smooth seamless driving performance without any fluctuation in driving force during shifting.

However, on the other hand, in situations where sporty acceleration is required such as for passing, there are times when customers accustomed to driving a vehicle with a manual or AT experience a somewhat unnatural feeling with a CVT. That happens when engine speed remain stable during CVT shifts while vehicle speed is increasing. Customers and auto journalists tend to make the following comments about CVT shift behavior.

- Disconnected feeling (rubber band feeling)
- Unnatural engine speed
- Noisy, droning

A common issue for improvement with regards to these comments, is to have a shift control that establishes a linear relationship between rising engine speed and increasing vehicle speed. From that perspective, we have added various controls for improving shift performance since the 1st-generation CVT was introduced and have steadily evolved the shift performance of our CVTs.

- 1st-generation CVT shift control
  Engine speed rose according to the depth of the accelerator pedal press down.
  There was a strong rubber band feeling with medium to large of the accelerator pedal press down.
- 2nd-generation CVT shift control
  Adoption of linear mode
  The rubber band feeling was reduced by suppressing the engine speed rise right after medium to large of the accelerator pedal press down, followed by the use of a fixed ratio like that of a AT.
- 3rd-generation CVT shift control
  Adoption of new linear mode
  Use of the linear mode was extended to the region of a small accelerator pedal press down range. This control made it possible to select a rate of engine speed rise matching the accelerator pedal press down rate. In addition, it also achieved an acceleration feel matching drivers' intention.

The newly developed shift control described here is at the leading edge of the evolution. The aim of this shift control is to obtain the optimal shift feel matching the driving situation. This is accomplished by combining the CVT advantage of ratio flexibility with the linear and stretched acceleration feeling similar as AT.

We call this new shift control software “Dynamic step shift control” or D-STEP in short. The details of this new shift control are described below.

1.2. Concept of D-STEP

As mentioned above, the concept of D-STEP is to combine the following respective strengths of a CVT and AT.

- CVT strength
  Shift smoothness that only a CVT can provide
- AT strengths
  Acceleration matching the driver's intention
- Connected feel between the engine speed and the vehicle speed
- Feeling of sustained acceleration(stretched acceleration)

Fig. 2 outlines the concept of this new shift control. During normal cruising, the engine speed is maintained in the region conducive to the best fuel economy. In situations requiring sporty acceleration such as for passing, the engine speed rises linearly, emphasizing the feeling

● CVT の強み
　CVT にしか出来ないレベルのスムーズな変速
● AT の強み
　ドライバーの意図にマッチした加速
●直結感の演出
●加速感の持続

Fig. 2 は新変速制御のコンセプトを表したものである.

通常走行では，エンジン回転を最も燃費に有利な領域に維持させ，追い越し等のスポーティな加速を必要とするシーンでは，加速感を重視し，エンジン回転をリニアに上昇させ，直結感を演出する．また，AT のようにリズミカルにアップシフトを繰り返し，そのアップシフト量を最適化することにより，加速感を持続させる．更に，AT で課題となる変速開始直後に締結するクラッチと解放するクラッチが係合することによって発生する駆動力損失変動のない，CVT にしか出来ないレベルのスムーズな変速も実現させることが出来る制御である.

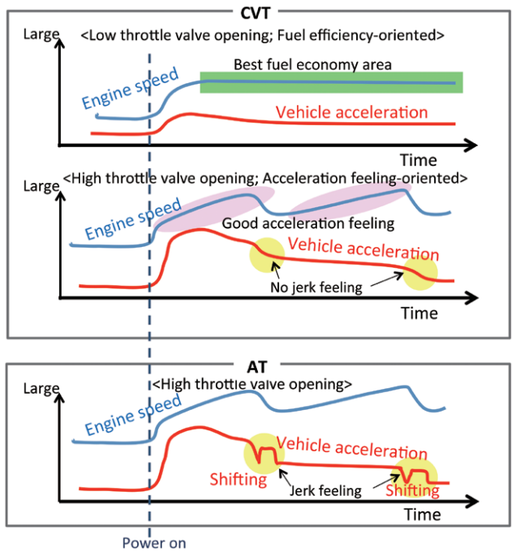

Fig. 2 Comparison of AT and CVT equipped with D-STEP

1.3. D-STEP 変速制御における主要技術

この D-STEP 変速制御において鍵を握るのは，制御の切り替えの判定技術である．ドライバーの運転傾向や交通環境に応じて，期待通りの走りを提供するために，種々の情報を活用する.

Fig. 3 に切り替え判定制御システムの概要を示す.

of acceleration, and a connected feel is achieved between the engine speed and the vehicle speed. In addition, the CVT upshifts repeatedly in a rhythmical manner like an AT, and the ratio change amount of of each upshift is optimized to sustain the feeling of acceleration. Moreover, this new control provides a level of shift smoothness that only a CVT can deliver without any driving force loss or fluctuation like the concern that occurs in an AT due to the engaging/disengaging of the clutches right after the onset of shifting.

1.3. Main technologies incorporated in D-STEP

The key technology of D-STEP control, is the system for judging the switching of the shift control modes. Various information inputs are used to provide the expected driving performance matching the driver's personal driving style and the traffic situation. An outline of the system for judging the switching of shift control modes is shown in Fig. 3.

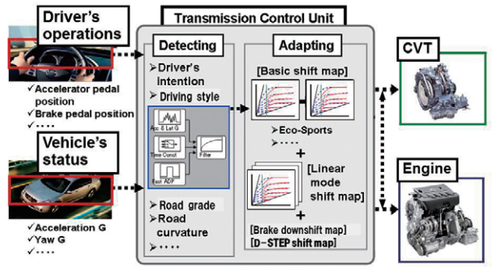

Fig. 3 System Outline of shift control changeover judgment system

The switching of shift control modes is executed on the basis of accurate detection of the vehicle's present operating status. In addition to information on the driver's operational inputs such as the positions of the accelerator pedal, brake pedal and steering wheel, calculation is also made for estimating vehicle's longitudinal acceleration, the road grade, cornering force and other parameters. The control system also estimates the driving condition, such as city driving, high-speed cruising or winding road driving, and also simultaneously detects the driver's personal driving style. On that basis, the system switches the shift control mode, selecting the shift control pattern that optimally matches the driver's intention.

In addition, the threshold for switching shift control modes can be set according to the engine displacement, market, vehicle concept (such as sporty performance or

アクセルやブレーキ，ステアリング操作量などの運転操作情報の他，車両前後加速度，道路勾配，コーナリング負荷の推定計算など，現在どのような運転状況にあるのかを的確に感知することで，制御の切り替えを実施している．市街地走行や高速クルージング走行，ワインディングロード走行等の推定も実施し，同時にドライバーの運転傾向も把握することによって制御を切り替え，ドライバーの意図に合った最適な変速制御を選択する.

更に，制御切り替えの閾値は，排気量や仕向地，車両コンセプト（スポーティ性を重視する車か否か等）で作り分けることも可能にした．例えば，排気量が小さく，低開度で思い通りの加速が出来ないような車両では，D-STEP 変速制御が作動し易い設定にした．また，MT に慣れたドライバーが多い欧州では，D スポーツレンジを選択した場合，常時 D-STEP 変速制御を作動させることで，スポーティな走りを好むお客様に満足頂けるようにした.（Fig. 4）

Fig. 5 は，変速制御の切り替えによって，従来に対して変速フィーリングを大きく変えたポイントの詳細をまとめたものである.

赤色は燃費を重視した従来の CVT 変速制御，青色は D-STEP 変速制御の特徴でもある加速感重視制御の波形である．橙色で囲まれた領域がその特徴であり，従来 CVT に対して改善したポイントである．その特徴をまとめると，以下の各項目になる.

●意のまま
　AT ではダウンシフトのギヤ比段差が固定であったが，アクセル開度に応じ最適量のギヤ比段差でダウンシフトすることで，加速意図に応じた最適 G を発生させる.
●ダイレクト感
　変速比を固定することで，車速とエンジン回転を相関させながらリニアに上昇させる.
●滑らかさ
　アップシフト時に，AT のような変速クラッチ同士の競合による駆動力損失変動が発生しない．また，アップシフト量を最適化することで，駆動力低下を抑制する.
●伸び感
　変速比を固定することで，G を持続させる.

not) and other factors. For example, D-STEP is designed to be easily activated in a vehicle that cannot accelerate as the driver wishes at a small accelerator pedal angle owing to its small displacement engine. Or for vehicles in Europe where drivers are accustomed to manual transmissions, D-STEP can be activated at any time when the D Sports Range is selected. This makes it possible to satisfy customers who prefer sporty driving (Fig. 4).

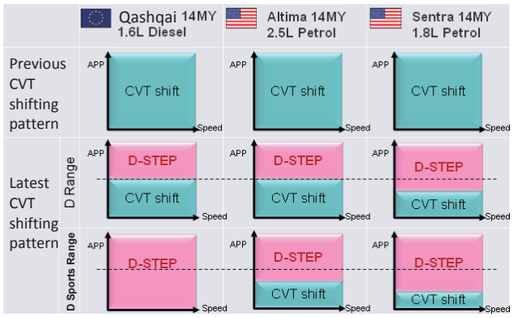

Fig. 4 Operating range of D-STEP compared with previous CVT

Fig. 5 summarizes in detail the points where the shift feel is significantly improved by switching the shift control mode. The red waveform in graph shows the previous CVT shift control mode that emphasizes fuel economy. The blue waveform in graph shows shift control that emphasizes the feeling of acceleration, which is also a distinctive point of D-STEP. The orange regions indicate the features of this new shift control and represent aspects that have been improved compared to previous CVT control. The details of these control features are summarized below.

● Matching the driver's intention
　With an AT, the rate of change in the ratio for a downshift is fixed. In contrast, D-STEP enables the CVT to downshift with the optimum rate of ratio change, matching the accelerator pedal press down amount. This produces the optimum G matching the driver's acceleration intention.
● Connected feel
　The use of a fixed ratio correlates the vehicle speed and the engine speed so that they rise together linearly.
● Smoothness
　The CVT upshifts without any driving force loss or fluctuation like what occurs with an AT due to competition between the shift clutches. Moreover, because the ratio change rate during upshift is

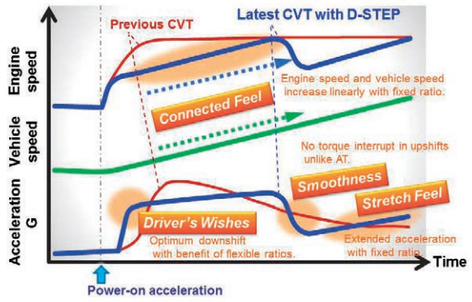

Fig. 5 Features of D-STEP

1.4. D-STEP 変速制御開発におけるチャレンジ

先述のとおり，D-STEP 変速制御の採用により，CVT のスムーズな変速に AT のリニアでリズミカルな加速を融合させることが出来た.

更に，CVT の変速ポテンシャルを最大限に活かし，AT のような速いアップシフト変速と目標変速比への追従性を実現させるために，アップシフト終盤における目標変速速度及び目標変速比の可変最適化と，変速比フィードバック制御量（積分ゲイン）の最適化を実施した.

Fig.6 に示すように，変速直後のアンダーシュートをドライバーには感知出来ない量とする改良にも成功した．上記変速制御改良前後の実験波形を示す.

1.5. ジャーナリストからの評価

上記 D-STEP 変速制御は既に製品化されており，北米ではセントラ，アルティマ，ローグ，欧州ではキャッシュカイ，日本ではエクストレイルに採用されている.

これら上記車両は，加速フィーリングが良く，走る楽しさを与えてくれるといった評価を種々の自動車誌から得ている．その事例を以下に記載する.

USA Today 誌（ローグの評価）

● Not our usual anti-CVT rant here.

● Nissan's tried mightily to take advantage of the CVT's improved mileage and still provide some of a conventional automatic's preferable driving feel, using software it calls D-STEP.

（出典：USA TODAY, December 20th 2013）

イギリス Auto Express 誌（キャシュカイの評価）

● And it works – this is one of the nicest CVT boxes we've tried. It's smooth, quick to react and with the artificial steps doing the job of eliminating the engine whining well. In everyday driving it's a delight, and even when pushing harder and using the gearlever to shift manually through the fake gears, it's fun.

（出典：Auto EXPESS, January 8th 2014）

optimized, the reduction of driving force is suppressed.

● Sustained acceleration feel

Acceleration (G) is sustained by using a fixed ratio.

1.4. Challenges in developing D-STEP

As explained above, the adoption of D-STEP combines the smooth shifting of a CVT with the linear, rhythmical acceleration of an AT. In addition the shift potential of the CVT was maximized to allow variable optimization of the target shift speed and optimization of the feedback control amount (integrated gain). That makes it possible to obtain quick upshifts like an AT and the capability of following the ratio to the target value.

As shown in Fig. 6, another improvement obtained with D-STEP control is that the engine speed undershoot just after upshift is kept to a level that is imperceptible to the driver. The figure shows experimental waveforms of engine speed undershoot before and after improvement of shift control.

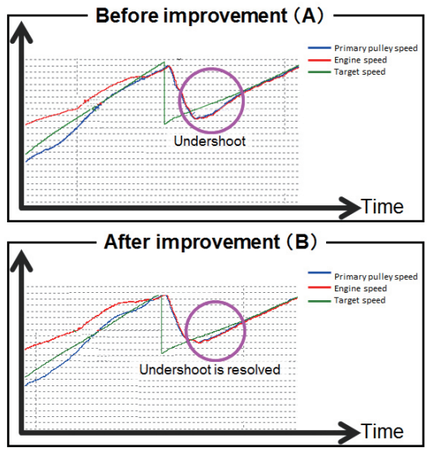

Fig. 6 Effect of D-STEP on improving ratio undershoot

1.5. Evaluations by auto journalists

The D-STEP shift control described here has already been implemented on production vehicles. It has been adopted on the Nissan Sentra, Altima and Rogue in North America, on the Qashqai in Europe and on the X-Trail in Japan. These vehicles have been evaluated by various automotive magazines for providing a good feeling of acceleration and excellent driving pleasure. Excerpts from typical articles are cited below.

USA TODAY (evaluation of the Rogue)

● Not our usual anti-CVT rant here.

● Nissan's tried mightily to take advantage of the CVT's improved mileage and still provide some of a conventional automatic's preferable driving feel, using software it calls D-STEP.

Source: USA TODAY, December 20, 2013

U.K. Auto Express (evaluation of the Qashqai)

● And it works – this is one of the nicest CVT boxes we've tried. It's smooth, quick to react and with the artificial steps doing the job of eliminating the engine whining well. In everyday driving it's a delight, and even when pushing harder and using the gearlever to shift manually through the fake gears, it's fun.

Source: Auto Express, January 8, 2014

2. 終わりに

D-STEP 変速制御の採用により，従来の新リニア制御でもまだ残っていたラバーバンドフィーリングを払拭し，ダイレクト感，リズム感とリニアで伸びのある加速感を実現させた．それによって，ＣＶＴの低燃費でスムーズな走りと，ＭＴやＡＴのダイレクトでリニアな走りを融合させ，更に，AT で課題となる変速開始直後の駆動力損失変動が発生しない，CVT にしか出来ないレベルのスムーズな変速も実現させ，全く新しい走りを生み出す車作りに貢献することが出来た.

今後はこの新制御をベースに，CVT の自在変速の利点を活かし，様々なシーンにおいて，ドライバーの感性に更にマッチして感動を呼び起こすような革新制御を開発して行きたい.

3. 参考文献

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3) Development of variator system on Jatco CVT8 and CVT8 HT, JSAE drive train symposium, Nov. 11th, 2012
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■ Authors ■

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2. Conclusion

The adoption of D-STEP shift control has eliminated the rubber band feeling that still remained with the previous new linear control. As a result, D-STEP provides a connected feel and a linear, rhythmical feeling of sustained acceleration.

D-STEP combines the smoothness and excellent fuel economy of a CVT with the linear and connected driving feel of a manual or an AT. Moreover, it provides a level of smoothness that only a CVT can deliver, without any driving force loss or fluctuation right after the onset of shifting, which has been concern of ATs. As a result, this new shift control has contributed to the engineering of vehicles that deliver a totally new driving experience.

Based on this new D-STEP control, we intend to take effective advantage of the ratio flexibility of CVTs to develop innovative shift control software that impresses drivers and inspire their emotions in all sorts of driving situations.

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2) JATCO Technical Review, No. 12, March 2013.
3) Development of variator system on Jatco CVT8 and CVT8 HT, JSAE Drivetrain Symposium, November 11th, 2012 (in Japanese).
4) USA TODAY, December 20th, 2013.
5) Auto Express, January 8th, 2014.

Jatco CVT7 副変速スムーズフィーリング向上制御の開発

Development of New Shift Controls for Jatco CVT7's Auxiliary Transmission to obtain a Smoother Shift Feel

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抄　録　Jatco CVT7 は，ベルト&プーリー変速と副変速機構を組み合わせることで，ワイドレンジの変速比幅を実現しており，軽自動車から小型車までの幅広い車両モデルに適用され，燃費性能の向上を実現してきた．ベルト&プーリー変速と副変速機との協調制御により CVT ならではのスムーズな変速を実現できている．この協調制御は発売以来進化を遂げており，更にスムーズ性を向上する最新制御が開発された．

本稿では，その最新制御について紹介する．

Summary　The Jatco CVT7 combines a belt & pulley shift mechanism with an auxiliary transmission to achieve wide ratio coverage for improving fuel economy when applied to a broad range of models from minivehicles to compact cars. Collaborative control of the belt & pulley shift mechanism and the auxiliary transmission ensures smooth shift performance characteristic of a CVT. Collaborative control has continued to evolve since the Jatco CVT7 was first introduced, and new shift controls further has been developed to improve shift smoothness. This article describes these newly developed shift control features.

1. はじめに

2009 年 7 月に副変速機を備えた新小型 CVT が製品化され，その幅広いレシオカバレッジを適用することにより種々の新車の燃費・動力性能を大幅に向上してきた．これは副変速機を有する事で可能となっているが，副変速機をよりスムーズに変速させることが重要な課題となっていた．

特に副変速機の変速時に発生する車両加速度変動（以下 G-drop）は，副変速機付き CVT の主要課題であり，Jatco CVT7 の進化としてこれまで多くの改善制御が開発されてきた．

本稿では，G-drop 改善の為に開発された最新技術について紹介する．

1. Introduction

The new compact CVT featuring an auxiliary transmission went into production in July 2009. The wide ratio coverage of this new CVT has been applied to markedly improve the fuel economy and dynamic performance of a wide variety of new vehicles. These improvements have been possible because the Jatco CVT7 incorporates an auxiliary transmission. However, a crucial issue here was to obtain smoother shift performance during auxiliary transmission shift.

The main issue of a CVT equipped with an auxiliary transmission is the fluctuation in vehicle longitudinal acceleration, referred to here as the G-drop, which occurs when the auxiliary transmission shifts. We have so far developed many new control features as improvements for the further evolution of the Jatco CVT7.

This article describes the latest shift control technologies we have developed to improve the G-drop.

2. 副変速時の課題

副変速機の変速パターンには大きく分けて 3 種類ある．アクセル開度一定で加速中に副変速ギア比を 1 速から 2 速へ変速させるオートアップシフト（以下 オートアップ）．

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アクセル開度変化を伴う場合では 2 種類の変速があり，足離し時に副変速ギア比を 1 速から 2 速へ変速させるリフトフットアップシフトと，踏み込み時に 2 速から 1 速へ変速させるキックダウンシフトである．

この 3 種類の変速パターンの中で今回オートアップ時の制御について取組んだ内容を紹介する．オートアップはドライバーのアクセルペダル操作が伴わないシーンにおいて副変速機のクラッチ架け替えが自動的に行われるため，CVT と同等のスムーズな変速性能を実現する必要があった．

オートアップ時の副変速機の変速タイムチャートを Fig. 1 に示す．トルクフェーズにおける 1 速から 2 速へクラッチの架け替え及び，イナーシャフェーズにおけるベルト&プーリーと副変速機の協調制御により，車両前後加速度が変化し，V 字型の G-drop が発生する．

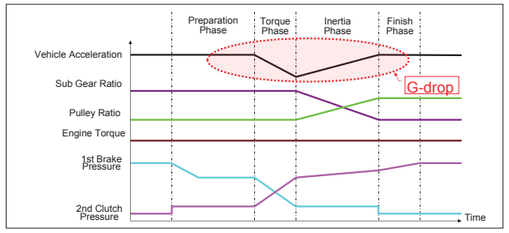


Fig. 1 Jatco CVT7 automatic 1st → 2nd upshift control

G-drop 段差は副変速機への入力トルクと副変速ギア比により決まるため，従来は副変速機への入力トルクが最も低くなるベルト&プーリー変速比最 High 付近において副変速機の架け替えを実施することにより，G-drop を低減してきた．本開発ではエンジンとの協調制御を組み合わせることにより，G-drop をさらに低減し，副変速のスムーズフィーリング向上に成功した．次項に，エンジンとの協調制御の詳細について紹介する．

3. エンジンとの協調制御

車両前後加速度の単位時間当たりの変化率（以下 傾き）を縦軸，G-drop の段差を横軸とした変速性能感度線を Fig. 2 に示す．有段変速機としての変速性能目標赤）に対し，CVT ではスムーズな変速を要求されている為，CVT としての変速性能目標（青）は，G-drop の傾き，段差共に低く目標は有段変速機よりも厳しくしている．

2. Issues of Auxiliary Transmission Shift

The shifting patterns of the auxiliary transmission can be broadly divided into three types. One is an automatic upshift, whereby the auxiliary transmission ratio shifts from 1st gear to 2nd gear during vehicle acceleration at a certain constant accelerator pedal press down rate. The other two types of shifts, mentioned next, occurs just after accelerator pedal operation. During accelerator pedal release, lift-foot-upshift from 1st gear to 2nd gear occurs in auxiliary transmission, and during accelerator pedal press down, kick-down-shift from 2nd gear to 1st gear occurs in auxiliary transmission.

Among these three patterns, this article describes in detail the control we developed for the automatic upshift. An automatic upshift occurs in situations where the clutches in the auxiliary transmission are automatically changed without the driver operating the accelerator pedal. Therefore, it was necessary to ensure smooth shift performance identical to that of the CVT.

Fig. 1 shows a time chart of an automatic upshift by the auxiliary transmission. It is seen that the change in vehicle longitudinal acceleration takes the form of a V-shaped G-drop. This is due to the engagement and disengagement of shift clutches during shift from 1st to 2nd gear in the torque phase and the collaborative control of belt & pulley shift control with auxiliary transmission shift control in the inertia phase.

The rate of change in the G-drop is determined by the torque input to the auxiliary transmission and the gear ratio difference between 1st to 2nd gear of the auxiliary transmission. Previously, the G-drop was reduced by changing the clutches of the auxiliary transmission near the highest belt & pulley ratio where the input torque to the auxiliary transmission is the lowest. The aim of this development work was to reduce the G-drop further in combination with collaborative control with the engine and thereby improve the smooth shift feel of the auxiliary transmission. In the following sections the collaborative control of the transmission and engine are described in detail.

3. Collaborative Control with the Engine

Fig. 2 compares the sensitivity of shift performance to the rate of change/time (hereafter slope) in vehicle longitudinal acceleration on the vertical axis and the rate of change in the G-drop on the horizontal axis. The shift

そこで CVT と同等のスムーズフィーリングを実現するため，G-drop の傾きを改善する制御として従来の有段変速機におけるエンジンとの協調に加え，ベルト&プーリー変速制御を統合したエンジントルクダウン協調制御を採用した．また，G-drop の段差を改善する制御としてエンジントルクアップ協調制御を採用した．

次項にて各協調制御の詳細を記述する．

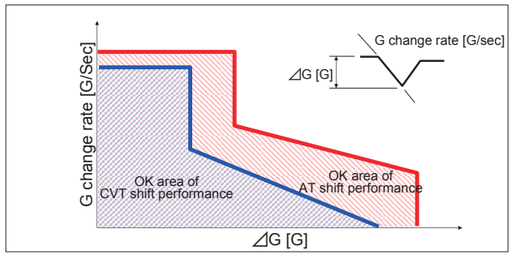


Fig. 2 Driving performance target

3.1. エンジントルクダウン協調制御

エンジントルクダウン協調制御では，副変速前半（準備フェーズ・トルクフェーズ），後半（イナーシャフェーズ，終了フェーズ）においてエンジントルクダウン協調することにより，G-drop の傾きを緩やかにした．Fig. 3 の破線がトルクダウン協調制御無し，実線が協調制御有りを示す．

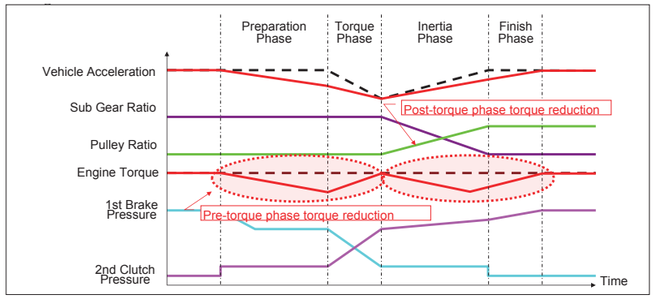


Fig. 3 Collaborative control for engine torque reduction

副変速前半では準備フェーズでトルクダウンを作動させることにより，従来トルクフェーズで発生していた G-drop の引き傾きを緩やかにすることができる．また副変速後半においても同様に，イナーシャフェーズでトルクダウンを作動させることにより，イナーシャフェーズでの G-drop の上昇傾きを緩やかにすることができる．

G-drop の傾きを緩やかにする別な手段として，副変速の変速時間を長くすることも検討したが，摩擦材滑り量

performance target of a CVT (blue line) is more severe than that of a stepped transmission (red line) because it is required to shift more smoothly than the latter. Both the G-drop slope and rate of change in the G-drop are set lower for a CVT.

In order to obtain the same smooth shift feel with the auxiliary transmission as that of the CVT, we adopted a collaborative control system for reducing engine torque for the purpose of improving the G-drop slope. This system combines the collaborative engine control of a conventional stepped transmission with a belt & pulley shift control. In addition, we adopted a collaborative control system for increasing engine torque as a measure for improving the rate of change in the G-drop. The details of each collaborative control feature are explained below.

3.1. Collaborative control by reducing engine torque

This collaborative control coordinates a reduction of engine torque in the first half (preparation phase & torque phase) and in the second half (inertia phase and finish phase) of an auxiliary transmission shift to moderate the G-drop slope. Figure 3 shows the effect of the collaborative control for reducing engine torque, where the dashed and solid lines are the results obtained without and with the system, respectively.

In the preparation phase of the first half of an auxiliary transmission shift, reducing the engine torque works to moderate the downward slope of the G-drop that occurred previously in the torque phase. Similarly, reducing the engine torque as well in the inertia phase of the second half of an auxiliary transmission shift moderates the rising slope of the G-drop in inertia phase.

As another method of moderating the G-drop slope, we also investigated the idea of lengthening the shift duration

増加による燃費悪化や，副変速中のアクセル操作等による運転性悪化につながりかねない為，得策ではないと判断した．エンジンとの協調制御を実施することにより，変速時間を変えることなく性能向上を実現した．

3.2. エンジントルクアップ協調制御

エンジントルクアップ協調制御では，トルクフェーズ，イナーシャフェーズで発生する G-drop に合わせてトルクアップを実施することにより，G-drop 段差低減を実現した．Fig. 4 に本制御有り（実線）と制御無し（破線）の比較を示す．

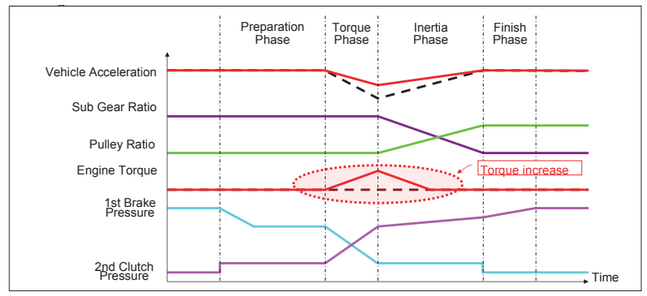


Fig. 4 Collaborative control for engine torque increase

トルクアップ量については，ドライバーが G-drop を感じない段差になるよう適合を実施した．トルクアップ量が大きすぎる場合，エンジントルクアップによる押し出され感などフィーリング悪化が懸念されるため種々の運転条件にあわせてトルクアップ量を最適化した．

3.3. トルクダウン協調制御とトルクアップ協調制御の選択

トルクダウン協調制御とトルクアップ協調制御のどちらを活用するかは運転シーンに応じて使い分けることとした．高開度領域ではトルクアップ量に限界があるためトルクダウン協調制御を作動し，低開度領域ではトルクアップ協調制御を作動することとした．

of the auxiliary transmission. However, we concluded that it was not a suitable approach owing to the deterioration of fuel economy due to the increased slipping of the friction materials and the fact that it might lead to a degradation of driveability if the driver operated the accelerator pedal while the auxiliary transmission is shifting, among other reasons. The adoption of collaborative control with the engine resulted in improved performance without changing the shift duration.

3.2. Collaborative control by increasing engine torque

This collaborative control requests an increase in engine torque concurrent with the G-drop that occurs in the torque phase and the inertia phase, thereby reducing the rate of change in the G-drop. Fig. 4 compares the results with (solid line) and without (dashed line) this collaborative control.

Engine torque is increased in certain amount that provides a suitable rate of change so that the driver does not perceive the G-drop. The amount of increase in engine torque was optimized under a variety of driving conditions because there was concern that too large engine-torque-up would produce surplus driving force which would lead to unnatural acceleration feeling as if somebody is pushing from behind.

3.3. Selection of torque down collaborative control or torque up collaborative control

The collaborative controls for reducing and increasing engine torque are used selectively according to the driving situation. The collaborative control for reducing engine torque is activated in the region of a large accelerator pedal press down rate because the amount the torque can be increased is limited. The collaborative control for increasing engine torque is activated in the region of a small accelerator pedal press down rate.

4. D-STEP 変速と副変速機制御の組み合わせ最適化

昨今では本特集に掲載された野々村らの記事のようなD-STEP 変速も多用されるようになってきた．副変速機付 CVT における D-STEP 変速の改善事例を以下に紹介する．

従来 D-STEP 変速では，ベルト&プーリーを所定変速比へアップシフトすることにより回転変化を発生させている．そのベルト&プーリー変速後に副変速機を 1 速から 2 速へ変速させた場合，D-STEP 変速による車両前後加速度変動と副変速機による G-drop が連続して発生してしまう．(Fig. 5)

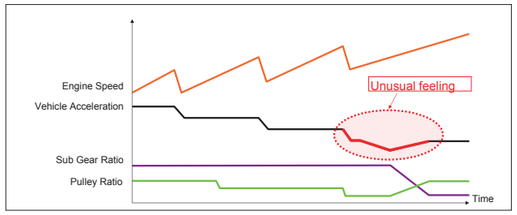


Fig. 5 Previous 1st → 2nd upshift control after D-STEP shift

この連続した車両前後加速度変動を防止し，フィーリングを向上する手法として，D-STEP 変速と副変速機の変速タイミング協調制御を開発した (Fig. 6)．副変速機の 1 速から 2 速へのアップシフトで発生するエンジン回転変化が D-STEP 変速で要求される変化よりも大きくなる場合には，ベルト&プーリーを協調して適量のダウンシフトさせることにより，狙いとする D-STEP 変速の回転変化に整合した回転変化を実現し，なおかつ連続した車両前後加速度変動の発生も防止することができた．連続して行われる D-STEP 変速のひとつは副変速機で行うという新発想の制御である．

Fig. 6 New collaborative control between D-STEP shift and 1st → 2nd upshift

4. Optimized Combination of D-STEP and Auxiliary Transmission Shift Control

In recent years there has been increasing use of shift controls like the Dynamic Step Shift (D-STEP) described by Nonomura and Oota in their article in this special feature. This section describes an example of an improvement made to D-STEP for the Jatco CVT7 incorporating an auxiliary transmission.

The previous D-STEP shift control caused the engine speed to change by upshifting belt & pulley ratio. After upshifting to that belt & pulley ratio, if the auxiliary transmission shifted from 1st to 2nd gear, the change in vehicle longitudinal acceleration induced by D-STEP and the G-drop due to the shifting of the auxiliary transmission occurred in succession (Fig. 5).

To prevent that consecutive change in vehicle longitudinal acceleration and improve the shift feel, we developed a collaborative control for the shift timing of D-STEP shift and the auxiliary transmission shift (Fig. 6). In cases where the change in the engine speed for causing the auxiliary transmission to upshift from 1st to 2nd gear is larger than the change required for a D-STEP shift, a suitable downshift is executed in collaboration with the belt and pulley system. As a result, that obtains an engine speed harmonized with the targeted engine speed for a D-STEP shift and it also works to prevent consecutive changes in vehicle longitudinal acceleration. This control is based on the new idea that one of the rhythmical D-STEP shifts can be executed by auxiliary transmission.

5. 終わりに

エンジントルク協調制御や，D-STEP 変速とのタイミング協調制御の実施により副変速機のスムーズフィーリング向上を実現し，クルマの性能改善に貢献することができた．

本制御の開発における日産自動車の関係部署及び社内関係部署の多大な協力に対し感謝を表します．

今も尚，お客さまの感性にマッチする車両開発に貢献するために，エンジンだけではなく車両システム全体と協調する開発を進めている．

今後も Jatco CVT の更なる進化を目指して全力で貢献していきたい．

5. Conclusion

The adoption of engine torque collaborative control and collaborative control for harmonizing the shift timing with D-STEP has improved the smooth shift feel of auxiliary transmission, which is contributing to improve vehicle performance.

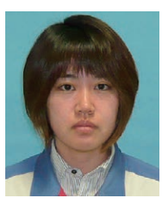
We would like to thank the related departments at Nissan Motor Co., Ltd. and those within JATCO for their tremendous cooperation for development of these new shift control.

Presently, we are making further development of collaborative control not only with the engine but also with all vehicle systems, so as to contribute to the development of vehicles matching to customers' driving intention.

We will continue to devote utmost efforts for further evolution of Jatco CVT.

■ Authors ■


Fumito SHINOHARA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アイドリングストップの進化に貢献した CVT 技術

CVT Technologies contributing to Start-stop System Evolution

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抄　録　軽自動車用 副変速機付き CVT である Jatco CVT7（以下 CVT7）では，レシオフレキシビリティ性を活かし，減速時の燃料カット域を低車速域まで広く取ることが出来ていた．更に減速時アイドリングストップ技術を組合せ，燃料カット領域の更なる拡大を図ることも進んでいる．

本稿では，これらの燃料カット領域拡大に大きく貢献した最新の減速時アイドリングストップシステムに対応した CVT のキー技術について紹介する．

Summary　Jatco CVT7 (hereafter CVT7) with an auxiliary transmission designed for minivehicles, effectively expand fuel cut-off region during deceleration to the low vehicle speed range utilizing its ratio flexibility. The fuel cut-off region has now been expanded further in combination with start-stop technology during deceleration. This article describes the key CVT technologies that have contributed greatly to further expanding the fuel cut-off region in conjunction with the latest start-stop system that is activated during vehicle deceleration.

1. はじめに

CO_2 排出量削減に対し大きな効果が認められているアイドリングストップ（以下 IS）の採用が近年軽自動車を中心に急速に増加している．最新の IS 技術としては，車両が完全停車する前からエンジンを停止させる減速時 IS の採用により燃料カット領域の更なる拡大が図られている．

CVT7 では，IS 専用部品を廃止することで，費用対効果の面で価値が高く，強い競争力を持った IS システムを開発した．IS 技術の進化とコストアップ抑制に貢献した CVT のキー技術について以下に紹介する．

2. 開発の狙い

2.1. 減速時アイドリングストップによる燃費向上

従来の燃費技術として，減速走行中はトルクコンバーター内のロックアップ（以下 LU）機構を直結させて，エンジンの燃料噴射を停止させる燃料カット技術があるが，CVT は，そのレシオフレキシビリティ性を活かしステップ AT と比べより低車速域まで燃料カットを実施している．

1. Introduction

The use of start-stop systems has increased rapidly in recent years especially on minivehicles owing to their recognized large effect on reducing CO_2 emissions. The latest version of this technology stops the engine even before the vehicle completely stop. The application of this newest system expands fuel cut-off duration during vehicle deceleration.

For the CVT7, we developed a start-stop system with high value in terms of cost performance by eliminating dedicated parts of the system, thereby giving it strong competitiveness. This article describes the key CVT technologies that contribute to the further evolution of start-stop technology and suppress the associated cost increase.

2. Scope of Development

2.1. Fuel economy improvement by actuating start-stop system during deceleration

Fuel cut-off technology that stops fuel injection into the engine by directly engaging the lock-up (hereafter LU) clutch in the torque converter during vehicle deceleration is a traditional technique for improving fuel economy. Because of their ratio flexibility, CVTs enable the fuel cut-off region to be expanded to even lower vehicle speeds than stepped automatic transmissions. In addition, the start-stop system cuts the fuel supply after the vehicle comes to a stop.

However, in the interval from the end of fuel cut-off by LU clutch engagement to the onset of fuel cut-off again by the start-stop system, fuel is consumed by engine idling while vehicle decelerates till stop. To reduce this fuel consumption due to idling, we set out to develop a start-stop system to be utilized during vehicle deceleration (Fig. 1).

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また，停車後は停車時 IS によって燃料カットを実施している．

しかし，LU による燃料カットが終了した後に再び停車時 IS で燃料カットに入るまでの間は，アイドリングにより燃料を消費しながら減速走行している．そこで，このアイドリング燃料消費を削減するために，減速時 IS の開発に着手した．（Fig. 1）

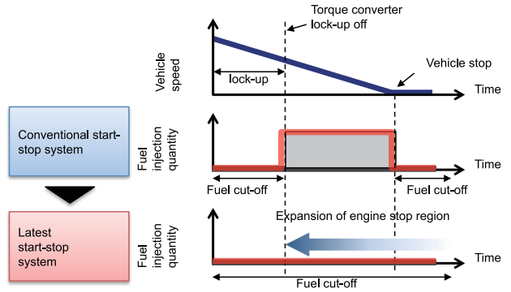


Fig. 1 Expansion of fuel-cut-off region

2.2. コストアップ抑制による競争力向上

停車／減速時 IS の主要課題として，エンジン再始動による再発進／再加速レスポンス性能の向上がある．具体的には，エンジンの始動早期化とトランスミッションの動力伝達応答性の確保が，パワートレイン系の主な課題となる．

CVT 7においては，電動オイルポンプを搭載してエンジン再始動時の動力伝達油圧を確保し課題の解決を図っていたが，その一方でコストアップにも繋がっていた．そこで，電動オイルポンプを廃止しコストアップ抑制を図りつつ，動力伝達応答性も満足させた競争力の高い CVT7 の技術開発を行ってきた．

3. アイドリングストップの進化に貢献した CVT 技術

減速時 IS システムを成立させるにあたり，CVT としては下記 2 つの要件を満足する必要があった．

（1）エンジン停止前プーリー比最 LOW の確保
（2）エンジン停止中の減速時ベルト滑り防止

CVT7 では，以下の対応によりこれらの必要要件を満たしシステムを成立させている．

2.2. Improvement of competitiveness by suppressing cost increase

The principal issue for stop-start technology while the vehicle is stationary or decelerating is to improve re-launching or re-acceleration response after the engine is restarted. Specifically, the main issues for the powertrain are to achieve quicker engine restart and to ensure the responsiveness of the transmission for transmitting driving force to vehicle.

An electric-driven oil pump was initially adopted for the CVT7 to resolve the issue of ensuring sufficient pressure for transmitting driving force at the time the engine is restarted. However, on the down side, it led to increased cost. Therefore, we developed technologies for the CVT7 to satisfy the required response for transmitting driving force, while suppressing the cost increase by eliminating the electric-driven oil pump, thereby achieving high competitiveness.

3. CVT Technologies contributing to Start-stop System Evolution

The CVT must satisfy the following two conditions to make the start-stop system during deceleration.

(1) To ensure that the pulley ratio is at the lowest value before the engine stops.
(2) To prevent belt slippage during deceleration while the engine is stopped.

Above two conditions have been achieved for CVT7 by adopting the following measures.

3.1. エンジン停止前プーリー比最 LOW の確保

減速時 IS を実行するには，駆動力確保の観点からプーリー比を LOW 位置へ戻しておく必要がある．LU 解除後も燃料カットを継続させるには，LU 解除するタイミングまでに LOW へ変速させなければならない．

Fig. 2 に示す通り，CVT7 の副変速機の 2 速ギヤで減速することにより，エンジンブレーキが作動した状態であっても不快な減速感もなく，LU 解除タイミングまでに最 LOW に変速することによって必要要件を満足させることができた．

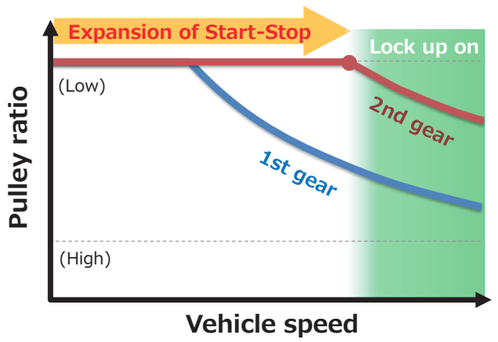


Fig. 2 Characteristics of coast down ratio

3.2. エンジン停止中の減速時ベルト滑り防止

減速時 IS 中はベルトクランプ力が低いため，ブレーキペダルを踏み増され急減速状態になると，ベルト滑りを引き起してしまう恐れがある．

Fig. 3 に示す通り，CVT7 ではプーリー軸より後端に取り付けられている副変速機内のクラッチを利用してベルトへの減速トルク入力をカットできるため必要用件を満足している．

例えば，電動オイルポンプ式の場合ではクラッチ締結トルク容量を最適化することにより，ヒューズの機能を持たせている．また，電動オイルポンプレス式の場合ではニュートラル状態となり減速トルク入力をカットしている．いずれの場合でもベルト滑りを防止することが可能となっている．

このように CVT7 では，その構造メリットを活かしてこれらの必要要件を満たしており，他社に先駆けて減速中のアイドリング燃料消費を全て削減した減速時 IS 技術へと進化を遂げることができた．

3.1. Assurance of lowest pulley ratio before engine stops

In order to execute a start-stop event during deceleration, the pulley ratio must be shifted to the lowest level from the standpoint for ensuring sufficient driving force. The transmission must shift to LOW before LU clutch disengagement in order to continue fuel cut-off even after LU clutch is disengaged.

As shown in Fig. 2, by decelerating the vehicle in the 2nd gear of the CVT7's auxiliary transmission, the necessary conditions can be satisfied by shifting to the lowest pulley ratio before the LU clutch is disengaged, without causing any uncomfortable deceleration feel even if engine braking torque is being applied.

3.2. Prevention of belt slippage during deceleration with the engine off

Belt clamping force is low during start-stop system operation while decelerating. Therefore, belt slippage may occur if the driver depresses the brake pedal deeper to decelerate the vehicle more rapidly.

As shown in Fig. 3, this requirement is satisfied by using the clutch in the auxiliary transmission installed at the rear of the pulley shaft to cut the input of deceleration torque to the belt.

For example, in the case of start-stop system with electric-driven oil pump, a fuse-like function is obtained by optimizing the clutch engagement torque capacity. On the other hand, in the case of start-stop system without electric-driven oil pump, a neutral state is created to cut the input of deceleration torque. In either case, it is possible to prevent belt slippage.

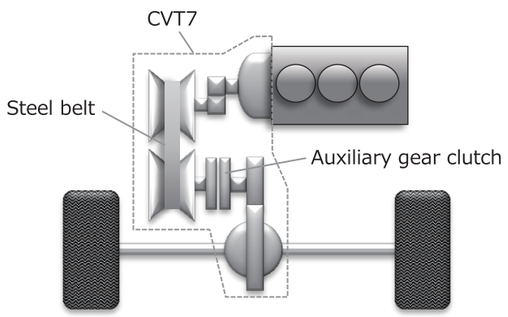


Fig. 3 Layout of CVT7

4. 電動オイルポンプレス CVT のシステム概要

CO_2 削減を図るためには，IS 車両を普及させていくことが極めて重要であるため，普及に適したシステムコストでお客様に提供する必要がある．

CVT7 では，プーリー油圧シールおよび潤滑関連部品のハード構造変更やクラッチ締結制御等を開発することにより，コスト／燃費／運転性を成立させている．

4.1. 電動オイルポンプ廃止によるシステム課題

電動オイルポンプを廃止した場合のシステム課題としては，下記 2 つの課題が挙げられる．

(1) ライン圧立ち上がり応答の維持

(2) クラッチ締結の維持

まず，ライン圧立ち上がり応答遅れが発生してしまうメカニズムについて解説する．

エンジン停止後はオイルポンプの供給が停止するため，CVT上部に設置されているプーリー油室に溜まっていたオイルが自重でオイルパンへ流れ落ちる現象（以下オイル落ち現象）が発生する．

これによりプーリー油室内が空洞化してしまうため，エンジン再始動時のオイルポンプ供給量のみでは空洞容積を埋め合わせることに時間が掛かってしまい，ライン圧の立ち上がり遅れが発生する．これが応答遅れの発生メカニズムであり，これを防止することが課題となる．(Fig. 4)

一方，クラッチ締結の維持の課題は，再始動時にライン圧が立ち上がってからクラッチ締結を開始させることによる応答性悪化によって発生する．

これらのシステム課題について，ハードウェア／ソフトウェアの両面での解決に取り組んだので，その内容について次項にて紹介する．

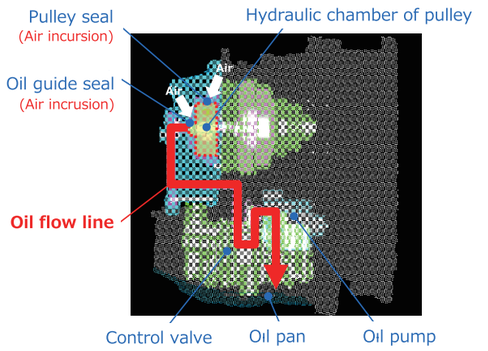


Fig. 4 Cross section of CVT7

These measures utilize the structural advantages of the CVT7 to satisfy the operating requirements. As a result, JATCO has successfully advanced start-stop technology ahead of other companies to create a system that completely eliminate fuel consumption due to engine idling during deceleration.

4. Overview of CVT System without Electric-driven Oil Pump

Vehicles fitted with start-stop technology are extremely important for reducing CO_2 emissions. Therefore, it is essential to provide customers with a system at a reasonable cost conducive to promote it in market.

For the CVT7 we modified the pulley pressure seals and the hardware structure of lubrication-related parts and also developed a clutch engagement control, among other improvements, to make this model viable in terms of cost, fuel economy and driveability.

4.1. System issues caused by elimination of electric-driven oil pump

The following two points can be cited as examples of issues that would occur in the system if the electric-driven oil pump were eliminated.

(1) Line pressure increase response assurance

(2) Clutch engagement assurance

First, we will explain the mechanism causing a delay in the line pressure increase response.

After the engine stops, the supply of oil by the oil pump would also stop. Consequently, the oil collected in the pulley hydraulic chamber provided on the upper section of CVT would drain down into the oil pan due to its own weight (hereafter oil draining). Since that would empty the pulley hydraulic chamber, it would take time for the oil supplied from oil pump, to fill the empty volume of the chamber after engine is restarted. That would delay the increase of line pressure. This is the mechanism causing the response delay, and preventing this delay is an issue that we had to address (Fig. 4).

On the other hand, the issue of assuring clutch engagement is one that occurs due to the degrading of response caused by the fact that clutch engagement begins after the line pressure rises following engine restart.

These system issues were resolved by addressing them in terms of both hardware and software aspects, the details of which are explained below.

4.2. ハードウェアによる課題解決

4.2.1. シール構造変更によるオイル落ち対策

オイル落ち現象は，プーリーシールとオイルガイドシールの合口部および外周から空気を吸い込んでいる現象(以下エア吸い）が根本原因であることを確認した．そこで，シール部からのエア吸いを徹底的に排除することに重点をおき課題解決を図ることとした．

まず，プーリーシールからのエア吸い防止については，耐エア吸い性を高めるためゴム製のDリングを採用することとした．Fig. 5 に示す通り，FEM（Finite Element Method）解析を用いて種々の仕様について加圧時に発生するゴムのはみ出し量と発生応力を算定し，最適仕様に絞り込んだ．

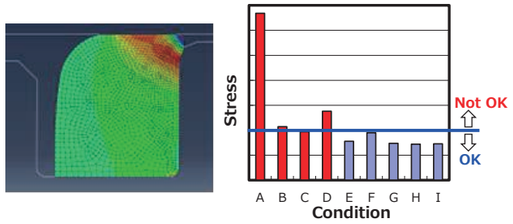


Fig. 5 Results of FEM analysis for D-ring seal

次に，オイルガイドシールからのエア吸い防止を進めた．このシールは，回転摺動部位のためゴム製の密閉シールの採用は難しい．したがって，シールの合口部や外周部からのエア吸いの防止が必要であった．（Fig. 6）

そこで粘度，表面張力，濡れ性等を把握し CFD（Computational Fluid Dynamics）を用いて混相流解析を実施し，可視化実験結果と比較を行いながら外周クリアランス幅の最適化設計を行った．（Fig. 7）

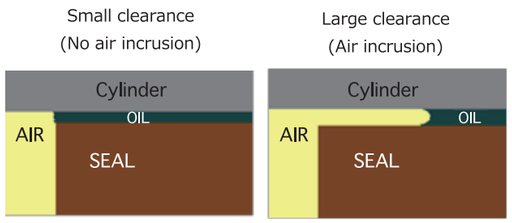


Fig. 7 Results of CFD analysis for oil guide seal

4.2. Resolution by hardware

4.2.1. Oil draining countermeasure by changing the seal structure

The fundamental cause of oil draining was confirmed to be the drawing in of air (i.e., air incursion) at and around the clearance of the oil seal and the oil guide seal. We decided to resolve this issue by putting emphasis on thoroughly eliminating this air incursion.

First, to prevent air incursion from the pulley seal, we adopted a rubber D-ring to improve resistance to air incursion. Fig. 5 shows the results of an analysis using the finite element method (FEM) to examine various specifications by calculating the resultant stress and the amount the rubber seal protruded when subjected to pressure. In this way, the optimal specifications were found.

We then proceeded with a measure to prevent air incursion from the oil guide seal. It is difficult to adopt a hermetic rubber seal at this location because the seal rotates under sliding contact. Therefore, it was necessary to prevent air incursion at the clearance of seal ends and clearance on outer side of seal (Fig. 6).

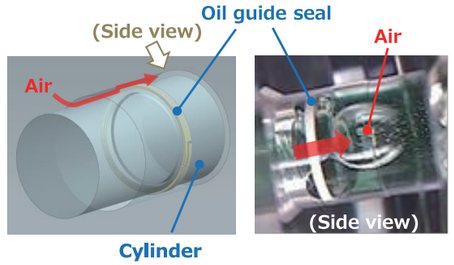


Fig. 6 Visualization experiment of air incursion

Computational fluid dynamics (CFD) was used to conduct a mixed-phase flow analysis in order to ascertain the viscosity, surface tension, wettability and other properties. The optimal width of the circumferential clearance was then designed by making a comparison with the results of a visualization experiment (Fig. 7).

4.2.2. Assurance of bearing lubrication performance

Previously, the clearance of the oil guide seal was intentionally designed to allow oil to leak in order to forcibly lubricate the pulley bearings. However, the narrowed clearance width of the oil guide seal described in the preceding section may raise issue of side effect of insufficient supply of oil for bearing lubrication.

4.2.2. ベアリング潤滑性能の維持

従来オイルガイドシールのクリアランス設計は，プーリーベアリングを強制潤滑するため意図的にオイルをリークさせるように設計していた．

しかし，前項で縮小したオイルガイドシールのクリアランス幅では，プーリーベアリングへの潤滑供給が不足してしまう副作用が課題となった．

そこで，プーリーベアリングに潤滑供給する方策として，別の油圧回路から安定的に潤滑供給できる強制潤滑油路を追加設置した．この強制潤滑油路は，ベルト潤滑油路から分岐させる回路とすることで，油圧回路を追加したサイドカバー以外の部品は，仕様変更することなく流用できる構造とした．（Fig. 8）

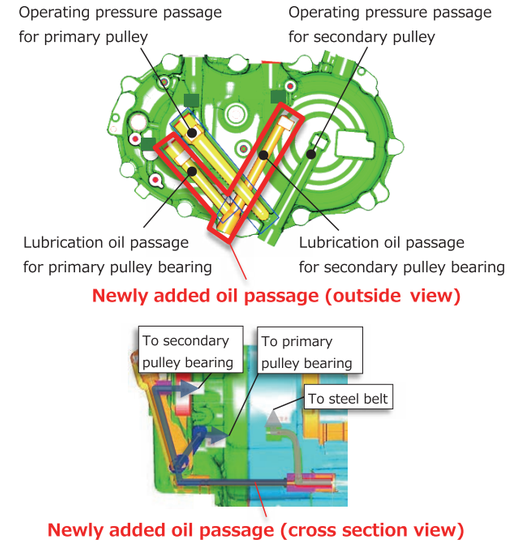


Fig. 8 New layout for lubrication oil passage

上記の通り，必要最小限の変更で電動オイルポンプレス CVT のシステムを構築することできた．

4.3. ソフトウェアによる課題解決

4.3.1. クラッチ締結時の運転性向上

減速時 IS 中は，エンジン停止にともないクラッチ入力軸回転も停止しているが，クラッチ出力軸回転は走行車速に応じた速度で回転状態となる．

この減速時 IS 状態からエンジン再始動する場合，クラッチ締結タイミングが課題となる．エンジン始動直後に

Therefore, as a measure for supplying lubrication oil to the pulley bearings, we added a forced lubrication oil passage for stably supplying lubrication oil from an independent hydraulic circuit. This forced lubrication oil passage was structured as a circuit that branches from the belt lubrication oil passage. Accordingly, except for the side cover to which the hydraulic circuit was added, all the other parts were used as they were without any specification changes (Fig. 8).

As explained here, only the minimum necessary changes were made in constructing the CVT system without an electric-driven oil pump.

4.3. Resolution by software

4.3.1. Improvement of driveability during clutch engagement

When the stop-start system is activated during vehicle deceleration, the clutch input shaft also stops rotating when the engine stops, but the clutch output shaft continues to rotate at a speed in proportion to the vehicle speed.

The clutch engagement timing becomes an issue when the engine is restarted during start-stop system operation while decelerating. If the clutch is engaged right after the engine is restarted, the large difference in rotational speed between the clutch input and output shafts would cause the driving force to fluctuate on the deceleration side (Fig. 9). Conversely, if the clutch input shaft is rotating too fast, it would cause the driving force to fluctuate on the drive side. Moreover, even if the clutch engagement timing is set so as to inhibit these fluctuations, there will be a long interval before the driving force for re-acceleration is generated owing to the clutch engagement lag. The issue in all of these cases is that the driver would receive an unpleasant impression.

Adaptive learning control was adopted for clutch engagement in order to satisfactorily resolve the trade-off between driving force fluctuation and the clutch engagement lag at the time of re-acceleration. Using information on vehicle deceleration and other conditions, adaptive learning control optimizes the condition for allowing start-stop system activation, optimizes the clutch capacity, and enables swift operation until the clutch completes its stroke. As a result of adopting this control, excellent performance is obtained at all vehicle speeds as shown in Fig. 10.

クラッチ締結してしまうとクラッチ入出力軸回転差が大きいため，減速側の駆動力変動が発生してしまう．(Fig. 9) 逆に，クラッチ入力軸回転が大きくなりすぎると駆動側の駆動力変動が発生してしまう．更に，これらの変動を抑えるタイミングでクラッチ締結させても，締結までのラグに起因して再加速時の駆動力発生までの時間が長くなってしまう．いずれの場合においても運転者に不快な印象を与えてしまう課題がある．

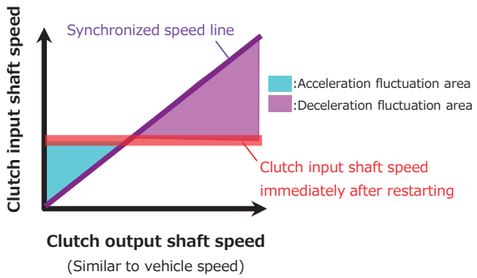


Fig. 9 Driving force fluctuation during clutch engagement

この駆動力変動や再加速時ラグのトレードオフを両立させるため，減速度などの情報をもとに IS 許可条件の最適化ならびにクラッチ容量の最適化，またクラッチストローク完了までを素早く作動できるようにクラッチ締結学習制御を採用した．これによって Fig. 10 に示すように全ての車速において良好な性能を実現できた．

4.3.2 エンジン始動時のベルト滑り防止

エンジン再始動後クラッチ締結中は，CVT 入力トルクとクラッチ伝達トルクに応じてベルト伝達トルクが決まる．その際，ベルトクランプ圧によって決まるベルトトルク容量とベルトに伝わるベルト伝達トルクの大小関係が課題となり，ベルト滑りを防止する必要がある．

しかし，エンジン再始動直後はベルトクランプ圧に必要な比較的高い油圧が得られるまでには時間を要するため，ベルトクランプ圧を安定的に制御することは難しい．

そこで，比較的低い油圧で作動するクラッチ圧を制御することにより，ベルトを通過するベルト伝達トルクを抑制することとした．具体的には，CVT に入力されるトルク信号および入力回転数，ライン圧センサー値，油温等の情報をもとに時々刻々のベルトトルク容量を算出し，クラッチ伝達トルク容量をクラッチ圧ソレノイドで制御することで，ベルト伝達トルクを抑制し，ベルト滑り防止を実現

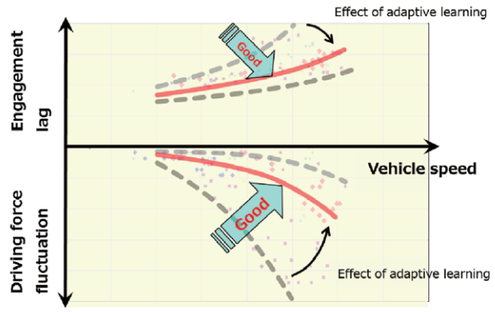


Fig. 10 Effect of adaptive learning control for clutch engagement

4.3.2. Prevention of belt slippage at engine restart

The torque transmitted by the belt during clutch engagement after engine restart is determined by the CVT input torque and the torque transmitted by the clutch. An issue that occurs at that time is the relationship between the available belt torque capacity, which is determined by the belt clamping pressure, and the magnitude of the torque to be transmitted by the belt. In this regard, it is necessary to prevent belt slippage.

However, some time is needed right after engine restart before the relatively high pressure necessary for producing the belt clamping pressure can be obtained. That makes it difficult to stably control the belt clamping pressure.

Therefore, we decided to hold down the torque level transmitted through the belt by controlling the clutch pressure, which can be accomplished with a relatively low line pressure. Specifically, the constantly varying belt torque capacity is calculated based on the torque signal and rotational speed of CVT input shaft, the line pressure sensor value, oil temperature and other information. The torque transmission capacity of the clutch is controlled using a clutch pressure solenoid, which makes it possible to prevent belt slippage by holding the torque level transmitted by the belt. This is based on the concept of controlling the clutch like a fuse as shown in Fig. 11.

5. Conclusion

The structural advantages of the CVT7 were utilized to the maximum extent in constructing the system described here. That made it possible to evolve start-stop technology further for activation during vehicle deceleration, which JATCO has accomplished ahead of other manufacturers. This system completely eliminates fuel consumption due

することができた．これは，クラッチをフューズにする考えであり，Fig. 11 にその概念を示す．

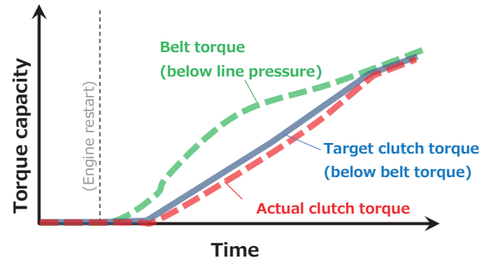


Fig. 11 Concept of fuse-like clutch control

5. 終わりに

CVT7 では，その構造メリットを最大限に活かしてシステム構築ができたため，他社に先駆けて減速中のアイドリング燃料消費を全て削減した減速時 IS 技術へと進化を遂げることができた．

また，可視化実験などから解き明かしたメカニズムをもとに，シミュレーション解析を活用してシール部品の改良設計ができた功績も大きく，これにより短期間で商品開発を終えることができ，お客様に提供することができた．

本稿を記載するにあたり，ご支援いただいた社内外関係部署の方々へ感謝の意を表します．

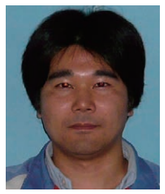
to engine idling during vehicle deceleration.

The mechanisms involved in this start-stop system were revealed through visualization experiments and other means. Based on that knowledge, a simulation analysis was used to improve the seal design. That achievement was also greatly effective in shortening the product development lead time, enabling us to supply the CVT7 to our customers more quickly.

Finally, the authors would like to thank everyone in related departments inside and outside the company for their support.

■ Authors ■


Masayoshi NAKASAKI


Yoshimasa NISHIHIRO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更なる CVT フリクション低減への挑戦

Challenge to Further Reduce CVT Friction

服部　靖司* Yasushi HATTORI　水落　知幸** Tomoyuki MIZUOCHI　吉田　武雄*** Takeo YOSHIDA　太田　雄介*** Yusuke OOTA　青田　和明* Kazuaki AOTA

抄　録　地球環境維持へ貢献する為，自動車業界では燃費向上につながる環境技術への取組みに注力している．

ジヤトコは早くから有力な環境技術であるベルト式 CVT に着目し，他社に先駆けてフルラインナップ化の取組みを行ってきた．今後も燃費向上を求めてジヤトコの CVT は更にフリクションを低減し進化していく．

Summary　The automotive industry is devoting concerted efforts to developing environmental technologies for improving vehicle fuel economy in order to contribute to the preservation of the global environment. JATCO early on focused attention on steel-belt CVTs as a leading environmental technology and developed a full CVT lineup ahead of other manufacturers. JATCO's CVTs will continue to evolve toward lower friction levels in the pursuit of higher fuel economy in the coming years.

1. はじめに

ジヤトコは燃費優位性を保つ為に，CVT の利点である変速比自由度の更なる向上に加え，効率向上（フリクション低減）が重要であると考え，開発を進めてきた．

これにより Fig. 1 に示すように，2012 年 2 月に生産を開始した Jatco CVT8 では，従来の CVT より大幅に効率向上し，他社トランスミッションに対し燃費で凌駕することが出来た．図中の矢印で示したように，効率向上に大きく寄与したのがフリクションの低減である．

本稿では，これまでのフリクション低減技術の紹介及び，更なるフリクション低減への着眼点と改善技術を紹介する．

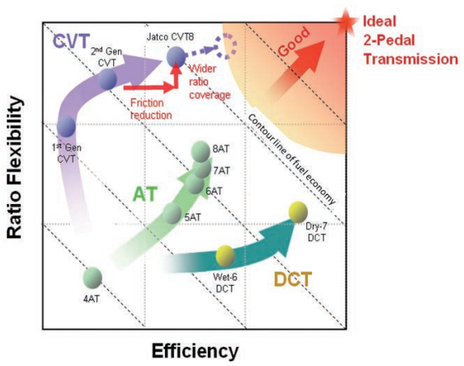

Fig. 1 Powertrain evolution map

1. Introduction

For the purpose of maintaining fuel economy superiority of CVTs, JATCO has emphasized the importance of enhancing efficiency, i.e., reducing friction, in addition to further improving ratio flexibility, which is a major advantage of CVTs. This development approach created the Jatco CVT8 (hereafter CVT8) that went into production in February 2012. As shown in Fig. 1, the CVT8 has notably higher efficiency than previous CVTs and surpasses the transmissions of other manufacturers in terms of fuel economy. As the arrow in the figure indicates, the reduction of friction contributed greatly to improve efficiency.

This article describes the technologies adopted till now to reduce friction and presents JATCO's focal points and improvement technologies for reducing friction further.

2. History of CVT Friction Reduction

At a CVT seminar held in Berlin in December 2013, Professor Ferit Kucukay[(1)] presented his research results that showed CVTs are well-suited to drive with optimal fuel economy by taking advantage of their excellent ratio flexibility. On the other hand, he evaluated power transmission efficiency at around 80% on average under the New European Driving Cycle (NEDC). However, for

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2. CVT フリクション低減の歴史

2013 年 12 月に Berlin で行われた CTI セミナーのクチュカイ教授の研究発表[1)]によると，CVT は高い変速比自由度を生かした燃費最適走行は得意であるが，その一方で伝達効率は約 80%前後（NEDC モード走行時平均）と評価されていた．

しかし Jatco CVT8 では，伝達効率低下要因を分析し（Fig. 2）各要因別にフリクションを低減することで 85%近くまで効率を向上させることができた[2)]．（Fig. 3）

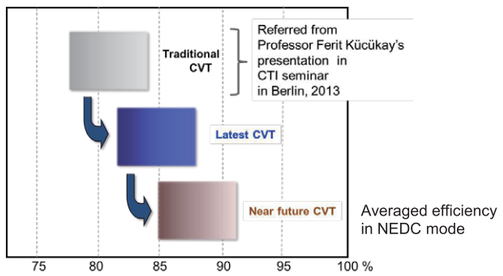

Fig. 3 Transmission efficiency trend

Jatco CVT8 では，主にハード部品の機械損失低減（オイルポンプ駆動トルク低減，変速機構伝達損失低減，オイル攪拌抵抗低減 etc）を行ってきた[3)]．

< 主なフリクション低減技術 >（Fig. 4）

●オイルポンプ駆動トルク低減
　オイルポンプサイズ最適化
　オイルリーク低減
　プーリー油圧の最適化によるライン油圧を低減
●変速機構伝達損失低減
　新型プッシュ式ベルトの開発
　新型チェーン式ベルトの開発
●オイル攪拌抵抗低減
　オイルレベル低減（プーリーレイアウト改善）
　バッフルプレートの形状改善
　低粘度油の開発

ジヤトコでは更なるフリクション低減に向けて挑戦を続けている．具体的にはフリクションに占める割合が大きいオイルポンプフリクション低減に取組んでおり，次にその改善アプローチを紹介する．

the CVT8, we thoroughly analyzed the various factors causing low transmission efficiency (Fig. 2). As a result of reducing the friction caused by each of these factors, we succeeded in raising the efficiency of the CVT8 to nearly 85%[(2)] (Fig. 3).

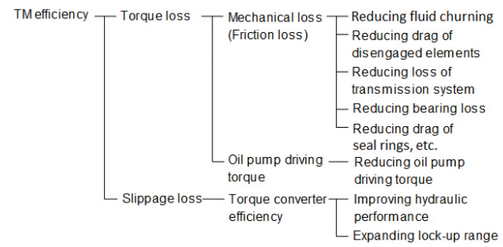

Fig. 2 Transmission efficiency factors

For the CVT8, we primarily reduced mechanical losses, including reducing the oil pump drive torque, transmission loss in the shift mechanism and fluid churning resistance, among other things.[(3)] The main technologies adopted for reducing friction are noted below and are shown in Fig. 4.

● Reduction of oil pump drive torque
　Optimizing the oil pump size
　Reducing fluid leakage
　Reducing the line pressure by optimizing the pulley pressure
● Reduction of transmission loss in shift mechanism
　Development of a new push-type belt
　Development of a new chain belt
● Reduction of fluid churning resistance
　Reduction of fluid level (by improving the pulley layout)
　Improvement of baffle plate shape
　Development of a low-viscosity fluid

Jatco continuously challenges to reduce friction levels further. Specifically, we are working on reducing oil pump friction that accounts for a large proportion of the overall friction. The following section describes our approaches to reduce friction levels.

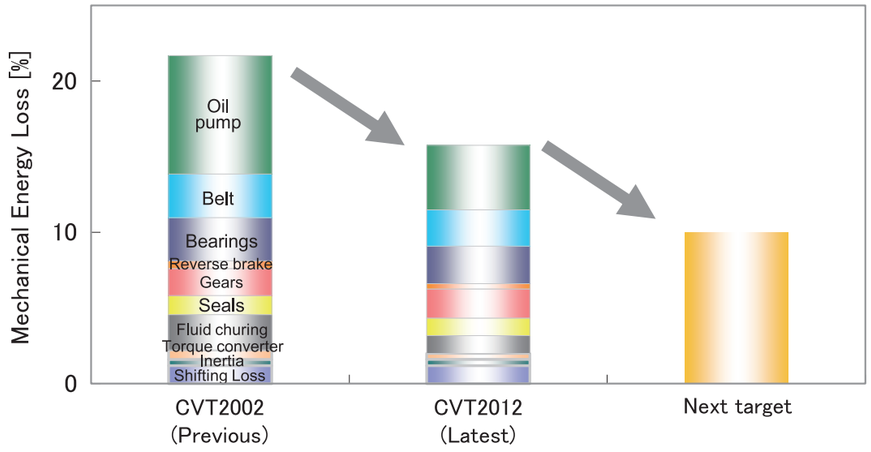

Fig. 4 Breakdown of CVT mechanical losses

3. 更なるフリクション低減への着眼点

3.1. オイルポンプ吐出流量と消費エネルギーの関係

オイルポンプ吐出流量の内訳は，Fig. 5 に示すようにクラッチ締結圧に必要な流量，プーリークランプ圧に必要な流量，冷却の為の潤滑流量，コントロールバルブからのドレーン，リーク，部品のバラツキ等によるその他の要因を加えた構成となっている.

Fig. 6 に示すように，吐出流量の増加に伴い駆動トルクが大きくなり，エネルギー消費が増大する為，吐出流量を低減することがエネルギー消費低減に有効である.

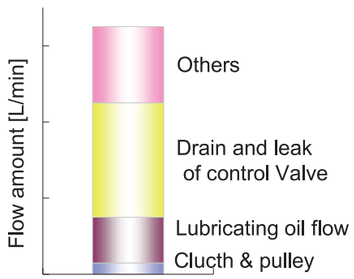

Fig. 5 Breakdown of oil pump discharge flow

3.2. オイルポンプ固有吐出量の設定手法

オイルポンプの吐出流量低減が消費エネルギー低減の鍵となるが，CVT の制御において重要なのはベルトをクランプしてトルク伝達を行いつつ，油を給排してプーリーをスライドさせながら変速制御を行うことである．その為 Fig. 7 に示すようにあらゆる車両運転シーンにおいてもベルトのトルク容量を確保する為に必要十分な油圧・流量を供給しなければならない.

よってその走行シーンの中で最も供給流量が厳しいシーンを満足できるようオイルポンプ固有吐出量を決めている.

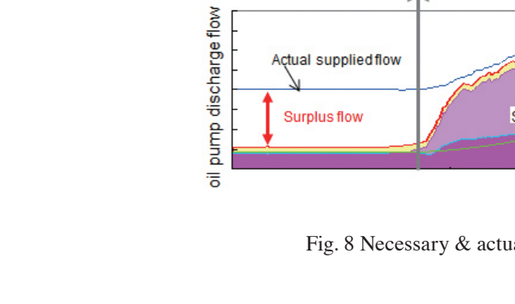

Fig. 7 Various kinds of CVT shifts

しかしながら最も吐出量が必要なシーンに合わせてオイルポンプ固有吐出量を設定すると，通常の走行のような比較的低負荷な走行条件下では，必要流量に対して供給流量が余剰となり必要以上のオイルポンプエネルギーを要してしまうこととなる.

Fig. 8 に踏み込みダウンシフト時に必要な流量と一定速走行時に必要な流量の差の一例を示す．図中に示したように一定速走行での必要流量を越える吐出量は余剰流量となる.

ここにオイルポンプエネルギー低減の可能性があると考えられる.

つまり要求に応じた必要最小限の油圧と流量を確保することで，運転性を損なうことなくオイルポンプに起因するエネルギー消費を低減することができる.

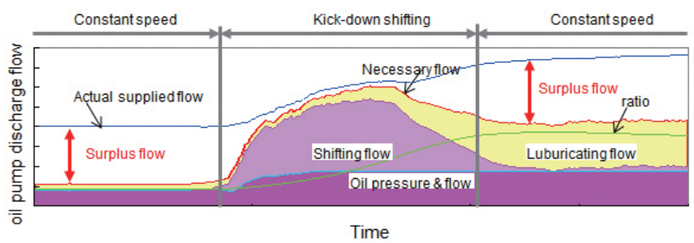

Fig. 8 Necessary & actual supplied oil pump output flow

3. Focal Points for Further Friction Reduction

3.1. Relationship between oil pump discharge rate and energy consumption

Fig. 5 shows a breakdown of the oil pump discharge rate. It consists of the flow needed to engage the clutches, the flow needed to produce the pulley clamping pressure, the flow of lubricating oil for cooling, the draining and leaking of fluid from the control valve, and various other factors due to parts variability.

As shown in Fig. 6, oil pump drive torque increases along with discharge rate, resulting in greater energy consumption. Accordingly, reduction of discharge rate is effective in lowering the amount of energy consumption.

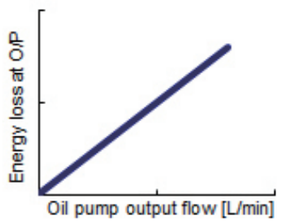

Fig. 6 Relation between discharge flow and energy loss of oil pump

3.2. Method of setting the oil pump's specific discharge rate

It was noted above that the key to reduce energy consumption is to lower the discharge rate of the oil pump. However, the crucial point of CVT control is to control shifting by supplying and draining the fluid for sliding the movable pulley, while transferring torque by clamping the belt. For that purpose, the necessary and sufficient pressure and flow rate must be supplied to ensure the torque capacity required of the belt in a variety of driving situations as shown in Fig. 7. To accomplish that, the specific discharge rate of the oil pump is determined so as to satisfy the most severe flow rate that must be supplied among these various driving situations.

However, setting the specific discharge rate of the oil pump to match the largest required flow rate results in a surplus flow rate above the necessary level under ordinary driving conditions while the load is relatively low. That means more energy is required then actual necessary energy for oil pump operation.

Fig. 8 shows one example of the difference in the required flow rate between a power-on downshift and steady-speed driving. As indicated in the figure, the flow rate exceeding the necessary level for steady-speed driving becomes surplus flow.

This suggests the potential for reducing energy consumption by the oil pump. In other words, by supplying just the minimum necessary pressure and flow rate needed to match what the driving situation demands, energy consumption by the oil pump can be reduced without affecting driveability.

3.3. オイルポンプ流量低減への着眼点

各走行シーンでオイルポンプに要求される最適な必要油圧と最適な流量を確保しつつオイルポンプにおけるエネルギー損失を低減する為の技術を以下に示す.

①ライン油圧最低設定値の低減の可能性

CVT の進化の歴史の中で，プーリークランプ圧の最適化等，必要油圧・流量の低減をしてきた．しかしながらオイルポンプの吐出圧であるライン油圧は一般的に最低油圧が設定されており，最低ライン油圧以下のプーリークランプ圧で十分容量確保できるシーンにおいても最低ライン油圧を吐出してしていた．そのため必要油圧・流量に対し余剰状態となっていた.

特に低車速での一定速走行のような比較的低負荷な走行シーンでは上述のような余剰なライン油圧を使用する頻度が多くなり，オイルポンプエネルギーを必要以上に消費しフリクション悪化要因となっていた.

Fig. 9 は典型的な走行シーンでの油圧の動きである. 図に示すように低い油圧が使えるにもかかわらず黄色の実線で示すようにオイルポンプ吐出圧を最低ライン油圧以下にならないようにしていた区間が発生していた.

この最低ライン油圧の改善が着眼点の一つである.

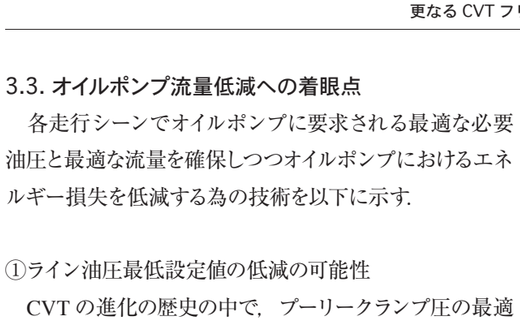

Fig. 9 Oil pump discharge pressure in NEDC mode

②必要流量の低減の可能性

低車速での一定速走行や比較的低負荷な走行シーンでは，必要なオイルポンプ吐出流量は少量となる．また急な変速が要求されるような過渡条件では必要な吐出流量が多量となる．Fig. 10 は種々の運転シーンにおいて必要なオイルポンプ吐出流量をまとめたものである．図のように必要吐出流量はシーン毎に変動する.

3.3. Focal point for reducing oil pump's flow rate

The following discussion describes techniques for reducing energy losses by the oil pump operation while maintaining the optimal necessary pressure and flow rate required by oil pump in each driving situation.

(1) Potential for reducing the minimum line pressure setting

In the history of CVT evolution, we have reduced the necessary pressure and flow rate by optimizing the pulley clamping pressure, among other measures. However, the line pressure, which is the discharge pressure of the oil pump, has generally been set at the minimum necessary level. The minimum line pressure has been discharged even in driving situations when sufficient torque capacity could be secured with pulley clamping pressure lower than the minimum line pressure. That has resulted in surplus pressure and flow rate, which is more that actually required. Surplus line pressure has often been used, especially in driving situations with a relatively low load such as in steady-speed driving at low vehicle speeds. That means the oil pump consumes more energy than what is really necessary, which is a factor that increases friction.

Fig. 9 shows the change in the oil pump discharge pressure in a typical driving situation under the NEDC mode. As shown in the figure, there is a duration, indicated by solid yellow line, when the oil pump discharge pressure is controlled so as not to drop below the minimum line pressure even though a lower pressure could be used. The minimum line pressure is thus another focal point for improvement.

(2) Potential for reducing the necessary flow rate

The required oil pump discharge rate is at a low level in driving situations with a low steady vehicle speed or a relatively low load. A large discharge rate is required under transient conditions such as when rapid shifting is demanded. Fig. 10 summarizes the required oil pump discharge rate in various driving situations. As seen in the figure, the necessary discharge rate varies in various driving situation. This suggests that it is possible to reduce friction further by configuring an on-demand system that varies the oil pump discharge rate to match these various driving situations. We are now proceeding with further developing work, taking that potential as the second focal point for improvement.

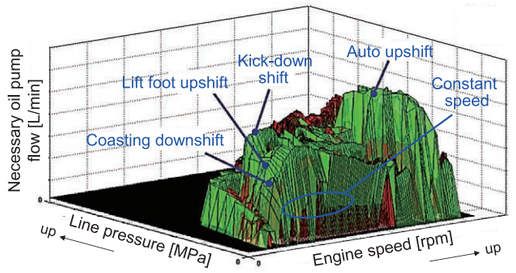

Fig. 10 3D map of necessary oil pump flow

これらの種々のシーンに応じて，オイルポンプ吐出流量を変化させるオンデマンドシステムを構築することで更なるフリクション低減を図ることが可能であり，それを第二の着眼点として更なる改善開発に取り組み中である.

4. 着眼点に基づいたフリクション低減技術の採用

①ライン油圧最低設定値の低減

従来は最低ライン油圧を更に低減すると最大最小油圧のレンジが広がることにより制御性確保の課題やクーラー・潤滑流量の減少による熱・潤滑性能への影響，クラッチ類のトルク容量不足が課題となっていた.

本課題に対し，一定圧特性の弁特性から可変特性を可能とした油圧制御用コントロールバルブに変更することで, 油圧レンジ拡大に適用できるようにした．そしてクラッチ容量や冷却潤滑流量を考慮したライン油圧指示設定とすることで，最低ライン油圧低減を実現し Jatco CVT 7 の最新型に採用することが出来た.

②潤滑流量オンデマンドコントロール

Jatco CVT8 HYBRID では電動オイルポンプを採用した．これによりクラッチ発熱量の高い走行シーンでは必要十分な潤滑油を供給し，発熱量の低い走行シーンでは少量の潤滑油を供給するような潤滑流量オンデマンドコントロールを実現できた[4].（Fig. 11）

4. Adoption of Friction Reduction Technologies based on Foregoing Focal Points

(1) Reduction of minimum line pressure setting

Previously, efforts to reduce the line pressure further resulted in expansion of the range of minimum and maximum pressures, which caused various issues. These included the assurance of controllability, the impact on thermal and lubrication performance due to the reduced flow rate for cooling and lubrication, and insufficient torque capacity of the clutches. To address these issues, we changed the hydraulic pressure control valve from one with fixed pressure characteristics to one with variable characteristics. This control valve can be applied to a wider pressure range. The line pressure command value was also set by taking into account the clutch torque capacity and the flow rate needed for cooling and lubrication. As a result, the minimum line pressure was reduced and the lower pressure level was applied to the Jatco CVT7, our latest model.

(2) On-demand control of lubricating oil flow rate

The Jatco CVT8 Hybrid adopts an electric-driven oil pump. This created an on-demand system for controlling the lubricating oil flow rate(4) as shown in Fig. 11. This system ensures supply of the necessary and sufficient lubricating oil flow in driving situations where the clutches generate large amount of heat. A lower lubricating oil flow rate is supplied in driving situations where less amount of heat is generated.

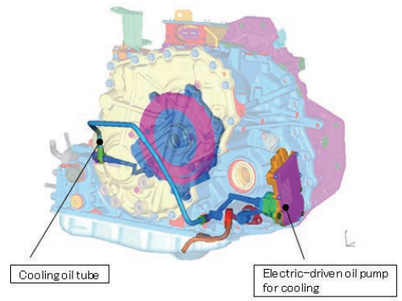

Fig. 11 On-demand control system for cooling

5. まとめ

ジヤトコではこれまで燃費向上の為，主にハード部品の機械損失低減を実施してきた.

そして更なる CO_2 削減の為，ユニットシステムとして損失低減の余地が残っている部分に着目し，フリクション低減検討を進めている.

特に着眼すべき点は，オイルポンプ消費エネルギー低減であり，最低ライン油圧の低減や電動オイルポンプによるオンデマンド流量システムを着実に採用できた.

現在も燃費向上を求めて更なる CVT フリクション低減への挑戦を継続中である.

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(2) Yoshikazu Oota and Masayoshi Nakasaki,“Key technologies which contributed to evolution of CVTs: 8th International CTI Symposium: Automotive Transmissions, HEV and EV Drives.

(3) Tomoyuki Mizuochi, Youhei Shimokawa, Keiichi Nakao, and Shintaro Ohshio,“Technical Introduction related to Fuel Economy of Newly Developed CVT Applied to Midsize and Large Vehicles,”2012 JSAE Annual Autumn Congress (in Japanese).

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5. Conclusion

With the aim of improving vehicle fuel economy, JATCO has so far primarily implemented measures to reduce the mechanical losses of hardware parts. To reduce CO_2 emissions further, we have been working on reduction of parts friction , focusing on components of the transmission system where, there is still room for reducing losses. One focal point in particular is to reduce the energy consumed by the oil pump. We have steadily taken steps toward that end such as by reducing the minimum line pressure and adopting an on-demand flow rate system using an electric-driven oil pump.

Our challenge to reduce CVT friction further for improving vehicle fuel economy is still being pursued today.

6. References

(1) Ferit Küçükay,“Automotive drive concepts,”12th International CTI Symposium and Exhibition: Innovative Automotive Transmissions and Hybrid & Electric Drives, Berlin, December 2nd, 2013.

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(3) Tomoyuki Mizuochi, Youhei Shimokawa, Keiichi Nakao, and Shintaro Ohshio,“Technical Introduction related to Fuel Economy of Newly Developed CVT Applied to Midsize and Large Vehicles,”2012 JSAE Annual Autumn Congress (in Japanese).

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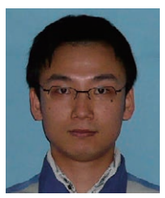
■ Authors ■


Yasushi HATTORI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Kazuaki AOTA

Memo

Jatco CVT8 の新型ベルト開発

Development of a New Steel Belt for the Jatco CVT8

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Masahiro KUSUDA　Kazuhiro HAYAKAWA　Kunihiko NISHIMURA　Makoto MOMOI

抄　録　Jatco CVT8（以下 CVT8 ）において，高効率，小型軽量化に貢献するために新型 28mm ベルトの開発を行った.

このベルトはジヤトコ株式会社が企画し，Bosch Transmission Technology B.V.（以下 Bosch 社）との共同開発により実現させたベルトであり，さまざまな新開発技術を織り込んでいる.

本稿では，日産自動車向けに初めて CVT が採用された 1997 年から約 20 年経過して，世界で初めて 28mm 化を実現した新ベルトについて紹介する.

Summary　A new 28-mm steel belt was developed for the Jatco CVT8 to obtain higher efficiency, smaller size and lighter weight. This new belt was planned by JATCO and developed jointly with Bosch Transmission Technology B.V.(hereafter Bosch) , and it incorporates a wide variety of newly developed technologies. This article describes about world first 28-mm width belt, which has been developed nearly 20 years after first adoption of CVT on Nissan vehicle in 1997.

1. はじめに

当社は 2012 年に CVT8 の生産を開始した.

この FF 車用 CVT は，以下の 1）～ 3）に示す開発コンセプトのもと，排気量 2.0L から 3.5L クラス車向けに，従来の 2 機種を 1 機種に統合して幅広い適用領域をカバーすると同時に，構成部品を徹底的に見直すことで大幅な低燃費を実現している.

1）ワイドレンジ化による低燃費と動力性能の両立
2）フリクション低減による低燃費化
3）小型化による 2.0 ～ 3.5L クラス FF 車用 CVT の共通化

本稿では上記 CVT8 に適用することを狙いに企画開発し，低燃費（高効率化），動力性能等の CVT 性能向上と，CVT の小型化に貢献することができた新型 28mm ベルトの技術について紹介する.

Fig. 1 にベルトの概要図を示す.

1. Introduction

The Jatco CVT8 (hereafter CVT8) went into production in 2012. This CVT for use on front-wheel-drive vehicles was developed around the three concepts noted below. Two previous CVT models were unified into one model for use on 2.0L to 3.5L class vehicles, thereby covering a wide range of vehicle application. Simultaneously, a thoroughgoing review was made of the component parts to improve fuel economy substantially.

(1) To obtain both high fuel economy and excellent power performance by expanding ratio coverage
(2) To improve fuel economy by reducing friction
(3) Common use of CVT for 2.0-3.5L class front-wheel-drive vehicles by downsizing

This paper describes the technologies incorporated in the new 28-mm steel belt that was planned and developed for application to the CVT8. This new belt has contributed significantly to improving the performance of the CVT8, including obtaining higher fuel economy (i.e., higher efficiency) and greater power performance, as well as helping to downsize CVT.

An outline of the new belt is shown in Fig. 1.

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** 実験部　Experiment Department

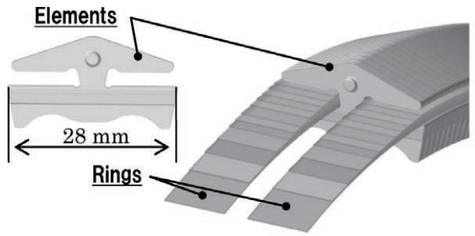

Fig. 1 New 28-mm belt

2. ベルト開発の狙い

今回 CVT8 に搭載されたベルトは，『10 年後でも競争力のあるベルトを提供する』をコンセプトに，従来のベルトに対して①から⑤の向上を目指した．それぞれの項目について『Goal Unlimited（制限のない，高い目標値）』を目指して新型ベルトの目標値を決定した.

①高効率化
②動力性能向上
③小型化
④信頼性の向上
⑤量産性向上

これらを実現する為に開発したアイテムを Table 1 に示す.

3. 新ベルトの特徴

特筆すべき特徴は，全長短縮に貢献すべく企画した 28mm 化であり，エレメント幅を短縮しながら，剛性の最適化をすることにより，容量とレシオカバレッジ（以下 R/C）の拡大を両立することが可能となった.

また，量産性向上と信頼性向上の両立については共同開発パートナーの Bosch 社から最新工法の提案を受けて企画に織り込んだ.

4. 技術開発内容の紹介

開発コンセプトである前項 5 項目の目標を達成するために取り組んだ技術開発の内容を紹介する.

4.1. 高効率化

効率向上の取り組みとしてはベルト内部フリクション低減と，パワートレイン全体としての効率向上のために最 High レシオを更に High 側に拡張したことである.

2. Development Aim for New Belt

The concept of the new belt adopted for the CVT8 was “to provide a belt that will still be competitive even ten years from now.” The aim was to improve the five attributes below in comparison with the previous belt. High performance targets were determined for the following attributes of the new steel belt in line with the concept of “Goal Unlimited” for each item.

(1) Higher efficiency
(2) Improved power performance
(3) Smaller size
(4) Improvement of reliability
(5) Improvement of productivity

New belt development items for attaining these targets are listed in Table 1.

Table 1 Measures developed for new belt

Target	Item
Efficiency improvement	Smaller belt running radius for extended high ratio
	Belt internal friction reduction
	Element thickness optimization
Driving performance	Element stiffness optimization
	Smaller belt running radius for extended low ratio
	Element thickness optimization
Downsizing	Smaller element width
Durability	New ring material
Productivity	New heat treatment process
	New deburring process

3. Features of New Belt

One notable feature is the 28-mm element width designed to contribute to reducing the overall length of the CVT. Optimizing the belt stiffness made it possible both to increase the torque capacity and to expand the ratio coverage (hereafter R/C) while shortening the element width.

From our development partner, Bosch, we received suggestions for the advanced manufacturing methods that were incorporated into the planning for improving both productivity and reliability.

4. Details of Newly Developed Technologies

This section explains the technologies that were developed to attain the targets of the five items of the

4.1.1. ベルト内部フリクションの低減

ベルトの内部フリクションの低減のためにリングのフリクション低減を行った．具体的には，エレメント形状最適化によるリングとの相対運動の低減と，リング幅縮小によるリング同士の接触面積の低減である．

Fig. 2 に新旧のベルト効率の比較を示す．

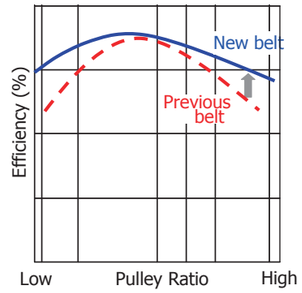

Fig. 2 Efficiency comparison between previous belt and new belt

4.1.2. 最 High レシオの拡張

パワートレイン全体の効率向上の為には，高速走行中のエンジンの回転数を下げることが有効である．具体的にはベルトの最小巻き付き半径を小径化することで，最 High レシオを更に High 側に拡張し，エンジン回転数を下げることとした．しかし，最小巻き付き半径を過剰に小径化すると，エレメント同士がエレメントの内周側で干渉し動力を伝達できない状態となる．そのため Fig. 3 に示すようにエレメント形状を最適化し，クリアランスを保つことができるようにした．これにより最 High レシオを 0.393 から 0.378 への拡張が実現できた．

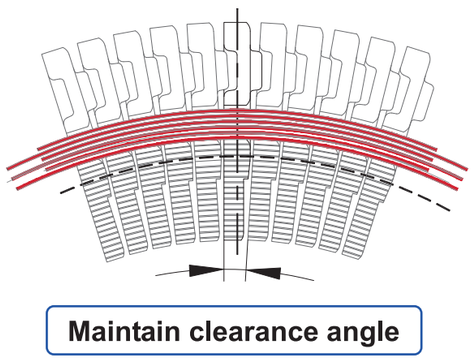

Fig. 3 Element shape optimization

development concept mentioned in the preceding section.

4.1. Higher efficiency

One effort made to improve efficiency was to reduce the internal friction of the belt. Another effort was to extend the highest ratio further to High side for improving the overall efficiency of the powertrain.

4.1.1. Reduction of internal belt friction

Friction between rings was reduced so as to lower the internal friction of the belt. Specifically, the relative movement between the elements and the rings was reduced by optimizing the element geometry. In addition, the contact area between the rings was reduced by shortening the ring width.

Fig. 2 compares the efficiency obtained with the previous belt and the new belt.

4.1.2. Extension of highest ratio

Lowering the engine speed during high-speed driving is effective in improving the overall efficiency of the powertrain. Specifically, the smallest running radius of the belt was narrowed to extend the highest ratio further to High side, contributing in reduction of engine speed. However, reducing the smallest running radius of the belt excessively would create a state where interference would occur between the elements on their inner periphery, making it impossible to transmit driving force. To avoid this situation, the element geometry was optimized so as to maintain sufficient clearance as shown in Fig. 3. As a result, the highest ratio was extended from 0.393 to 0.378.

4.2. Improvement of power performance

The efforts were made to improve power performance to extend the lowest ratio and to increase the rotational speed in order to enhance start-off acceleration performance.

4.2.1. Extension of the lowest ratio

Extending the lowest ratio further to Low side so as to increase the driving force is effective in enhancing the start-off acceleration performance of the vehicle. Specifically, the lowest ratio was extended from 2.394 to 2.631, thereby improving power performance.

4.2.2. Higher rotational speed

Optimizing the element geometry made it possible to secure sufficient stiffness against the centrifugal force that

4.2. 動力性能向上

動力性能向上の取り組みとしては発進加速性能を高める為に最 Low レシオの拡張と高回転化に取り組んだ．

4.2.1. 最 Low レシオの拡張

車両として発進加速性能を高める為には最 Low レシオをさらに Low 側に広げ駆動力を高めることが有効である．具体的には最 Low レシオを 2.394 から 2.631 へ拡張し動力性能向上を実現できた．

4.2.2. 高回転化

エレメントの形状を最適化して高回転時の遠心力に対する剛性を確保することが可能となった．従来の Pri プーリー回転 6250rpm に対し，新型ベルトでは 7000rpm まで使用領域の拡大を実現した．使用領域拡大の概要を Fig. 4 に示す．

4.3. 小型化

R/Cを拡大しようとすると既存のユニットレイアウトに対してレイアウトが大きくなってしまい，商品性が損なわれてしまう懸念がある．既存レイアウト内で成立させる為には R/C 拡大によって増加したプーリーのストローク量を吸収する必要があり，ストローク量の増加を吸収する為にエレメント幅を Fig. 5 で示すように 28mm に短縮することを実施した．

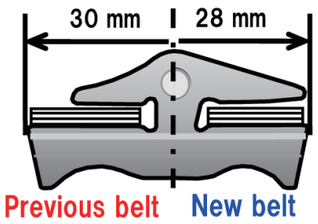

Fig. 5 Element design difference between previous belt and new belt

4.4. 信頼性向上

28mm 化に伴いリング幅が縮小され，リングの応力増加による寿命の低下が課題となったが，新リング材料の採用により従来以上の信頼性の確保が可能となった．その結果，既存のレイアウトと同一の全長で R/C の拡大が可能となった．小型化と信頼性向上を実現した新リング材の材料成分を Table 2 に示す．

occurs at high rotational speeds. The new belt expands the usable range of the primary pulley to a rotational speed of 7,000 rpm, whereas that of the previous belt was 6,250 rpm. An outline of the expansion of the usable range is shown in Fig 4.

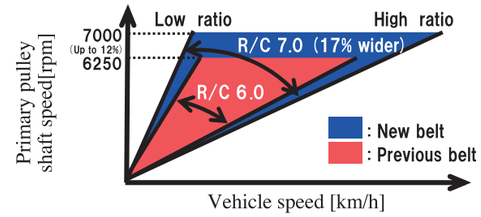

Fig. 4 Improvement of belt usage range

4.3. Downsizing

Trying to expand the ratio coverage would enlarge the unit layout compared with the existing model. There was concern that might compromise the marketability of the product. It was necessary to absorb the increased pulley travel due to the expanded ratio coverage in order to make the CVT viable within the existing layout. To absorb the increased pulley travel, the element width was shortened to 28 mm as shown in Fig. 5.

4.4. Improvement of reliability

Reducing the element width to 28 mm also narrowed the ring width. This might have caused issue that increased stress in the rings might has shorten the belt's operating life. The adoption of a new ring material secured better reliability than before. That made it possible to expand the ratio coverage within the existing layout and with the same overall length. The chemical composition of the new ring material that contributed to downsizing and improved reliability is shown in Table 2.

Table 2 Chemical composition (mass %)

	Ni	Co	Mo	Ti
Previous	18.0	9.0	5.0	0.5
New	18.0	16.5	5.0	-

従来材は Ti 成分を配合していた為，チタンナイトライド（以下 TiN）が生成され疲労の起点となる介在物となっていた．新材料では Co の配合比率を増量することで Ti の配合を不要とし TiN の生成を抑制した．その結果 Fig. 6 に示すように約 4 倍の寿命向上を実現できた．

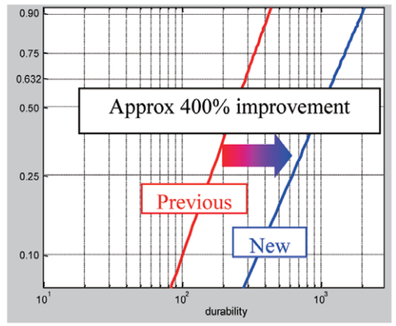

Fig. 6 Ring durability comparison between previous belt and new belt

4.5. 量産性向上

新型 28mm ベルトでは量産性向上を目的にパートナーの Bosch 社から提案を受けた 2 つの新工法開発に取り組んだ．

①リングを複数積層した状態で熱処理を行う（従来は 1 枚ごとに熱処理を実施していた）

②リングの端面をレーザーで溶解してバリをなくす（従来はバレル研磨にてバリ取りを実施していた）

Fig. 7 に新工法の概略を示す．

新工法に伴う技術課題を列挙し，ばらつきの見極めや工程管理のためのパラメータ設計開発を Bosch 社と共同で実施し，進捗を図った．

The previous ring material was mixed with titanium (hereafter Ti), which produced titanium nitride (hereafter TiN) and its inclusion acted as a source of fatigue. The new ring material has a higher mixture ratio of cobalt (Co) that makes it unnecessary to mix Ti, thereby eliminating the generation of TiN. As a result, the lifetime of the new rings has been improved by approximately four-fold as shown in Fig. 6.

4.5. Improvement of productivity

For the purpose of improving the productivity of the new 28-mm belt, two advanced manufacturing methods were developed according to suggestions received from Bosch, our development partner.

(1) To conduct heat treatment on an assembled stack of multiple rings. Previously, each ring was heat-treated individually.

(2) To eliminate burrs by melting the ring ends with a laser. Previously, burrs were removed in a barrel polishing process using tumbling stones.

Fig. 7 shows an outline of the new ring manufacturing process. A list was drawn up of the technical issues involved in the new manufacturing process and progress was made in addressing them. Process and parts variation was thoroughly ascertained, and parameters for process control were designed and developed together with Bosch.

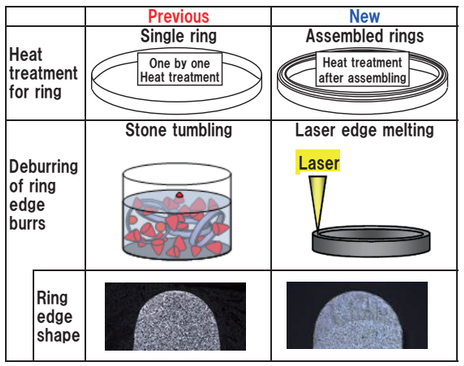

Fig. 7 New ring manufacturing process

5. まとめ

CVT8 に対して，当社としては初の企画から開発まで行った新型ベルトを採用した．この新型ベルトは『10 年後でも競争力のあるベルトを提供する』をコンセプトに『Goal Unlimited（制限のない，高い目標値）』を目指して開発し，低燃費（高効率化），動力性能向上，小型化に大きく貢献できた．

さらに信頼性向上，量産性向上の高い目標にも取り組み，数多くの課題があったが，エレメント形状最適化や新リング材料，新工法を開発することで高い目標を達成することができた．

本開発に際して多大なる協力を頂いた Bosch 社および，関係者の皆様に深く感謝の意を表します．

6. 参考文献

Francis van der Sluis, Erik van der Noll, Hendrik de Leeuw: The Success of the Pushbelt CVT-Status and new Developments-, JSAE Annual Congress on May 24 2012

5. Conclusion

The new steel belt adopted for CVT8 was the first one for which JATCO was involved from the initial planning stage through final development. This belt was developed around the concept of “providing a belt that will still be competitive even ten years from now” and the aim was to attain high performance targets in line with the concept of “Goal Unlimited.” This new belt has contributed significantly to higher fuel economy (i.e., higher efficiency), improved power performance and downsizing.

In addition, vigorous efforts were made to attain high targets set for improvement of reliability and productivity. While there were many issues to be tackled, the high performance targets were attained by optimizing the element geometry, adopting a new ring material and developing a advanced ring manufacturing process.

Finally, the authors would like to thank Bosch Transmission B.V. and everyone concerned for their tremendous cooperation with the development of this new steel belt.

6. References

Francis van der Sluis, Erik van der Noll, and Hendrik de Leeuw, “The Success of the Pushbelt CVT: Status and new Developments,” JSAE Annual Congress, May 24, 2012.

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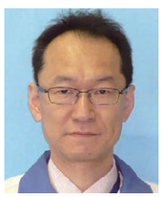

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ハイブリッド車用 CVT 湿式発進クラッチの冷却性能向上システム開発

Development of a Lubrication System for Improving the Cooling Performance of a Wet Start-off Clutch for a Hybrid Vehicle CVT

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高橋　功*　Kou TAKAHASHI
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抄　録　ハイブリッド車用 CVT の発進用クラッチ 2（以下 CL2）の開発については，昨年発行の JATCO Technical Review No.13「FF ハイブリッド車用の発進要素の開発」において，電動オイルポンプによる冷却制御，発進制御，及び温度予測技術について紹介した．

しかしながら，CL2 に対する市場からのニーズは一段と高まっており，更なる進化として，より発熱量が大きい発進制御を実現することが必要となってきた．

本稿では，そのニーズに応える為に開発した冷却性能向上システムについて紹介する．

Summary　Cooling control by means of an electric oil pump, a new start-off control and a temperature prediction technique were incorporated into the development of the start-off clutch, denoted as clutch-2 (hereafter CL2), of a CVT for use on hybrid vehicles. Those technologies were described in last year's JATCO Technical Review No. 13 in an article entitled “Development of the Start-off Element for FWD Hybrid Vehicles.”

However, market requirements for the CL2 have continued to become more rigorous, thus further evolution of the clutch is required and to develop a new control for vehicle launch when the clutch generates large amount of heat has become necessary.

This article describes a new lubrication system that has been developed to improve CL2 cooling performance in order to meet the higher market requirements.

1. はじめに

ハイブリッド車用 CVT の発進用クラッチとして使われる CL2 は，発進時のスリップ量をコントロールして使う為，温度上昇を抑制することが極めて重要であり，本稿では，CL2 の冷却性能を向上した内容を実例も含めて紹介する．

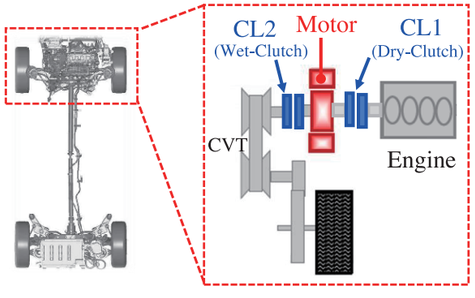

Fig. 1 Hybrid system architecture

1. Introduction

The CL2 start-off clutch of the CVT for hybrid vehicles is controlled to slip with required amount of slippage during vehicle launch, making it extremely important to suppress the rise of clutch temperature. This article describes the improvements made to the cooling performance of CL2 and also presents specific examples of the results.

2. Issue of Improving the Cooling Performance of CL2 System

The CL2 start-off clutch must absorb the rotational speed difference between the engine speed and the drive wheel speed during vehicle launch. The torque level transmitted by the clutch increases in driving situations when large driving force is required such as when driving up a steep

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2. CL2 システムの冷却性能向上課題

CL2 は発進時にエンジン回転と車輪速との差回転を吸収しなければならない．特に，要求駆動力が高い高勾配路の走行や，トレーラー牽引走行等では，伝達トルクも高くなり CL2 の温度が上昇する．CL2 の温度が許容範囲を超えてしまうと，湿式摩擦材の特性低下による車体振動の発生や，CL2 保護制御に入り走行性能が低下する可能性が増える．また，車両重量が重い SUV への搭載の為にも，CL2 の冷却性能向上が重要な課題であった．

3. CL2 冷却性能向上の考え方

CL2 の冷却性能は，発生した熱をいかに効率良く冷却油に伝達するかで決まる . 理想的には，油浴のような液相状態で冷却油を循環させた方が，エアーを含んだ冷却油を循環させる場合よりも冷却効率が良いことが分かっている．（Fig. 2）

しかし，CL2 は既存の CVT の前後進クラッチをベースにしており，軸心からの流量供給で冷却するシステムとなる為，周囲の空気を取りこんだ気液混合状態の環境が発生しやすい．そこで，CL2 の潤滑環境を理想的な液相状態に近づける為，冷却油の流し方を改良することに取り組んだ．

4. 冷却油の流し方の改良

Fig. 3 に示すように，軸中心から供給された冷却油は，遠心力によってハブの油穴→湿式摩擦材の油溝→ドラムの油穴の順に通過する．その為，油溝と油穴形状により，冷却油の流れを最適にすることで湿式摩擦材の接触面をより油浴状態に近づけることが可能と考えた．これを実現する為に，流体解析により改善案を作成し，その案を試作して効果を検証する為の測温試験を実施した．次節以降にその詳細を示す．なお，本稿では読者の理解を得やすくする為に，冷却能力が高い事例と低い事例の 2 例について紹介する．

slope or pulling a trailer, and the CL2 temperature also rises. If the CL2 temperature exceeds the allowable range, there is a greater likelihood that the resultant decline in the properties of the wet friction materials might cause vehicle body vibrations or that activation of the CL2 protection control function might affect driving performance. In addition, improving the cooling performance of CL2 was also a crucial issue for applying the hybrid CVT to SUVs that have a heavier gross vehicle weight.

3. Concept for Improving CL2 Cooling Performance

The cooling performance of CL2 is determined by how efficiently the generated heat can be transferred to the cooling oil. Ideally, it is well known that circulating cooling oil in a liquid phase like an oil bath would provide better cooling efficiency than if the circulated cooling oil contained air (Fig. 2).

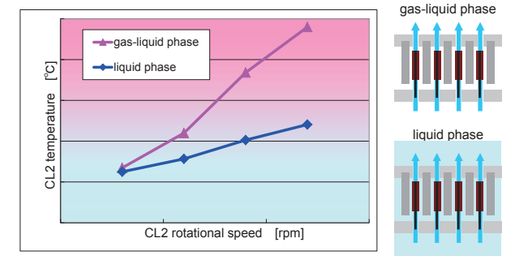

Fig. 2 Temperature of clutch plates in clutch bench tests (gas-liquid phase and liquid phase)

However, CL2 is based on the forward-reverse changeover clutch of the existing base CVT and is cooled by the cooling oil flowing through the shaft center. This arrangement can easily produce a mixed gas-liquid phase in which air is taken in from outside. Therefore, efforts were exerted to improve the cooling oil flow in order to make the CL2 lubrication environment resemble an ideal liquid phase.

4. Improvement of the Cooling Oil Flow

As illustrated in Fig. 3, the cooling oil supplied through the shaft center flows under centrifugal force from the hub oil holes to the oil grooves in the wet friction material to the drum oil holes, in that order. Therefore, it was conceived that the contact surface of the wet friction materials could be brought similar to an oil bath

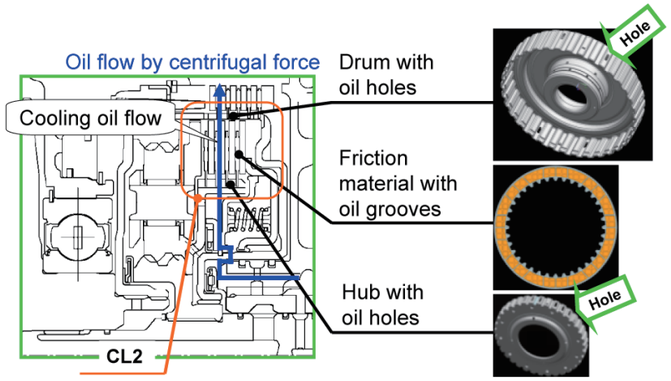

Fig. 3 Cooling oil flow for CL2

5. 冷却油流の流れ解析

5.1. 解析モデル

まず，湿式摩擦材の接触面付近の冷却油の流れを比較する為に，冷却油に作用する遠心力を考慮した動的な流れ解析を用いて，以下の 2 つの仕様について摩擦面を通過する油と空気の割合を比較した．(Fig. 4)

Spec ①:油穴面積と油溝幅を広くし流路面積を大きく取った，冷却油の排出性が高い仕様

Spec ②:油穴面積と油溝幅を狭くし流路面積を小さく取った，冷却油の排出性が低い仕様

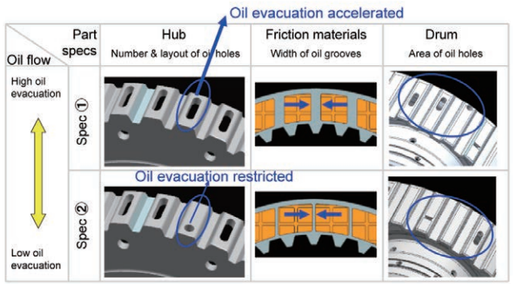

Fig. 4 Comparison of specifications

5.2. 流れ解析結果 (CL2 断面)

CL2 断面から見た冷却油の流れの比較を Fig. 5 に示す．

青色が冷却油 100%，赤色が空気 100%で気液比率を示している．Spec ①は，摩擦面付近は赤色に近く空気の割合が多い．逆に，Spec ②は，冷却油で満たされていて理想とする油浴状態に近づけることができている．

state by optimizing the cooling oil flow by means of the geometry of the oil grooves and oil holes. To accomplish that, a flow improvement plan was devised based on flow simulation results and prototypes were built. Tests were then conducted to measure the CL2 temperature in order to validate the improvement effect. The details of the simulations are presented in the following section. To give the readers a better understanding, two examples are explained, one each for high and low cooling performance.

5. Simulation of Cooling Oil Flow

5.1. Simulation model

First, dynamic flow simulations taking into account the centrifugal force that acts on the cooling oil were conducted to compare the cooling oil flow around contact surface of the wet friction materials. A comparison was made of the fractions of air and cooling oil flowing along the friction material surface for the following two specifications (Fig. 4).

Spec (1): The oil hole area and oil groove width were enlarged to increase the flow passage area, thereby creating a specification that accelerated cooling oil evacuation

Spec (2): The oil hole area and oil groove width were narrowed to reduce the flow passage area, thereby creating a specification that restricted cooling oil evacuation

5.2. Flow simulation results for CL2 cross section

Figure 5 presents a comparison of the cooling oil flow for the two specifications as seen in a cross section of CL2. The fractions of air and oil are shown by the color codes where blue indicates 100% cooling oil and red indicates 100% air. With Spec (1), the area near the friction material

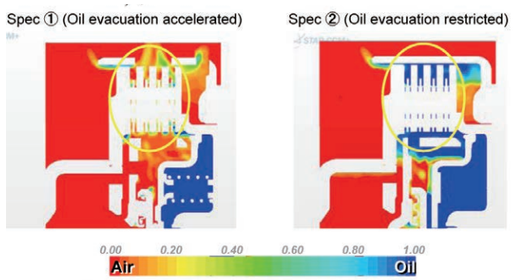

Fig. 5 Comparison of flow simulation results (Cross section of CL2)

5.3. 流れ解析結果 (摩擦面正面)

次に，摩擦面正面から見た冷却油の流れの比較を Fig. 6 に示す．

Spec ①は，摩擦材表面の油溝が赤色に近く，冷却油が充分行き渡っていない．逆に，Spec ②は，摩擦材表面の油溝に冷却油が行き渡っている．

5.4. 流れ解析結果(冷却油の流速と空気混合率の比較)

同じ解析結果から，各摩擦面の油溝を通過する冷却油の流速と空気混合率を定量的に比較した．冷却油の流速比較を Fig. 7 に，空気混合率の比較を Fig. 8 に示す．

Spec ①は，摩擦面の油溝を通過する冷却油の流速が高い．また，空気混合率が大きく空気を多く取り込んでいる．更に，摩擦面の油溝を通過する冷却油の流速と空気混合率におけるプレート間のバラツキが大きい．Spec ②は，Spec ①より冷却油の流速が低い．また，空気混合率が小さく油浴に近い状態である．更に，冷却油の流速と空気混合率におけるプレート間のバラツキが Spec ①に比べ抑制されている．

surface is alomost red in color, indicating a large fraction of air. Conversely, with Spec (2), the friction material surface is covered with cooling oil, creating nearly an ideal oil bath state.

5.3. Oil Flow simulation results around friction material surface

Fig. 6 compares the cooling oil flow for the two specifications as seen from the front side of friction material surface. With Spec (1), the oil grooves in the friction material surface are almost red in color, indicating

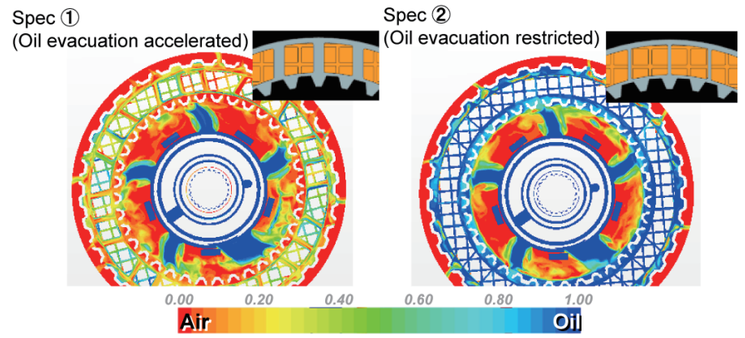

Fig. 6 Comparison of flow simulation results (Friction material surface)

that the cooling oil does not fully cover the surface. In contrast, with Spec (2), the oil grooves in the friction material surface are covered entirely with cooling oil.

5.4. Flow simulation results comparing the cooling oil flow rate and the air mixture rate

Based on the same simulation results, a comparison was made for the oil flow rate and air mixture rate of the cooling oil, flowing through the oil grooves in each friction material surface. Fig. 7 compares the oil flow rates, and Fig. 8 compares the air mixture rates.

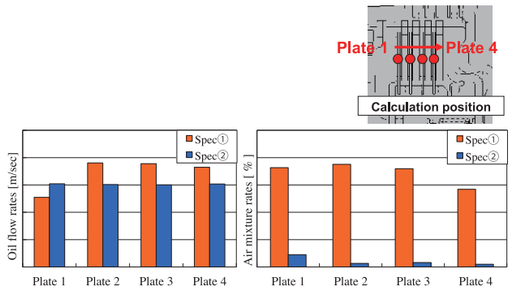

Fig. 7 Oil flow rates

Fig. 8 Air mixture rates

この解析結果より，Spec ②は Spec ①より油浴に近い状態である為，冷却性能が良く，プレート間の冷却性能バラツキも抑制されており，より最適に近い仕様であることを確認した．冷却性能改善の検証の為に，CL2 の測温試験を実施した．

6. 冷却性能改善の検証試験

6.1. 測温試験評価（CL2 単体）

測温試験はCL2 単体と実車の 2 種類を実施した．まず，CL2 単体の測温結果を Fig. 9 に示す．

試験は単体ベンチを用いて，社内評価で規定している登坂発進時の CL2 の滑り回転数と伝達トルク条件で各摩擦面の温度を実測した．CL2 の最高温度は，Spec ①に対し Spec ②の方が 20℃低い．また，Spec ①の摩擦面間の温度バラツキは 40℃に対し，Spec ②は 20℃である．これにより，前節の解析結果からの考察の通り Spec ②は Spec ①より CL2 の冷却性能が良く摩擦面間の温度バラツキも小さいことが確認された．

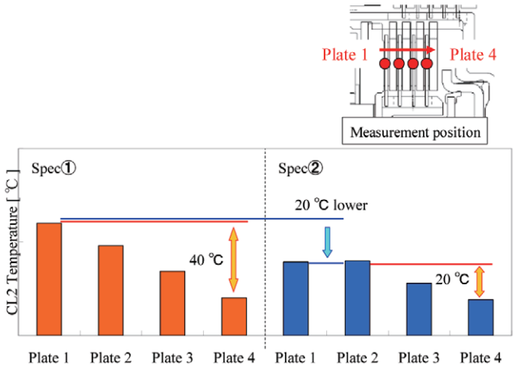

Fig. 9 Temperature of each clutch plate in clutch bench tests

6.2. 測温試験評価（実車）

実車の測温結果を Fig. 10 に示す．

試験は実車で勾配路を発進させ，CL2 単体測温結果で最も温度が高かった Plate1 の摩擦面の温度を実測した．勾配路は，CL2 単体測温試験と同じ条件と，当社が規定している実用で想定される最大勾配（以下，実用最大勾配条件）の 2 条件で実施した．

単体測温試験条件相当の勾配では，Spec ①に対し Spec ②の方が CL2 温度は 25℃低い．また，実用最大勾配条件においても，Spec ②の方が 100℃低い．

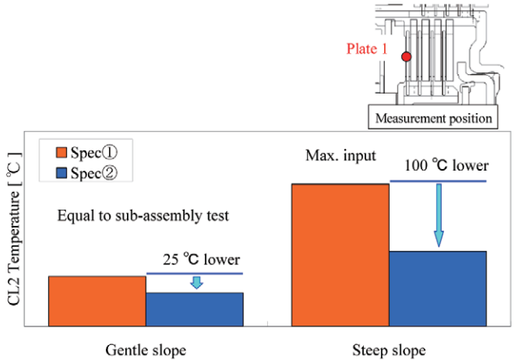

Fig. 10 Temperature of each clutch plate in vehicle tests

以上より，実車測温評価においても，Spec ②は Spec ①より冷却性能が良いことが確認された．

これらの解析および検証実験の結果を活用して冷却性能改善仕様を決定し，市場ニーズへの対応案を開発する事ができた．

7. まとめ

新開発したハイブリッド車用 CVT の重要課題である CL2 の冷却性能を向上させる潤滑システムを開発できた．システム改善のポイントは，摩擦面の冷却油の流し方の改良である．冷却油量の流量増を狙うと流路面積の拡大が有効と当初考えていたが，流路面積を大きく取りすぎると摩擦面の気相の割合が大きくなり , かえって冷却性能が低下してしまうという知見が得られた有益な開発であった．

また，予め解析によって効果比較をすることによって試作実験を行う仕様を絞り込むこともでき，効率的な開発を行うことができた．

本開発にご協力頂いた社内外の関係諸氏に感謝の意を表します．

With Spec (1), the cooling oil flowing through the oil grooves in the friction material surface shows a higher flow rate. The air mixture rate is also high, indicating the oil contains a large fraction of air. Moreover, the flow rate and air mixture rate of the cooling oil flowing through the oil groves in the friction material surface show large variation among the four plates. The cooling oil flow rate is lower for Spec (2) than for Spec (1), and the air mixture rate is also lower, indicating a state similar to an oil bath. In addition, Spec (2) suppresses the variation in the oil flow rate and the air mixture rate among the four plates more effectively than Spec (1).

These flow simulation results revealed that the lubrication state with Spec (2) was similar to an oil bath than with Spec (1), indicating better cooling performance and less variation in cooling performance between the plates. This confirmed that Spec (2) resemble to the optimal specification. In order to validate the cooling performance improvement, tests were then conducted to measure the temperature of CL2 when Spec (2) was applied.

6. Verification Tests of Cooling Performance Improvement

6.1. Temperature evaluation test of CL2 alone

Two types of temperature tests were conducted, a bench test of CL2 alone and an in-vehicle test. First, Fig. 9 shows the temperatures measured in the CL2 bench test.

A clutch bench test setup was used to measure the temperature of each friction material surface under the CL2 slipping speed and transmitted torque level specified for an in-house evaluation of an uphill vehicle launch. The CL2 temperature was 20ºC lower with Spec (2) than with Spec (1). In addition, the temperature variation among the friction material surfaces was 20ºC with Spec (2), whereas it was 40ºC with Spec (1). These results confirmed that Spec (2) achieved better cooling performance with less temperature variation among friction material surfaces than Spec (1), as was mentioned in the discussion of the simulation results in the preceding section.

6.2. In-vehicle temperature evaluation tests

Fig. 10 presents the temperatures measured in-vehicle tests. In these tests, the vehicle was launched on uphill slopes, and the temperature of the friction material surface of plate 1 was measured. Plate 1 had showed the highest temperatures in the results measured in the CL2 bench test. The vehicle was launched on two types of uphill slopes. One was the same low angle slope condition that was used in the bench test for measuring the CL2 temperature. The other was the maximum slope that JATCO has envisioned and specified for most severe condition of real world usage.

For the slope corresponding to the condition of the bench-test temperature measurement, the CL2 temperature was 25ºC lower with Spec (2) than with Spec (1). In addition, the CL2 temperature with Spec (2) was 100ºC lower for the maximum real-world slope condition.

These results for in-vehicle temperature evaluations also confirmed that Spec (2) provided better cooling performance than Spec (1). The simulation and verification test results were used in deciding the specifications for improving CL2 cooling performance. This made it possible to develop a lubrication system specification to meet market needs.

7. Conclusion

A new lubrication system was developed to slove crucial key issue of improving the cooling performance of the start-off clutch (CL2) in a newly developed CVT for hybrid vehicles. A notable improvement made to this system was to improve the flow of cooling oil on the friction material surface. It was initially thought that expanding the flow passage area would be effective to increase the cooling oil flow volume. However, making the flow passage area too large would increase the air fraction at the friction material surface, which would have the contrary effect of reducing the clutch cooling performance. That insight was extremely useful in developing the lubrication system.

Predictive simulations were conducted to compare the improvement effect of different specifications. That made it possible to narrow down the specifications used to make prototypes for testing and resulted in efficient development work.

We would like to thank everyone concerned inside and outside the company for their cooperation in development of this new lubrication system.

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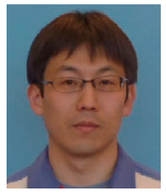
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Memo

誘電式テレメーターによる FF-HEV 実車クラッチ温度計測技術の紹介

New clutch temperature measuring system for FWD Hybrid Vehicles by using a dielectric telemeter

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抄　録　ハイブリッド車用 CVT の発進クラッチでは，発進時のスリップ量をコントロールして使う為，その温度上昇を正確に把握し，クラッチ耐力を知ることが重要である .

本稿では，そのために新たに開発したクラッチ温度計測技術を紹介する .

Summary　The start-off clutch in a CVT for front-drive hybrid vehicles is controlled to slip with required amount of slippage during vehicle launch, making it essential to detect the clutch temperature rise accurately so as to know the clutch endurance at detected temperature. This article describes a clutch temperature measuring system that has been newly developed for that purpose.

1. はじめに

クラッチの温度計測技術の歴史は長く，年々着実に進化を続けている .

古くはクラッチ単体テスターにおいて，停止している摩擦板の温度を計測することから始まり，最近では，ユニットの運転状態での温度計測や，実車走行状態での温度計測技術が発達してきている .

最も重要な課題は，回転しているクラッチの温度を計測した信号を，ノイズの影響を最小限にして，長時間信頼性を確保しながら，ユニットの外部に安定して取り出す方法である . 本稿ではこの課題を解決した新たな温度計測技術を紹介する.

2. 従来手法の課題

クラッチ温度計測の一連の進化においては，下記のような手法が開発されてきたが，いずれも課題があり，更なる改善が必要な状況であった .

①直接配線方式
●非回転クラッチ部位のみ計測可能.

1. Introduction

Techniques for measuring clutch temperatures have a long history and are continuing to evolve steadily year by year. Clutch temperature measurement began a long time ago with the use of a clutch tester to measure the temperature of stationary friction plates in a part test. In recent years, advanced techniques have been developed for measuring clutch temperatures during actual operation in a transmission and in a vehicle under real world driving conditions.

One of the most critical issues is to have a method of stable extraction of measured temperature signal from rotating clutch out of the transmission, while minimizing the influence of noise and maintaining reliability over a long period of time. This article presents a new temperature measuring system that solves this issue.

2. Issues in Conventional Measuring Methods

Methods like those noted below have been developed during the continuous evolution of clutch temperature measuring techniques. However, each one has its own issues and further improvement is needed.
(1) Direct wiring method

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②スリップリング方式
●配線を回転軸内から外部に取出すため，ユニット内部の大幅な改造が必要.
●ユニットの構造によっては，スリップリングへの配線が難しい .
③電池式テレメータ方式
●計測可能時間が短い.
●電源供給バッテリを搭載するためのスペース確保が難しいため，リバース機能等のCVT機能を犠牲にしてスペースを確保する必要があった.
④データロガー方式
●連続して長時間の計測が出来ない.
●モータ等から生じる磁界影響を受けノイズに弱い

以上のような計測データの蓄積や伝送の課題に加えて，温度計測の要となる熱電対についても，発進用クラッチの急激な温度上昇を正確に測定できるようにするため，応答性の改善が必要となっていた .

3. 新温度計測手法開発のねらい

これまでの温度計測手法の課題と，ハイブリッド車用CVT でのクラッチ温度計測に求められる要件から，新たに開発する計測手法では以下の６項目を満足することをねらいとした.
①回転クラッチ部位での計測が可能
② CVT ユニットとしての機能を保持
③計測可能時間に制約がなく連続計測が可能
④計測システムとして長寿命
⑤実車で連続して計測可能
⑥発進クラッチの温度急上昇を十分測定出来る応答性を確保

4. 本計測手法の詳細

前項に記載した開発のねらいを達成する手法として，本開発では誘電式テレメータ方式が最適であるという結論に至った .

以下，誘電式テレメータ方式について説明する .

● This method can only measure the temperature of non-rotating clutch parts.
(2) Slip-ring method
● The interior of the transmission must be substantially modified because wiring is taken outside from inside the rotating shaft.
● Depending on the structure of the transmission, it can be difficult to wire the slip-ring.
(3) Battery-powered telemeter system
● Measurements can be obtained only for a short period of time.
● It has been difficult to secure sufficient space for mounting the battery that supplies power. It has been necessary to secure space by sacrificing CVT function such as reverse capability.
(4) Data logger system
● Continuous measurement cannot be made over a long period of time.
● Susceptible to noise due to the effect of the magnetic field produced by the motor, etc.

In addition to the above-mentioned issues concerning the storage and transmission of the measured data, the response of the thermocouple at the heart of the measuring system also had to be improved in order to measure accurately the sudden temperature rise of the start-off clutch.

3. Aim for Development of New Temperature Measuring System

The aim set for the development of the new clutch temperature measuring system was to satisfy the following six items. That was necessary in order to resolve the issues in conventional measuring methods and also satisfy the requirements for measuring the clutch temperature in a CVT for use on hybrid vehicles.
(1) Must be possible to measure the temperature of rotating clutch parts
(2) Must maintain the function of the CVT
(3) Must be capable of measuring the temperature continuously without any restriction on the available duration for measurement
(4) Must have a long operating life as a measuring system
(5) Must be capable of continuous measurement in a vehicle
(6) Must have sufficient response to measure the sudden

4.1. 誘電式テレメータ方式の基本原理

今回採用した誘電式テレメータ方式は，ステータアンテナ，ローターアンテナ，センサーアンプ，レシーバで構成される．(Fig. 1-a)

熱電対の信号は，センサーアンプにてデジタル信号に変換され，ローターアンテナから送信されて，非接触にてステータアンテナに送信される．ステータアンテナからのデジタル信号は，レシーバにてアナログ信号に変換され出力される．

レシーバは外部から電源を供給され，ステータアンテナは高周波電磁波を発信し，周囲に磁場を形成することで非接触にてローターアンテナへ給電を行う．

この構成により回転体と固定部の間で非接触にて双方向デジタルデータで通信ができ，同時に電力供給が可能である．(Fig. 1-b)

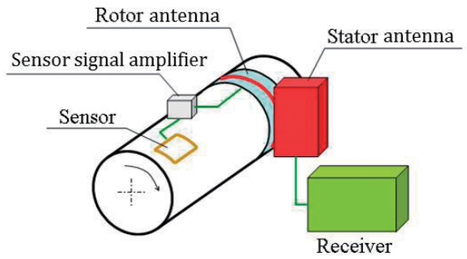

Fig. 1-a Configuration of dielectric telemeter system

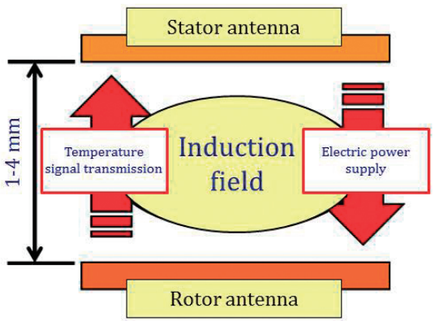

Fig. 1-b Operating principle of dielectric telemeter system

4.2. 本計測手法の計測時間と搭載性

誘電式テレメータでは，誘電磁界を利用して継続的に電源が供給されるため，計測可能時間に制約がなく連続計測が可能となった．

また，電源供給バッテリを CVT ユニット内部に搭載する必要はないため，従来の電池式テレメータ方式での課題であった CVT 機能を犠牲にするようなスペースの確保は不要となり，ユニットとしての機能を損なうことの無い計測が可能となった．

4.3. 本計測手法の信頼性

今回計測の対象としたクラッチはユニットの内部深くにレイアウトされていたため，従来のスリップリング方式では，信号を CVT ユニット内部から外部に取出す際に，周辺部品に種々の加工をして長い配線を行なう必要があった．そのため，配線部の断線が発生しがちであり，加工された部品の強度も低下しがちであった .

これに対し，誘電式テレメータ方式では長い配線をする必要がなく，周辺部品の改造も極力抑えることができるため，CVT 機能や耐久性を損なうことなく搭載することができる．

また，クラッチ温度計測において，しゅう動部の温度上昇による温度計測部の故障は避けなければならない．特に熱電対の被膜部は耐熱性が低く，しゅう動部の温度上昇による溶融が予想された．そこで，金属製プレートに加工した配線用穴を拡大し，熱電対被膜と金属製プレートの間に空間を確保することで，空気による断熱効果を利用し，熱電対の被膜が溶融することを防止した．(Fig. 2)

これら誘電式テレメータの採用による搭載機器の小型化と，熱電対設置法の工夫により，Fig. 3 に示すように従来の計測手法と比較して，本計測システムは 1000 倍以上の長寿命化が実現できた .

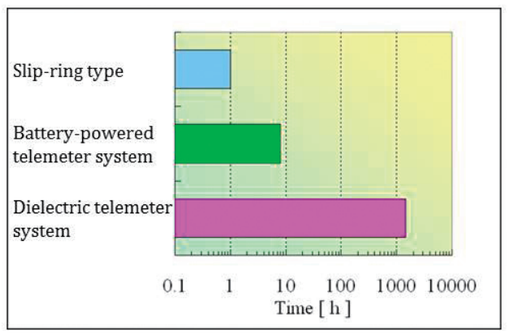

Fig. 3 Comparison of operating life of measuring systems

temperature rise of the start-off clutch

4. Details of New Temperature Measuring System

It was concluded that an inductive telemeter system would be the best method for accomplishing the development aim mentioned above. This section describes the new inductive telemeter system in detail.

4.1. Basic principle of dielectric telemeter system

The newly developed dielectric telemeter system mainly consists of a stator antenna, rotor antenna, thermocouple sensor, sensor signal amplifier and a receiver (Fig. 1-a). The thermocouple signal is converted to a digital signal by the sensor signal amplifier and transmitted from the rotor antenna to the stator antenna in a non-contact manner. The signal is then sent from the stator antenna to the receiver where it is converted to an analog signal and output.

The receiver is powered by an external power supply. The stator antenna transmits high-frequency electromagnetic waves that form a magnetic field in the immediate area to facilitate non-contact power supply to the rotor antenna.

This system configuration enables two-way non-contact transmission of digital data between the rotor and the stator as well as simultaneously facilitating electric power supply (Fig. 1-b).

4.2. Measurement time and mountability of new measuring system

Dielectric telemeter system uses an electromagnetic induction field to supply power continuously, thereby enabling continuous measurement because there is not any restriction on the available duration for measurement

Moreover, it is not necessary to mount the power supply battery inside the CVT. This makes it unnecessary to sacrifice CVT function for securing power source space, which has traditionally been an issue with battery powered telemeter systems. Temperature measurement is possible without detracting from the functions of the CVT.

4.3. Reliability of new measuring system

The clutch targeted for measurement in this project is located deep inside the CVT. With a conventional slip-ring method, it would be necessary to machine the surrounding parts in various ways in order to install a long wire for externally extracting the temperature signal from CVT. Consequently, the wire would be apt to break and the machined parts would likely suffer a loss of strength.

In contrast, the dielectric telemeter system does not require any long wire and modification of surrounding parts can be kept to a minimum. Therefore, the system can be mounted without sacrificing the function or durability of the CVT.

Furthermore, in measuring the clutch temperature, it is necessary to avoid any damage to the thermocouple sensor by the temperature rise of sliding parts. The thin film of the thermocouple signal harness in particular has low thermal resistance. It was predicted that the temperature rise of sliding parts might melt the film. To avoid that, the wiring hole machined in the metal plate was enlarged to secure space between the film and the metal plate. As a result, the insulation effect of the surrounding air can be used to prevent the film from melting (Fig. 2).

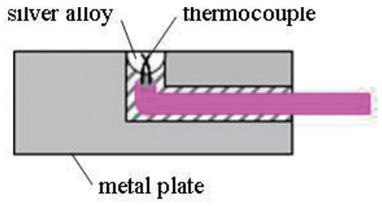

Fig. 2 Diagram of temperature sensing part

The adoption of this dielectric telemeter system reduced the size of the measuring device to be mounted and the thermocouple is installed in an innovative manner. As a result, the operating life of this new system has been extended 1,000-fold compared with that of conventional measuring methods as shown in Fig. 3.

4.4. Improvement of temperature response

The start-off clutch of this CVT for hybrid vehicles is allowed to slip in a controlled manner during vehicle launch. Accordingly, the temperature rise of the clutch is a key issue and must be detected accurately. In addition, the measuring system must have high responsiveness because the clutch temperature rises sharply in situations where large driving force is demanded of the vehicle, such as when driving up a steep slope or pulling a trailer.

With the previous temperature measuring system, the junction between the alumel and chromel wires of a K-type thermocouple was embedded in the clutch friction material plate and the sliding metal plate. In contrast, the junction of the alumel and chromel wires is now sealed inside a silver wax globe attached to the surface of the friction

4.4. 測温応答性の改善

ハイブリッド車用発進クラッチでは，発進時のスリップ量をコントロールして使う為，クラッチの温度上昇が重要な課題であり，その温度上昇を正確に把握することが必要であった．また，車両としての要求駆動力が高い高勾配路の走行やトレーラー牽引走行時には，急激に温度が上昇するため，計測手法には高い応答性が求められる．

従来の温度計測部では K 型熱電対のアルメル線とクロメル線の接触部をクラッチ摩擦板としゅう動する金属製プレートの内部に埋め込んでいた．これに対して，今回はアルメル線とクロメル線の接触部を球状の銀ロウの内部に溶け込ませ，クラッチ摩擦板としゅう動する金属製プレートの表面に取り付けた．しゅう動部表面には熱伝導率の高い銀ロウを使い，しゅう動面の近傍に設置することで，従来よりも高い応答性を得ることができた．

Fig. 4 は全く同じ条件でクラッチを急締結させた際の温度計測結果についての新旧比較である．図のように新計測手法により応答性を向上させることができた．

5. 本計測手法による計測データの実例

本計測手法を用いた計測システムの実例として，FF-HEV 発進クラッチ向けに製作したシステム一式の外観と組付け時の模式図を示す．(Fig. 5) 従来の計測手法と比べて，コンパクトな計測システムとなっており，周辺部品の改造は最小限に抑えることができた．図に示す青色部分のみの追加工をするだけで済み，実車運転中にも計測できるシステムとすることができた .

material plate and the sliding metal plate. Quicker response than before has been obtained by using silver wax, which has high thermal conductivity, on the surface of the sliding plate and installing the thermocouple close to the sliding surface.

Fig. 4 compares the temperatures measured with the previous and new measuring methods when the start-off clutch was suddenly engaged under the same operating conditions. As seen in the figure, the responsiveness of the new measuring system has been improved.

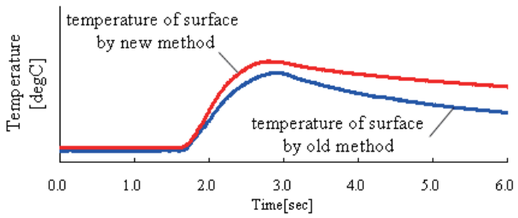

Fig. 4 Comparison of temperatures measured with old and new methods

5. Actual Example of Data Measured with the New System

As an actual example of this new measuring system, Fig. 5 shows the appearance and a schematic diagram of an assembled system that was manufactured for measuring the temperature of the start-off clutch in a CVT for FWD hybrid vehicles. The measuring system is much more compact than systems using previous measuring methods, thereby keeping modifications of surrounding parts to a minimum. Only the places indicated in blue in the figure had to be machined. Consequently, this system can also measure the clutch temperature during CVT operation in an actual vehicle.

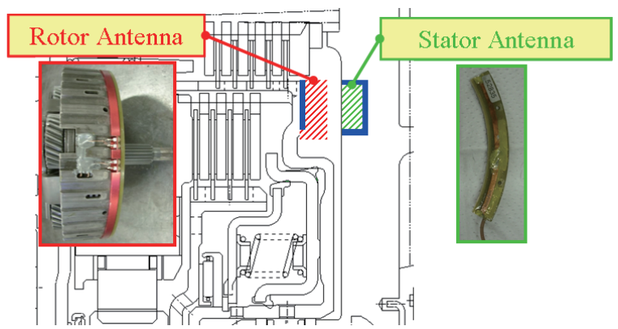

Fig. 5 Example of actual dielectric telemeter system

Fig. 6 に本計測システムを使用した実車でのクラッチ温度計測データを示す．図に示すように 0.5sec で 100℃上昇するような速い温度変化の計測が可能となり，図の青と赤の比較で示したシミュレーションの妥当性の検証におおいに役立った . 更に図でわかるようにデジタル化した信号の非接触転送のため，フィルター処理無しでもノイズの少ない計測が実現できた．

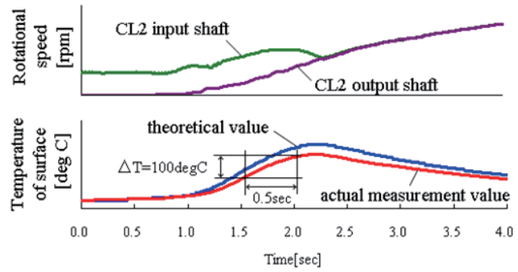

Fig. 6 Typical results of temperature measurement

6. まとめ

今回開発した誘電式テレメータを採用したクラッチ温度計測技術によって，従来の計測手法と比べて，高応答性化と，システムとして長寿命化，さらに CVT ユニットとしての機能を損なわない計測が可能となった．この計測技術を活用することで，本特集で杉村らが紹介しているハイブリッド車用 CVT の発進クラッチの冷却性能改善の開発に貢献できた．

また，本方式は種々の計測に応用可能であり，同様に計測が困難であった CVT ユニット内部のトルク計測や応力計測への活用も，次なるチャレンジとして取り組み中である．

7. 謝辞

本計測手法を開発するにあたり，多大なご協力を頂いた株式会社マツイの皆様に感謝の意を表します．

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山本毅，杉村晃，小辻弘一，折田崇一，岩佐大城，早川純平，内藤忠司：FF ハイブリッド車用の発進要素の開発，ジヤトコテクニカルレビュー，No.13, pp.37-46 (2013)

Fig. 6 presents an example of actual clutch temperature data measured in a test vehicle with this measuring system. As seen in the figure, the new system can measure sudden temperature changes such as a rise to 100ºC within 0.5 sec. This system was greatly helpful in validating simulation data (blue line) in comparison with actual measured values (red line) as shown in the lower figure. Moreover, as can be seen in the figure, the contactless transmission of digital data enables temperature measurement that is little affected by noise even without the application of filtering.

6. Conclusion

This article has described a newly developed clutch temperature measuring system that adopts dielectric telemeter technology. Compared with previous measuring techniques, this new measuring system provides higher response, a longer operating life and also facilitates temperature measurement without detracting from the functions of CVT. This measuring technology also contributed to the development of measures for improving the cooling performance of the start-off clutch in the CVT for hybrid vehicle application, as described by Sugimura and colleagues in another article in this special feature.

Another advantage of this system is that it is applicable to various types of measurements. We are now proceeding with our next challenge of using this system to measure torque and stress in a CVT, which have been similarly difficult to measure with existing techniques.

7. Acknowledgments

We would like to thank everyone at Matsui Co., Ltd. for their tremendous cooperation with the development of this new measuring system.

8. Reference

Takeshi Yamamoto, Akira Sugimura, Hirokazu Kotsuji, Shuichi Orita, Daiki Iwasa, Jumpei Hayakawa and Tadashi Naito, “Development of the Start-off Element for a Front-drive HEV CVT,” JATCO Technical Review, No. 13, pp. 37-46 (2013).

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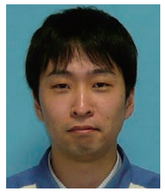
Tadashi NAITO



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Memo

JEPS のグローバル展開について

Global deployment of the JATCO Excellent Production System

渡辺　浩児*　Koji WATANABE
松本　昌浩*　Masahiro MATSUMOTO

抄　録　「限りないお客様への同期」を追求するため，1998 年 に JEPS（JATCO Excellent Production System）活動を開始し，以降 15 年が経過し，進化をし続けてきた（Table 1）.

本稿では，「限りない課題の顕在化と改革」を進める仕組みとそれを支える人材育成のグローバル展開について報告する.

Summary　In order to pursue a “never-ending quest of synchronized production with customer's vehicle production plan,” we started the JATCO Excellent Production System (hereafter JEPS) activity 15 years ago, and this activity is still evolving (Table 1).

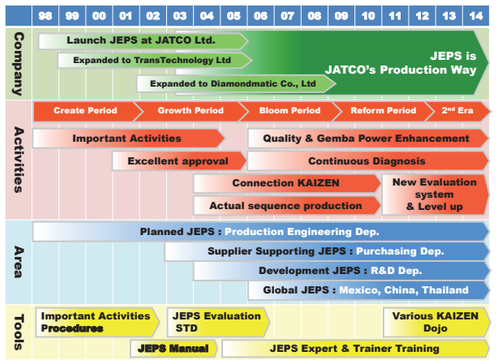
This article describes process and organization to carry out “never-ending quest to identify issues and to establish reconstructive solution” and to deploy measures for developing human resources globally, which supports above mentioned process and organization.

1. 取り巻く環境

2013 年ジヤトコは累計生産台数 2,140 万台，グローバルシェア 49％で前年同様 CVT（Continuously Variable Transmission）No.1 サプライヤとなった．2020 年には『Global No.1』のトランスミッションメーカになることを目指し，今後益々，CVT の生産比率は拡大する見込みである（Fig. 1）.

一方，モノづくり競争力は，グローバル化が急激に進展し，各拠点での「限りない課題の顕在化と改革」による改善力・改革力で決まると言っても過言ではない.

Table 1 The history of JEPS activities at JATCO.



1. Surrounding Circumstances

JATCO's cumulative production volume of continuously variable transmissions (hereafter CVT) reached 21.4 million units in 2013. Same as last year, JATCO continued its position as the world's No. 1 CVT supplier. JATCO's global market share in 2013 was 49% and we aim to be the global No. 1 transmission manufacturer by 2020. The CVT share of JATCO's total production volume is expected to increase even more in the coming years (Fig. 1).

Meanwhile, with the rapid globalization of our operations, it would not be exaggerating to say that our competitiveness in monozukuri (manufacturing) is determined by the capabilities of each plant to implement

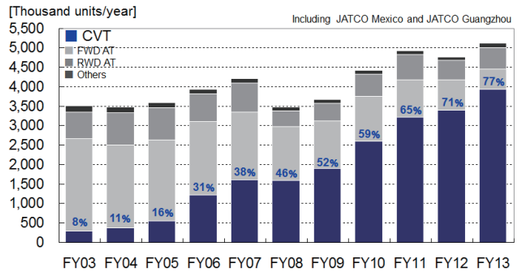


Fig. 1 JATCO's cumulative production volume

*JEPS 推進部
JEPS Promotion Department

2. JEPS を推進する 2 つの機能

JEPS 活動の「限りない課題の顕在化と改革」は，モノづくりの改善・改革を評価推進する機能と，それを実行できる人材を育成する機能の 2 つが継続して働くことにより推進される．特に，人材育成は，自ら課題に気付き顕在化させ，対策を講じ，飛躍的な効果を引き出せる人を育てることであり，その教育が出来る人の育成も不可欠である．環境変化に応じた JEPS 活動を推進するには，これら 2 つの機能の組み合わせが必要となり，各々の施策を以下に示す.

3. 改善・改革を評価推進する新たな取り組み

改善・改革の評価推進では，4 つの施策を展開した．1 点目は，事例共有である．良い改善事例は社内イントラネットで掲載し，ビジュアル（動画活用）化を進め言語を問わず理解できるようにした．また，サプライヤ支援にも活動範囲を広げた（Fig. 2）.

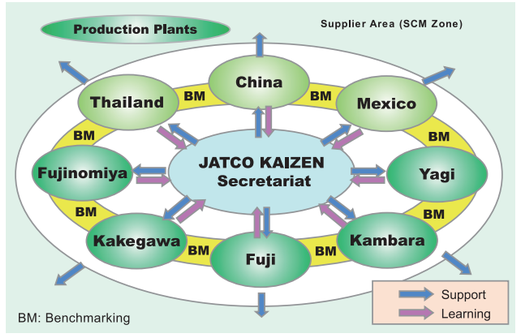


Fig. 2 Examples of horizontal implementation of kaizen

2 点目は，現場現物確認の強化である．2013 年度よりグローバル JEPS 現場確認会を四半期に 1 回のサイクルで始めた．毎回生産 4 拠点の機能代表者が参加し，互いの「良いとこ取り」をするだけでなく，共通課題を論議し新たな発想の場として機能し始めている（Fig. 3）.

3 点目は，改善・改革のスピードアップである．グローバルに共通評価ツールを導入し結果を共有化することで，その効果を得ている．具体的には生産ラインのパフォーマンスを測る JEPS 評価（Table 2）や監督者の現場管理レベルの診断する GGK 診断を 4 拠点で定期的に実施している.

improvements and reforms through a “never-ending quest to identify issues and to establish reconstructive solution.”

2. Two Functions Driving JEPS

The “never-ending quest to identify issues and to establish reconstructive solution” in the JEPS activity is advanced through the continuous operation of two functions. One function is to promote evaluations of monozukuri improvements and reforms, and the other is for developing human resources, this makes the first function feasible. The development of human resources in particular involves fostering employees who can proactively notice and identify issues, implement corrective measures and thereby produce dramatic results. It is also indispensable to develop people capable of training and educating such employees. These two functions must be combined in order to promote the JEPS activity in response to change of surrounding circumstances. The following sections explain measures for accomplishing these two functions.

3. New Activity for Improvements (Kaizen) and Reforms by Evaluations and Promotion

Four measures have been deployed for promoting evaluations and promotions for improvement (kaizen) and reform. The first measure is to share examples. Excellent examples of improvements are posted on the company's intranet. Videos are used to share suggestions and these can be understood regardless of the language. These examples are also being utilized to support our suppliers (Fig. 2).

The second measure involves strengthening

Fig. 3 Participants from all production plants at the Global JEPS Gemba Confirmation Meeting

Table 2 JEPS evaluation levels (points)

JEPS Evaluation Rank (points)				
1st	2nd	3rd	4th	5th
Lower than JATCO mean level	JATCO mean level	Present ideal figure Current superior level	Future ideal Figure (with external BM)	World top-level (with external BM)

4 点目は，ベンチマークである．現在の改善は，従来の発想だけではなく，飛躍や変革も同時に求められる．よって，社外の食品メーカ・電気メーカなどの異業種との交流も積極的に行い，新たな気づきに基づく活動と改善促進への活用を図っている．また，これらの情報も社内イントラネットで共有した．

4．グローバルな人材育成

急速なグローバル成長に追従するには，『モノづくりの経験のない人を速く改善できる人にすること』が必要となる．日本では，経験により体得された技能を蓄積・伝承することによりモノづくりを支えている．しかし，海外でのモノづくりでは，生産量拡大が早く，じっくり経験をさせることが困難となる．そこで，速く人材を育成するため，従来の改善トレーナやリーダの教育，グローバルトレーニングセンターやリージョナルトレーニングセンターの充実に加え，現場で現物に触れる教育を重視し，新たに機械加工のノウハウを教える「ツーリング道場」と単純な機構で物を運ぶ動かす原理・原則を体得する「からくり道場・展示場」を立ち上げた（Fig. 4）．またそこへ海外からの実習生を受け入れ，帰国後は自職場で学んだことを実践することで，各生産拠点のリーダ且つ JEPS 推進役として活躍できるようにした．

confirmation of the actual product and facility (gembutsu) in the actual workplace (gemba). Since fiscal 2013, a Global JEPS Gemba Confirmation Meeting has been held once every quarter. Representatives of each function at the four CVT plants attend these meetings each time. The meetings recently began to function not only as a place for presenting each other's best practices, but also as an opportunity for discussing common issues and stimulating new ideas (Fig. 3).

The third measure involves speeding up the pace of improvements (kaizen) and reforms. Common evaluation tools have been introduced globally and the results are shared in common, which is effective in quickening the pace. Specifically, JEPS evaluations (Table 2) for measuring the performance of the production lines and Gemba & Gembutsu Kanri (GGK) reviews for judging the workplace management level of supervisors are conducted regularly at the four CVT plants.

The fourth measure is benchmarking. Significant leap forward and dramatic reforms are required today for improvements, rather than just a slight improvement by conventional ideas. Therefore, exchanges are vigorously conducted with companies in other industries such as packaged food manufacturers, electrical equipment manufacturers and others. The resulting information is used to promote improvements and activities based on a new awareness by such benchmarking. That information is also shared via the company's intranet.

4. Global Development of Human Resources

In order to keep up with the rapid growth of our operations globally, it is necessary to quickly educate employees in order to have capabilities to make improvements who have never experienced monozukuri before. In Japan, monozukuri is supported by the accumulation and passing on of skills acquired through experience. However, production volumes at overseas plants are expanding rapidly, making it difficult to give employees sufficient time to experience monozukuri operations. Therefore, in order to develop human resources quickly, we are putting emphasis on education that gives employees opportunity to deal with actual production and facilities in the workplace, in addition to enhancement of accumulated know-how for training, such as developing kaizen trainers and leaders and education in global training center and regional training centers. In Japan we have

Fig. 4 Trainees from overseas plants at the karakuri and tooling kaizen dojos

5．改善の効果

JEPS 活動成果の例を挙げると，既存ライン効率化では，ジヤトコの生産機種は大別すると 23 機種有りその内 13 機種が CVT となっていることから，1 つの改善でも類似生産ラインへの水平展開，即ち改善効果の増大が可能となる．

また，新ラインの立ち上げでは，既存ラインの立ち上げ期間に比べて半分の期間で立ち上げ，かつ所要の生産量を確保で出来るようになった．これは，急速な人材育成と生産性向上が図られているためである（Fig. 5）．

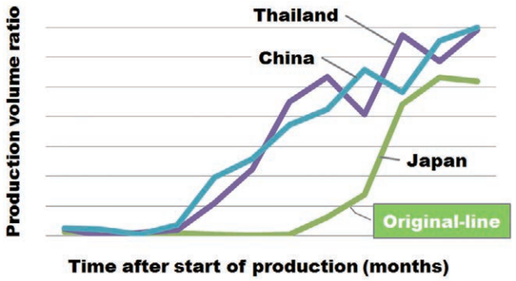


Fig. 5 Production volume ratio vs. time after start of production

6．今後の課題

近年のプロジェクトでは，モノづくりのパフォーマンスを測る JEPS 評価点が，立ち上がり直後でも既存ラインと同じレベルに達している．これは生産準備段階で生産技術と製造 (現場) が一体となって JEPS 活動を進めた活動

newly established a tooling dojo (tooling training center) for educating employees the fundamentals of machining and a karakuri dojo (simple and smart improvement training center) and an exhibition hall where employees can experience the principles of moving things by using simple mechanisms (Fig. 4). Trainees from overseas are accepted at these dojos (training centers) and the things they learn here in Japan (JATCO) can actually be practiced in their own workplaces after they return to their plants. This enables them to become leaders at their own plants and to play a key role to drive JEPS activity.

5. Benefits of Improvements

This section presents examples of the results of the JEPS activity, first with regard to improving the efficiency of existing lines. JATCO is currently producing approximately 23 types of transmissions, of which 13 are CVTs. Therefore, even a single improvement can be horizontally deployed on other similar production lines, making it possible to expand the benefits.

Moreover, new lines can now be launched and the required production volumes can be obtained in half the time that it took previously when the existing lines were launched. This has been achieved by above mentioned activity of rapid development of the human resources and productivity improvements (Fig. 5).

6. Future Challenges

Evaluation points of JEPS for measuring monozukuri performance of existing line and newly launched line have reached to same level, even though evaluation of newly launched line is carried out right after production launch. That is the result of Production Engineering team and Manufacturing team working closely together at the production preparation stage to drive the JEPS activity. The key challenges for becoming the global No. 1 transmission manufacturer by 2020 will be to incorporate into new lines all of the improvement know-how gained from the existing lines without leaving anything out and to certainly implement in new lines the improvements that could not be embodied in the present lines. In other words, it will be necessary to strengthen and enhance JEPS activity beginning from the planning stage in order to make improvement measure at earlier stage (headstream or upstream).

の成果である．2020 年に『Global No.1』となるには，現行ラインの改善ノウハウを漏れなく新ラインに織り込むこと，現行ラインでは実現できなかった改善を確実に織り込むことが鍵となる．即ち，企画段階より JEPS の強化・充実（源流・上流での対策）を推進する必要がある．

また，更なる飛躍・変革活動として，新たな道場立ち上げ（電気・電子制御，画像解析，ロボット制御），製造現場の創意工夫を共有できる事例展示場の拡大・充実を推進し，現場現物での人材育成を重点に行っていきたい．

7. 結論

モノづくり競争力の源泉は，「限りない課題の顕在化と改革」による改善力・改革力であり，これを継続して取り組むためのモノづくりの改善･改革を評価推進すること，それを実行できる人材を育成することを中心とする JEPS 活動が重要である．グローバルに各種ツールや技能訓練道場を活用し，『気づく，真似る，創る』を強力に推進していく．

8. 謝辞

本稿を執筆するに当たりご意見をいただいた社内外の関係諸氏に感謝を申し上げます．

We also intend to emphasize the development of human resources in the workplace using actual product and facilities in order to conduct activities for making dramatic advances and changes. This will include establishing new dojos (training centers) for electric/electronic control, image analysis and robot control as well as expanding and improving venues for displaying improvement examples so that creativity and ingenuity in manufacturing workplaces can be shared by everyone.

7. Conclusion

The source of competitiveness in monozukuri lies in capabilities to attain improvements and reforms through the “never-ending quest to identify issues and to establish reconstructive solution.” The JEPS activity is vital to the continuation of these efforts because it focuses on executing evaluations of monozukuri improvements and reforms as well as development of human resources capable of executing those improvements and reforms. Through global use of various tools and dojos (training centers), we intend to vigorously enhance the development of employees capable of identifying issues, utilizing best practices and creating better solutions.

8. Acknowledgments

We would like to thank various individuals concerned both within and outside the company for their advice for this article.

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Global 生産拠点展開におけるプロジェクト管理

ジヤトコタイランドプロジェクト，ジヤトコメキシコ第2工場プロジェクトへのジヤトコ版NPPS適用

Project Management of New Global Production Plant Launch

—Implementation of JATCO's Version of NPPS in JATCO Thailand's Project and JATCO Mexico's Plant No. 2 Project—

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抄　録　本稿では，CVT の生産拠点をグローバル且つ急速に展開する為に導入したプロジェクト管理ツールについて，その内容とそれを具体的に適用した事例について報告する.

Summary　This article presents the project management tools that were introduced to accomplish quick global launch of CVT production plants. The details of the management tools are described along with specific examples of their implementation in two projects.

1. はじめに

市場ニーズに対応する為，CVT の生産拠点をグローバルに且つ急速に展開する必要があったが，海外拠点を立ち上げる為の標準ステップが無かった.（Fig. 1）そこで，少リソースで短納期で立ち上げる方法として，日産自動車（株）が開発した New Plant Preparation System（以下 NPPS）の考え方を参考にして，これまで JATCO 生産技術部門で使用していた Stage Control Chart（以下 SCC）とを併用し，ジヤトコタイラインド（JTL）プロジェクトおよびジヤトコメキシコ（JMEX）第二工場プロジェクトに適用した.（Fig. 2）具体的には，日産の NPPS の考え方を参考に，ジヤトコのプロジェクトに特有な機能軸（工程機能軸:組立，加工，鋳造，鍛造，他）の視点のステップを考慮して，プロジェクトの全体を管理し，各プロジェクトともその時点でベンチマークとなる最短期間で，生産開始した.

1. Introduction

In recent years, we have had to build CVT production plants quickly and globally in order to meet market needs, but lacked a standard process for launching plants overseas (Fig. 1). Therefore, to create a method for launching a plant in a short period of time and with limited resources, we combined the concept of the New Plant Preparation System (hereafter NPPS) developed by Nissan Motor Co., Ltd. (hereafter NML) and the Stage Control Chart (hereafter SCC) used heretofore by JATCO's Production Engineering Division. The resulting method was implemented to JATCO Thailand's (hereafter JTL) project and JATCO Mexico's (hereafter JMEX) No. 2 plant project (Fig. 2). Specifically, in each case the overall project was managed in reference to the concept of Nissan's NPPS, taking into account the functions unique to JATCO's projects from the standpoint of the casting, forging, machining, assembly and other processes involved. In each project, production was launched in the shortest possible period, which became a benchmark of rapid launch at respective plant launch.

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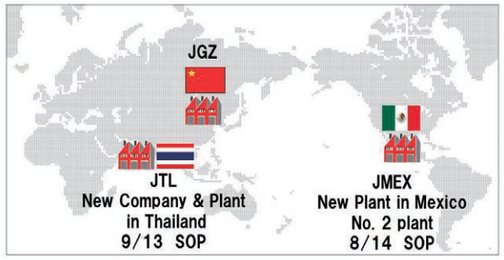


Fig. 1 Global expansion plan

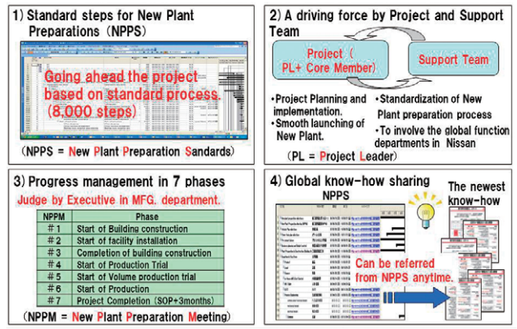


Fig. 2 Outline of NPPS (excerpt from NML material)

2. プロジェクトコントロールの手法

2.1. NPPS のジヤトコプロジェクトへの適用

NPPS（Fig. 2）とは，新工場準備に関し，工場建設と操業準備に関わる業務を列挙したもので，新工場準備進捗を一元管理するマネジメントツールである.

日産で使用している標準ステップに対し，ジヤトコのプロジェクトで適用する為には，生産設備準備等の共通項もあるが，組織，工法，工程が違う事から，足りないステップがあった．JATCO EXCELLENT PRODUCTION SYSTEM（以下 JEPS）活動で設定したありたい姿に対し，課題を分解し，拠点の特徴，事情により，必要なステップを加えた.

また，節目管理も，フェーズ移行判断，工場総合進行会議はあったが，会社設立，工場準備のための大きな節目の判断会は従来無かったので，本システムでは，New Plant Preparation Meeting（以下 NPPM）と呼ばれる，節目の判断会を設定，準備状況の確認を実施した.

2.2. SCC の適用　その有効性と課題

生産技術では，プロジェクトの進捗を管理するシステムとして Stage Control Chart（以下 SCC）を使用してきた．プロジェクトの難易度に従い，テンプレートと呼ばれる標準的な日程が準備されており，各機能軸は，必要な準備項目を追加して，基準計画を完成させる．月次の進捗を入力すると，自動的に月次報告グラフ（Progress Report）が作成できる．それを基に，関係者で進捗を確認して，挽回手段や方向付けの指示を行うシステムである.（Fig. 3）

2. Project Management Method

2.1. Implementation of NPPS to JATCO's projects

As outlined in Fig. 2, NPPS is a tool for centralized management of the progress of the preparations for establishing a new plant. It details all the work involved in preparing a new plant, including plant construction and preparations for launching production operations.

The standard steps used by NML included common items with JATCO with respect to preparing production equipment. However, because the organizations, methods and processes of the two companies differ, some steps were lacking in NPPS for JATCO's projects. It was necessary to add some steps concerning the ideal process defined in the JATCO Excellent Production System (hereafter JEPS) activity. That was done by breaking down the issues involved and taking into account the special characteristics and circumstances of each plant.

Moreover, with this system a review meeting, called the New Plant Preparation Meeting, was held at major junctures to assess and confirm the status of the preparations. In the past, meetings were held to review the overall progress of a production launch at a plant and to make decisions about moving to the next phase. However, those meetings had not involved such major junctures as the establishment of a new company or the building of a new plant.

2.2. Application of Stage Control Chart: Effectiveness and issues

Production Engineering has previously used the SCC as a system for managing the progress of a project. With this system, a standard schedule, called a template, is

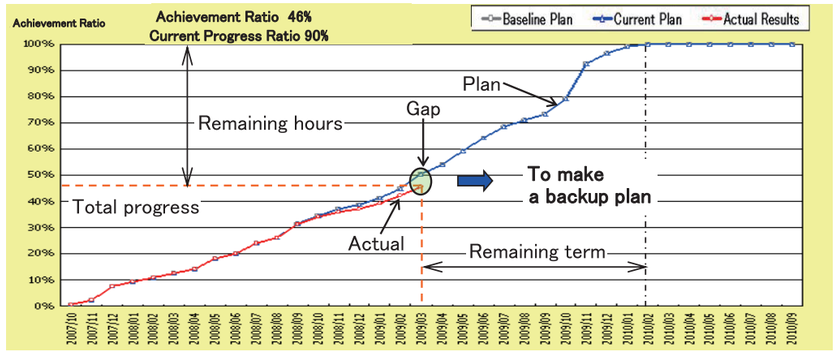


Fig. 3 SCC progress report

このシステムの最大の特徴は，進捗率の単位をステップ数ではなく，『時間』にしている事である．これは，過去のノウハウを蓄積して，また業務改善を加えて最適な生産準備リードタイムを積み上げた集大成のマスタースケジュールである．これにより，作業ボリュームを把握する事が出来，現実に即した進捗及び工数管理を行う事ができ，早期アクションが可能となる．

上記，2 つのプロジェクトでは，生産技術部門は蓄積したノウハウを適用できる SCC を利用して工数管理し，それ以外の機能軸部門（生産管理，品質保証，調達　その他）はステップ進捗を NPPS で管理した．そして，各節目で各ステップのリードタイムおよびマスタースケジュールを修正し運用した．尚，プロジェクトの節目は，NPPM を開催し，移行判断した．

3. JTL プロジェクトへの適用事例

3.1. プロジェクトへの適用

JTL プロジェクトは，2011 年 4 月よりプロジェクトチームが発足し，準備がスタートした．そして 2013 年に生産開始という短納期を達成する為に，JATCO 版 NPPS を活用しプロジェクトを管理していく事を決定した．

まず日産で使用している NPPS の考えを参考に JTL プロジェクトの時間軸を設定するとともに，ジヤトコ固有の業務を増やす作業を行った．

この作業により，一旦 JTL プロジェクト用に JATCO 版 NPPS を完成させ，準備及びフォローを 5 月より開始した．尚，最終的なステップ数は，計画ステップ数の約 1.5 倍となった．

prepared according to the relative degree of difficulty of a project. Each functional group adds its own necessary preparations and a baseline plan is completed. By inputting the progress made each month, a monthly progress report is automatically created. The people involved confirm the progress on the basis of the report, if necessary, devise measures for catching up to the original schedule and determine instructions for the future direction of the work (Fig. 3).

A remarkable feature of this system is that the rate of progress is expressed in units of hours rather than in the number of steps. This master schedule is a compilation of the optimum production preparation lead time and represents an accumulation of past know-how plus the addition of work improvements. This schedule makes it possible to ascertain the volume of work to be done, enables management of progress and man-hours based on realities and support action which needs to be taken at early stage.

The Production Engineering Division managed the man-hours of the two above-mentioned projects using SCC that helps in implementation of accumulated know-how. Other functional groups such as Production Control, Quality Assurance, Purchasing and others used NPPS to manage the progress of their steps of the projects. At each juncture, the lead time of each step and the master schedule were revised for future use. A New Plant Preparation Meeting was held at each juncture of the projects, and a decision was made regarding the transition to the next stage.

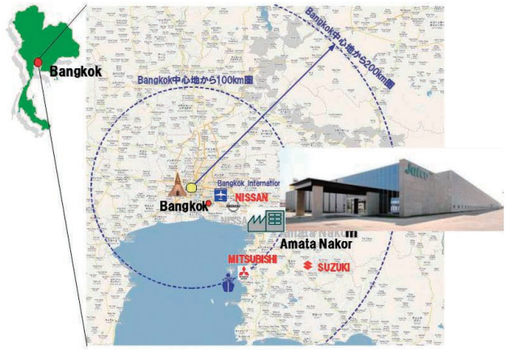


Fig. 4 Location of JTL

Fig. 5 Photo of JTL

3.2. 適用・運用の工夫

毎月関係者で JATCO 版 NPPS をベースに進捗確認および課題抽出を繰り返した．その過程で，予備品を管理する供給センター業務，工具研磨業務，利材廃材処理業務のような支援業務の不足に気づいた．そこで，プロジェクトメンバーと共に，現状業務の確認，課題の洗い出しを行い，それを解決する為の方策をステップに分解し，JATCO 版 NPPS に加えた．そして月次の会議で，全体進捗をフォローし，結果を，JTC（ジヤトコ日本）と JTL でシェアした．（Fig. 6）

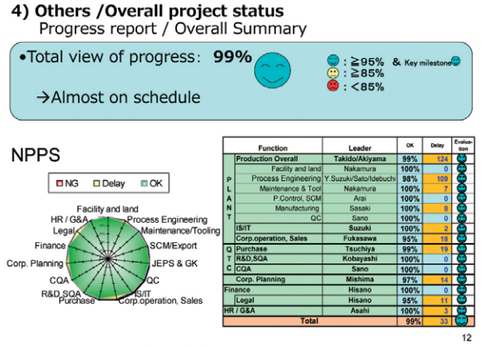


Fig. 6 Progress report

このプロジェクト管理上，最も大切なことは，各ステップのリードタイムの計画値を検証し，修正して，標準となるスケジュールを作っていったことである．この作業により，プロジェクト推進の為のノウハウを積み上げる事ができた．また，節目管理として，NPPM を実施，生産部門長が，準備状況と次の段階への移行判断を実施する機会を作ったことである．（Fig. 7,8）

3. Example of Implementation to JTL Project

3.1. Implementation to project

In April 2011, a project team was formed for JTL project and preparations were initiated. In order to accomplish the production launch in a short period by 2013, it was decided to apply JATCO's version of NPPS for managing the project.

First, the time line for the JTL project was set in reference to the NPPS concept used by Nissan. Activities were then undertaken to add the work specific to JATCO's operations.

Those activities initially completed JATCO's version of NPPS for implementation to the JTL project, and preparations and follow-up were initiated in May. It will be noted that the final number of project steps was approximately 1.5 times more than the number of planned steps.

3.2. Ingenuity in implementation and operation

Every month, the project members repeatedly confirmed the progress of the project based on JATCO's version of NPPS and identified any issues to be addressed. During that process, they noticed some support activities were lacking, including work at the parts supply center that manages spare parts, the dressing of tools, and clarify as well as decide how to deal with surplus parts (to be reused or to be discarded). Therefore, the actual work being done was confirmed together with the project members, issues to be addressed were identified, and measures for resolving them were broken down into respective steps and added to JATCO's version of NPPS. The overall progress of the project was monitored at the monthly meetings, and the results were shared between JATCO Japan (hereafter JTC) and JTL (Fig. 6).

Fig. 7 NPPM #7 three months after SOP

Fig. 8 NPPM #8 three months after SOP

また，仕事のしくみづくりの一環で，TS16949 の認証取得に向けたマイルストーンも作成し JATCO 版 NPPS に加えた. 本プロジェクトは，ジヤトコのグローバルスタンダードを最初に適用した海外プロジェクトである．JTL として必要なスタンダードを，グローバルスタンダード推進チームと連携し，優先順位を付けて，機能軸のメンバーが準備した.（Fig. 9, 10）

3.3. 結果

これらの活動により，新拠点で何も無い状態から，1000 人規模の新会社・新工場を短期間で立ち上げ，早期に目標の生産性を達成した．また今後ジヤトコの Global Standard として活用することができる海外生産工場立ち上げ標準ステップもジヤトコ版 NPPS として確立することが出来た．現場管理プロセスにおいても Quick Response Quality Control（QRQC）（Fig. 11），JEPS 活動板（Fig. 12）による組管理なども，JATCO 版 NPPS によりタイミングよくスタートを切ることが出来た.

Fig. 9 Audit by certification body

Fig. 10 Audit by certification body

One of the most important points in managing this project was to prepare a standard schedule by checking the planned lead time of each step against the actual progress and making adjustments as necessary. This work made it possible to accumulate know-how for driving the project. The critical junctures of the project were managed by holding a New Plant Preparation Meeting, which provided an opportunity for the general manager of the Production Division to assess the status of the preparations and to make a decision about the transition to the next stage (Figs. 7 and 8).

As part of implementing a system for executing the work, a technical specification was prepared as a milestone toward the attainment of ISO/TS 16949 certification and added to JATCO's version of NPPS. This project was JATCO's first overseas project to which we applied the company's global standards. We worked together with Global Standards Promotion Team to create and prioritize the necessary standards for the JTL project, and the members of the functional groups then worked to prepare them (Figs. 9 and 10).

Fig. 11 QRQC action

Fig. 12 JEPS Activity Board

4. JMEX 第 2 工場プロジェクトへの適用事例

4-1. プロジェクトへの適用

NAFTA 圏での CVT 要求増に伴い，2011 年から現地での増産対応の検討を開始，2012 年の計画承認と同時に，JMEX 第 2 工場プロジェクトでもマネジメントツールとして NPPS の正式運用を開始した．JTL プロジェクトに対して，約 1 年後に生産準備を開始した.（Fig. 13, 14）

Fig. 13 Location of JMEX

Fig. 14 Photo of JMEX #2 plant

3.3. Results

As a result of the foregoing activities, a new company and a new plant with a workforce of approximately 1,000 employees were launched at the new site where nothing had existed previously, and the targeted productivity was attained at an early date. In addition, standard steps for launching an overseas plant were also established in JATCO's version of NPPS, which will be utilized as JATCO's global standards for succeeding projects. Workplace management and other processes were also started in a timely manner under JATCO's version of NPPS, thanks to work team management based on Quick Response Quality Control (QRQC) (Fig. 11) and the JEPS Activity Board (Fig. 12).

4. Example of Implementation in JMEX's second manufacturing plant Project

4.1. Implementation to project

In 2011, JATCO initiated a study for increasing local production in the North America Free Trade Agreement (NAFTA) zone due to the growing demand for CVTs. Upon approval of a plan in 2012, official use of NPPS as a management tool was also initiated in the project to construct JMEX's second manufacturing plant (hereafter JMEX #2). Production preparations were begun approximately one year after the JTL project (Figs. 13 and 14).

4-2. 適用・運用の工夫

本プロジェクトは，プロジェクト管理手法の進化を図る為，JMEX 第 2 工場プロジェクトに適用し，且つ，既に JMEX 第 1 工場があるため，メキシコ人エンジニアが主体となり，JTC メンバーはサポート役として，現地オペレーション化を進めた．（Fig. 15）

Fig. 15 Operation by JMEX engineers

従って，プロジェクト管理も初期の段階から現地となることから，機能軸によるバリデーションを毎月実施し，実施項目に抜け漏れがないように，メキシコ人担当者が JTC 担当者と連携して進めた．

進化の 2 点目は，JTL プロジェクトで使用していた NPPS をそのまま使える工程は使用し，またメキシコの状況に合わせ修正すべきところは修正した新 NPPS をプロジェクトに適用した．現状生産をしている仕組みと新しい工場の生産の仕組みを上手く整合をとるところは難易度が高いが，現状の仕組みの課題を解消した上で，新工場へ展開するマネージメントを行った．

4-3. 結果

JMEX 第 2 工場プロジェクトでは生産準備期間の短縮 , 更には生産量の急激な上昇などにチャレンジした．各機能軸のバリデーションで課題を見える化し，スピード感を持って対応することで，生産準備期間は JTL プロジェクトに対し更に約 2 ヶ月間の短縮を実現できた．（Fig. 16, 17）

4.2. Ingenuity in implementation and operation

The system was applied to the JMEX #2 plant project in order to further evolve this project management method. Because JMEX #1 plant was already in operation, Mexican engineers were primarily responsible for promoting the project. JTC members served to provide support and assisted with the localization of the operations (Fig. 15).

Accordingly, because local people were responsible for managing the project from the beginning, validation by the functional groups was carried out at the monthly meetings. The Mexican project staff worked closely with the JTC people in charge to make sure that none of the items to be executed were left out.

JATCO's version of NPPS was applied to JMEX's processes where it could be used in the same form that was employed in the JTL project. Places that had to be modified to match the circumstances in Mexico were incorporated in a newly revised NPPS that was implemented to the JMEX #2 plant. That represented a second evolution of JATCO's version of NPPS. It was rather difficult to harmonize the differences between the production systems already in use at JMEX #1 plant and those for use at the new plant. However, that difficulty was overcome by first resolving the issues in the existing production systems and then applying JATCO's version of NPPS for managing their implementation in the new plant.

4.3. Results

In the JMEX #2 plant project, we undertook the challenges of shortening the production preparation period and quickly increasing the production volume, among other tasks. By visualizing the issues in each functional validation and addressing them swiftly, we succeeded in shortening the production preparation period by approximately two months compared with that of the JTL project (Figs. 16 and 17).

Fig. 16 Photo of opening ceremony on Sept. 10, 2014

Fig. 17 Production scene at #2 plant

5. まとめ

プロジェクト管理手法として，NPPS および SCC を用いて運用し，JTL プロジェクトから JMEX プロジェクトに進化させ，標準プロセスを構築できた．
今後も，更なるリードタイム短縮にむけ，業務プロセス改革に取り組んでいく．

最後に，本プロジェクトを進めるに当りご協力いただいた設備メーカー，および関係者の方々に，感謝を致します．

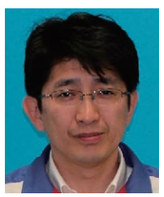
5. Conclusion

JATCO's version of NPPS and SCC were further advanced as project management methods from the JTL project to the JMEX #2 plant project and a standard process for launching overseas plants was established. Subsequently, we intend to make further innovations to our work processes for the purpose of shortening the lead time even more.

Finally, we would like to thank all the partners of equipment manufacturers and everyone involved for their tremendous cooperation in promoting these projects to a successful conclusion.

■ Authors ■

Kazuaki TAKIDO



Manabu MISHIMA

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サプライヤとの連携による THaNKS 活動の取り組み

THaNKS Activity through Cooperation with Suppliers

川田　尚史*
Naofumi KAWADA

抄　録　ジヤトコの購入品費は，Ideal TdC（ありたい Total delivered Cost）達成のために，サプライヤとの連携による改善活動を更に加速することが必要となっている．

本稿では，サプライヤとの協働改善活動（以下，THaNKS 活動）の取り組みについて紹介する．

Summary　It has become necessary for JATCO to further accelerate various improvement activities that are carried out in cooperation with our suppliers in order to achieve the ideal total delivered cost (hereafter TDC) for our purchased parts. This article describes the THaNKS activity that is conducted as a collaborative improvement program with our suppliers.

1. THaNKS 活動導入の背景

ジヤトコでは 2003 年 4 月より，調達プロジェクトセンター主導で，サプライヤとの協働改善活動として，ものづくり改善活動を推進してきた．ものづくり改善活動とは，JEPS（Jatco Excellent Production System）活動を基軸とした現場改善活動により，サプライヤの Quality, Cost, Delivery（以下，QCD）目標を達成すること，また，サプライヤにおける自主改善活動の活性化に取り組む活動である．

しかしながら，Ideal TdC を達成するためには，調達プロジェクトセンターの枠組みを超えて，ジヤトコ全社を挙げた取り組みにより，改善視点の拡大，および改善のスピードアップを行うことが必要となっている．

THaNKS とは，Trusty and Harmonious Nissan Kaizen activity with Suppliers の略称であり，お互いに「ありがとう」と言える活動でありたいという想いを強調した，サプライヤとの信頼と協働を重視する改善活動の感謝の意を込めた略語である．

日産自動車株式会社にて導入されていた THaNKS 活動における考え方をベースに，従来より蓄積してきたものづくり改善のジヤトコのノウハウを織込み，2013 年度より新たにサプライヤとの協働改善活動の進め方を構築した．その特徴は，JEPS 推進部，購入品品質保証部，生産管理部，SCM 推進部，テクニカル原低推進室，および開発各部といったあらゆる関連部門，部署との連携，改善ノウハウの結集による Ideal TdC の推進である．

1. Background behind Introduction of THaNKS Activity

Since April 2003, JATCO has been promoting a monozukuri (manufacturing) improvement program as a collaborative improvement effort with suppliers under the direction of the Purchasing Project Center. This monozukuri improvement program is aimed at enabling suppliers to achieve their quality, cost and delivery (hereafter QCD) targets through gemba (workplace) improvement activities based on the JATCO Excellent Production System (hereafter JEPS). It also involves efforts to promote more self-initiated improvement activities by suppliers.

However, in order to achieve ideal TDC, it has become necessary today to expand the focus of improvement and speed up the pace of improvement activities through company-wide efforts in JATCO that transcend the framework of the Purchasing Project Center.

THaNKS is an acronym that stands for Trusty and Harmonious Nissan Kaizen activity with Suppliers. This acronym embodies a feeling of appreciation for improvement activities that put emphasis on trust and collaboration with suppliers. It emphasizes the idea to appreciate efforts in which each party say “thank you” to the other.

In fiscal 2013, JATCO established a new method of promoting collaborative improvement activities with suppliers by incorporating our previously accumulated monozukuri improvement know-how, utilizing the basic concept of the THaNKS activity originally introduced by Nissan Motor Co., Ltd. A distinctive feature of this method is that it enables us to pursue the ideal TDC by concentrating our improvement know-how and through close teamwork among the various divisions, departments and sections concerned. These include the JEPS Promotion Dept., Purchased Parts Quality Assurance Dept., Production Control Dept., SCM (Supply Chain Management) Promotion Dept., Technical Cost Reduction Promotion Office and the departments of the R&D Division.

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Purchasing Project Center

2. THaNKS 活動の概要

2.1. THaNKS 活動のコンセプト

THaNKS 活動のスコープは，Fig. 1 に示すように，TierN サプライヤからジヤトコに納入されるまでのものの流れを対象としている．それはまさに TdC のありたい姿を追求することである．

改善の視点は，設備総合効率（以下，OEE）向上，物流荷姿改善，品質基準の適正化，経費削減まで多岐に渡る．

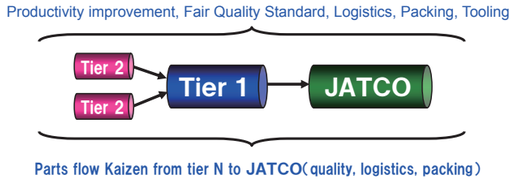

Fig. 1 Scope of THaNKS activity

OEE とは，Overall Equipment Efficiency の略語である．OEE は生産ラインの稼働時間内で，どの程度実際に稼働しているかを定量的に表す指標であり，時間稼働率，性能稼働率，良品率という測定可能な項目で分類される．非稼働項目は，Fig. 2 に示すように，故障ロス，段取りロス，速度ロス，チョコ停ロス，不良ロス，立上げロスの 6 大ロスに大別される．6 大ロスを徹底的に排除し，設備の効率を限りなく向上することが，OEE 向上活動であり，ものづくり現場の真の改善力を測る上で最も重要な指標である．

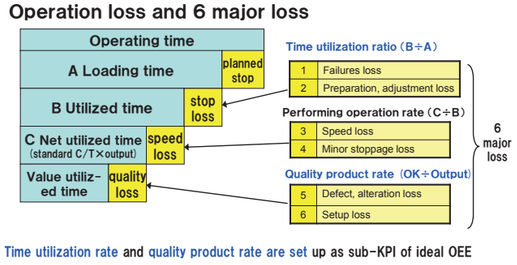

Fig. 2 Six major losses

OEE 向上による効果は，労働生産性のみならず，加工費として含まれる設備償却費，電力，油脂，切削工具，その他経費の低減に影響を与える．

2. Overview of THaNKS Activity

2.1. Concept of THaNKS Activity

As shown in Fig. 1, the scope of the THaNKS activity covers the flow of parts from tier N suppliers to delivery to JATCO. This is truly an optimal framework for pursuing the ideal TDC. The focus of improvement encompasses a wide range of aspects, including boosting overall equipment efficiency (hereafter OEE), improving logistics and packing of parts, optimizing quality standards and reducing costs.

OEE is an index for quantitatively expressing how efficiently equipment is actually operating during the period while the production lines are operating. It is indicated in measureable items such as time utilization rate, performance operation rate and quality product rate. As shown in Fig. 2, non-operating items are classified into six major types of loss, namely, failure loss, preparation adjust loss, speed loss, minor stoppage loss, defectiveness/alteration loss and setup loss. OEE improvement activities are aimed at boosting equipment efficiency infinitely by thoroughly eliminating these six major losses. The OEE index is one of the most important indicators for measuring the true improvement capability of monozukuri gemba (manufacturing workplaces).

The result of improving OEE influences not only on labor productivity improvement but also on reduction of equipment depreciation cost, which includes processing cost, and various expenses such as electricity, oils/greases and cutting tools.

The THaNKS activity is mainly focused on pursuing the ideal OEE. The Nissan Group uses a common ideal OEE for each manufacturing process. Activities for achieving the ideal OEE were discussed in cooperation with suppliers and specified in a three-year plan running from fiscal 2014 to fiscal 2016. Improvement activities are now being

THaNKS 活動は，このありたい OEE（以下，Ideal OEE）を追い求めることを主眼としており，日産自動車グループ共通の工法別 Ideal OEE を活用し，これを達成するための活動を 2014 年度から 2016 年度の 3 ヵ年計画をサプライヤと協働で論議，設定し，達成へ向けた改善活動を推進している．Table 1 は，OEE マイルストーン設定のワークシートである．

OEE の目標は，そのラインに投入する工数を無尽蔵に増加させて達成すべきものではなく，いかに少ない工数で達成できるかを計ることが必要である．これを計る指標としては，一人当り時間毎出来高，JPMH（Job Per Man Hour）の目標を設定し，確実に労働生産性が向上しているかを確認している．

2.2. 対象サプライヤ

基本的には，取引のある全サプライヤを THaNKS 活動の対象としている．

選定に当たっては，調達部と連携し，購入額大，将来性，新商品計画，供給あるいは品質に課題があるサプライヤを考慮し，現在は，グローバル全購入額の 6 割にあたるサプライヤを対象として活動している．Fig. 3 は，拠点別の活動対象サプライヤ数である．

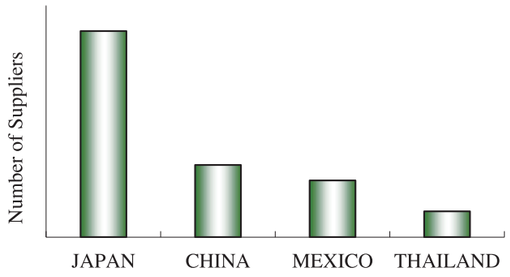

Fig. 3 Number of target suppliers

2.3. グローバル OEE のベンチマークデータを活用したマイルストーンの設定

Fig. 4 に示すように，類似部品，類似工法による OEE のベンチマーク（以下，BM）比較をグローバルで行い，サプライヤの競争力の向上，あるいは Ideal OEE 達成へ向けての意識付けに活用しながら，OEE マイルストーンの設定を行っている．

promoted to accomplish the plan. Table 1 shows worksheet for setting OEE milestones.

OEE targets are not to be achieved by inexhaustibly increasing the number of man-hour deployed on a production line, but rather it is necessary to measure how good OEE can be attained with fewest man-hours. As indexes for measuring their attainment, targets are set for jobs per man-hour (hereafter JPMH) and used to confirm whether labor productivity is definitely being improved.

Table 1 OEE milestone worksheet

Worksheet（Sample）Ideal OEE

OEE improvement milestone

Supplier:

Process:

			Present	Ideal	FY14	FY15	FY16
JPH		JPH					
JPMH		JPMH					
OEE		%					
	Time utilization ratio	%					
	Set−up	Min					
	Breakdown	Min					
	Performing operation rate	%					
	Quality product rate	%					
Cycle time		Min					
Operator number		Per					
	Direct	Per					
	Inspection	Per					
	Logistics	Per					
Logistics	Filling factor	%					
	Ratio of packing material	%					
Key activity							

2.2. Suppliers involved

Basically, all the suppliers are scope of THaNKS activity with whom JATCO does business. In selecting suppliers for the activity, we work in cooperation with the Purchasing Division and take into account purchase amounts, future prospects, new product plans and whether they have any delivery or quality issues. At present, suppliers involved in this activity account for 60% of our total purchase amount globally (Fig. 3).

2.3. Defining milestones using global OEE benchmark data

As shown in Fig. 4, global OEE benchmark comparisons are made for similar parts manufactured by different suppliers and similar manufacturing processes of different suppliers. The results are used to define OEE milestones for improving the competitiveness of suppliers or for motivating them to attain the ideal OEE.

Moreover, improvement proposals that can be shared in common are deployed horizontally by the THaNKS team at different suppliers so as to speed up the pace of improvement activities.

更に共有化できる改善案件は，THaNKS チームにて水平展開を行い，改善活動のスピードアップを進めている．

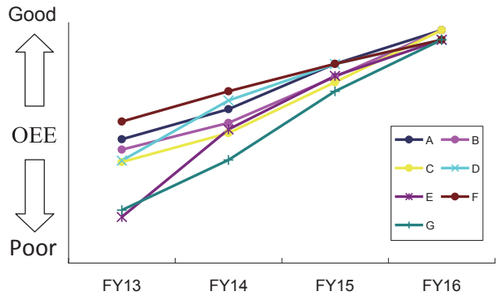

Fig. 4 Global OEE benchmarking

3. 改善事例

代表的な改善事例を紹介する．

(1) 時間毎出来高，JPH（Job Per Hour）の向上によるライン稼動時間の削減（Fig. 5）

(2) 梱包仕様の見直しによる充填率の向上（Fig. 6）

(3) 後加工のある部位のバリ取り作業の廃止（Fig. 7）

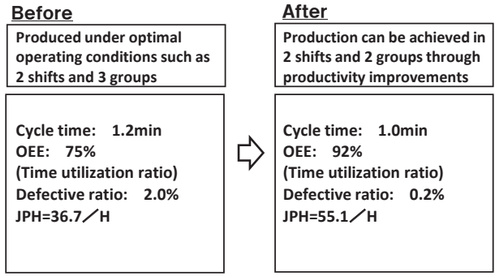

Fig. 5 JPH improvement

4. 海外拠点への展開状況

THaNKS 活動は，日本が CoE（Center of Excellence）機能を持ち，グローバル全拠点で等質化された活動を実施している．

(1) グローバル共通の改善ツール，進め方の展開

(2) 改善アイテムの水平展開

(3) 海外拠点メンバーの人材育成，技術サポート

3. Examples of Improvements

This section describes typical examples of improvements implemented.

(1)Reduction of production line operating time by improving the number of jobs done per hour (hereafter JPH) (Fig. 5)

(2)Increase in number of packing parts by revising the packing specifications (Fig. 6)

(3)Elimination of deburring process for parts to be machined in next process (Fig. 7)

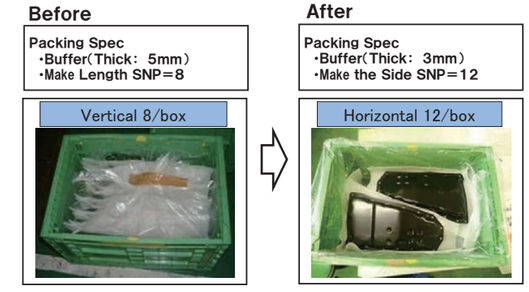

Fig. 6 Improvement of packing rate

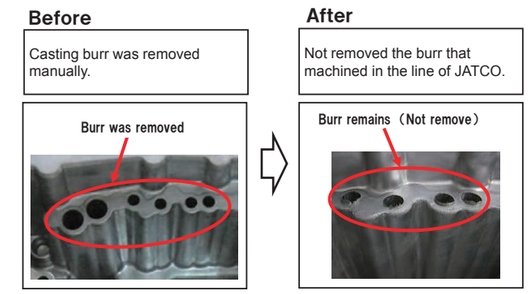

Fig. 7 Elimination of burr removal operation

4. Status of Deployment at Overseas Plants

The THaNKS activity is being conducted uniformly at all overseas plants worldwide, with JATCO Japan serving as the center of excellence.

(1)Deployment of improvement tools and methods that ought to be shared globally

(2)Horizontal deployment of improvement measures

(3)Technical support and education/training of overseas plant employees

Collaborative improvement activities with suppliers

海外におけるサプライヤとの協働改善活動は，2011 年より中国，2012 年よりメキシコを中心とした NAFTA 圏，2014 年よりタイでの活動をスタートさせた．今後のビジネスプランにおいては，Fig. 8 に示すように，更に急速な海外展開が進む計画であり，海外拠点での THaNKS 活動の推進は，より重要な位置づけとなっている．

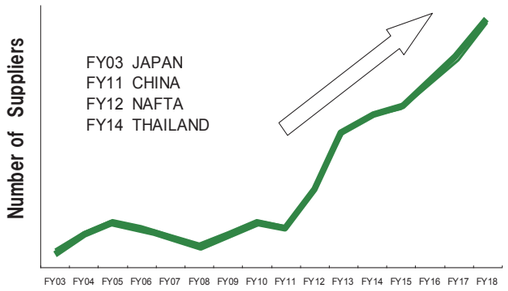

Fig. 8 THaNKS activity deployment

5. 課題および今後の取り組み

現在は，既存の商品に対する改善活動が主体となっている．開発段階からの最適工程設計の検討，あるいはサプライヤ選定段階での QCDDEM（Quality, Cost Delivery, Development, Engineering, Management）評価の充実など，フロントローディングアプローチにより，スムースなローンチングへ向けた取り組みを強化する必要がある．
特に，海外サプライヤの品質強化は今後の拡大を考慮すると重要なポイントであり，更なる品質改善活動の強化，拡大をしていきたい．

最後に，本活動の導入と実施に多大なるご協力をいただいているお取引先の皆様へ，深く感謝の意を表します．

overseas were initiated in China in 2011, in the North American Free Trade Agreement (NAFTA) zone centered on Mexico in 2012 and in Thailand in 2014. Promotion of the THaNKS activity at overseas plants is positioned as an even more crucial activity in the company's future business plan, which calls for more rapid overseas deployment in the coming years as shown in Fig. 8.

5. Issues and Necessary Activity for Future

Currently, improvement activities are mainly undertaken for existing products. However, there is a need to strengthen efforts for facilitating smooth launches based on a front-loading approach. This includes studying the optimal process design beginning from the development stage and improving evaluations of QCDDEM (quality, cost, delivery, development, engineering and management) capabilities of suppliers at the stage where they are selected.
Strengthening the quality of overseas suppliers will be an especially critical point, considering JATCO's plans for future global expansion. Toward that end, we intend to further strengthen and expand our quality improvement activities.

Finally, we would like to sincerely thank all of our suppliers for their tremendous cooperation in introduction and implementation of this activity.

■ Authors ■

Naofumi KAWADA

Memo

サプライヤとの連携によるグローバルな品質向上活動

Global Quality Improvement Activities in Cooperation with Suppliers

鈴木　健史*　Takefumi SUZUKI
田原　睦浩**　Mutsuhiro TAHARA

抄　録　ジヤトコは購入品の品質向上を目的として，サプライヤとの連携した継続的改善活動を行なっている．購入品の品質については高い要求を求めているが，今回は品質向上につながる活動と，グローバルな品質向上活動についての取組みを紹介する．

Summary　JATCO is carrying out continuous quality improvement activities in cooperation with suppliers for the purpose of improving the quality of purchased parts. There are high requirements for the quality of purchased parts. This article describes an activity that leads directly to quality improvements and an activity for improving global quality levels.

1. はじめに

急激な自動車市場の増加に伴い，購入品への品質向上の要求は益々その重要度が高まっている．

特にグローバル化が進む中で，購入品の品質を向上させ，継続的に改善していく事が急務となっている．

ジヤトコは部品を納入頂いているパートナーであるお取引様（以下サプライヤ）と共に，PDCA のサイクルを早く回す事で，いち早く品質向上に努め，お客様へ満足と安心を届けられるよう，改善活動を進めてきた．

今回はこの中で，お客様の品質に直接繋がる「品質ランクアップ活動」と，仕組みの見直しに有効な「グローバルマネージメント品質向上活動」について，紹介する．

2. お客様の品質に直接繋がる購入品品質向上活動

2.1. 購入品品質保証活動

購入品の品質保証に関しては，サプライヤと協議の上，高い目標を設定し，未然防止活動を主体に進めている．

毎月，サプライヤ毎に，納入不具合件数及び不具合発生時のインパクト，部品難易度等総合的に評価して，重点的な対象サプライヤを選定し，活動を進めてきた．

本活動対象は，前期の実績から対象サプライヤを選定し，半期毎の集中した改善活動として「品質ランクアップ活動」を実施している．

以下に，活動の概要を説明する．

（1）対象サプライヤの選定

前年度の品質納入不具合の実績等から，ジヤトコの海外拠点も含めた対象先の絞込み，各拠点と活動の合意を得る．

（2）活動内容

サプライヤとの間で，本活動について計画を策定する．活動メンバーは，品証，生産技術，工場での連携したチーム構成をする．

（活動期間は半年．ジヤトコ独自の品質評価ツール（Fig. 1）を用い，活動開始時，終了時に評価を行い，目標に達すれば活動は終了，未達の場合は活動継続となる）

①活動計画書の作成，実行

ジヤトコとサプライヤで，前年までの品質実績と解析に基き，ランクアップ活動の活動計画を作成し合意する．

②過去に経験したトラブル（過去トラ）対策状況の再点検，水平展開実施項目確認

過去トラや水平展開事項がFMEA，コントロールプラン，標準作業表等に落とし込まれているか確認

③品質評価ツール（現場 16 項目診断）による，16 分類の現場診断項目を更に細分化した，58 項目を定量的に評価し，総合点をつける．

このジヤトコ独自の評価ツールを使い，サプライヤの“強み”“弱み”の抽出を行なう．

1. Introduction

The rapid expansion of the global vehicle market has increasingly heightened the requirement to improve the quality of purchased parts. There is an urgent need to make continuous improvements and enhance the quality of purchased parts particularly in view of the ongoing globalization of JATCO's operations.

We have been proceeding with improvement activities with our partners who supply us with parts and materials in order to provide satisfaction and trust to our customers. This has involved efforts to speed up execution of the Plan-Do-Check-Action (hereafter PDCA) cycle with the aim of improving quality levels as quickly as possible.

This article describes the“Quality Rank Up Activity”that is directly related to our customers product quality and the“Global Management Quality Improvement Activity”that is effective for improving work processes.

2. Purchased Parts Quality Improvement Activity Directly Related to Customer's Product Quality

2.1. Quality assurance activity for purchased parts

For purchased parts quality assurance, high quality assurance targets are set through discussions with suppliers, and activities are focused on preventing quality issues occurrence in the first place.

Comprehensive evaluations have been made every month for each supplier with respect to the number of defective parts delivered, the impact on our operations by such defects, manufacturing difficulty level of parts and other aspects. Based on the results, suppliers have been selected for improvement and activities have been undertaken to improve their quality levels. The suppliers for this activity have been selected on the basis of their delivery results for the previous fiscal year, and the“Quality Rank Up Activity”has been carried out as a concentrated improvement program for six months. An overview of this activity is given below.

(1) Selection of suppliers

Among partner suppliers, including those of JATCO's overseas assembly plants, few of them are selected on the basis of their previous fiscal year's results for delivery of parts with quality defects and other criteria. An agreement is reached between the selected partner suppliers and each assembly plant concerning the improvement activities to be undertaken.

(2) Details of the activity

A plan for quality improvement activity is worked out together with each supplier. The activity team consists of member from quality assurance, production engineering and production plant. The activity is conducted for a period of six months. Evaluations are made at the beginning and end of the activity using JATCO's original quality evaluation tool (Fig. 1). If the quality targets are achieved, the activity is concluded; if they are not achieved, the activity is continued.

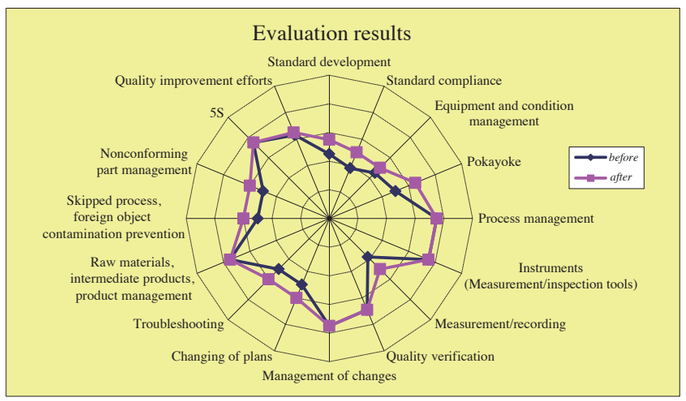

Fig. 1　Quality diagnosis

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Supplier Quality Assurance Section, Quality Assurance Department
** 品質保証部
Quality Assurance Department

④活動期間は 6 ヶ月を目標とし，“現場”“現物” で確認する事を惜しまない事が大切である.

(3) 活動終了

上記，対象期間の品質実績を確認し，不具合発生がないこと，また実活動での実施状況を確認し，活動計画書通りに実行され，改善が認められた時点で，活動完了確認は“現場”“現物”で行ない，節毎に完結させる.
活動のクローズについては，サプライヤ責任者，ジヤトコ責任者の合意の上で，判断する.

2.2. 活動の成果

以上の活動は 10 年前から活動がスタートし，年々活動の成果が上がり，品質向上に繋がっている．特に日本国内を中心に進めた結果，国内の購入品品質は安定してきている.

しかし海外の状況は，日系サプライヤを含め，まだ課題はある．ローカルサプライヤのみならず，増加する海外サプライヤと連携し，本活動の目的をしっかり合意して，海外拠点を中心に活動を進め，サプライヤ自身での，PDCA のサイクルが運用できるように広めていきたい.

3. 仕組みの見直しに有効な購入品品質保証活動

3.1. 概要

グローバルでの市場成長に伴い，ジヤトコも海外拠点の増産を進めている．購入品に関しても，現行の日本製部品から，海外での生産部品に現地化を進めており，協力サプライヤも海外へ進出を進めている.

現地化に当たっては，現行部品同等の品質レベルを要求しており，その為には日本拠点と海外拠点での連携はもちろん，本社機能としての役割分担を明確にして，他拠点を指導支援する事が，必要不可欠である.
(Fig. 2)

本活動では，サプライヤの組織，体制についても確認し，独自の評価手法を用い，定量的に評価する事で，サプライヤ毎の“強み”“弱み”を見出し，継続した改善活動に繋がるよう，支援するものである.

大切な事は，海外に進出したサプライヤの国内拠点の仕組み，ノウハウが転写され，マネージメントされているかが必要である．このマザー機能を評価する為の評価ポイントを整理した.（Fig. 3）

(1) Preparation and execution of the activity plan
JATCO and supplier jointly prepare and agree on a plan for the “Quality Rank Up Activity” based on an analysis of the quality results up to the previous fiscal year.

(2) The status of actions taken to address problems experienced in the past is re-examined, and measures designed for horizontal deployment are confirmed. Checks are made to verify whether measures against previous troubles and measures for horizontal deployment are duly incorporated in the Failure Mode and Effects Analysis (FMEA), process control plan, standard work sheets and other places.

(3) JATCO's quality evaluation tool for diagnosing 16 types of criteria in the workplace is further subdivided into 58 items and supplier status is quantitatively evaluated and an overall score is summed up. This JATCO original evaluation tool is used to identify the strengths and weaknesses of supplier.

(4) The target period of this activity is six months. It is essential to confirm the actual site and actual part (gemba and gembutsu) without sparing any effort.

(3) Conclusion of the activity

The quality improvement results are confirmed at the end of the target period. Checks are made to ensure that no defects are occurring and that the improvement measures have actually been implemented in workplace operations. At the point where it is verified that the measures have been implemented according to the activity plan and it is recognized that improvements have been achieved, the conclusion of the activity is confirmed on the basis of the actual situation in the workplace, and the activity is concluded at a suitable milestone. The person in charge at the supplier and the JATCO person in charge decide whether to conclude the activity based on a mutual agreement.

2.2. Results of the activity

The activity described above was initiated ten years ago and has been producing substantial results every year that have led to quality improvements. As a result of promoting this activity primarily in Japan in particular, the quality of parts purchased in Japan has stabilized at a high level.

However, the situation in overseas is still has scope of improvement, including the local subsidiaries of our Japanese suppliers. We have been working closely not

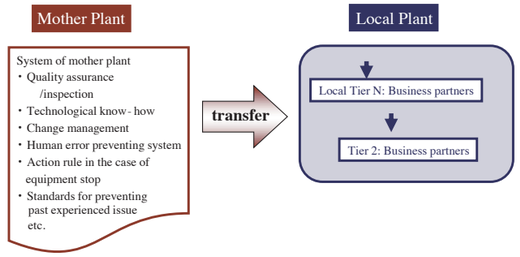

Fig. 2 Know-how transfer from mother plant to new plant to establish homogeneity

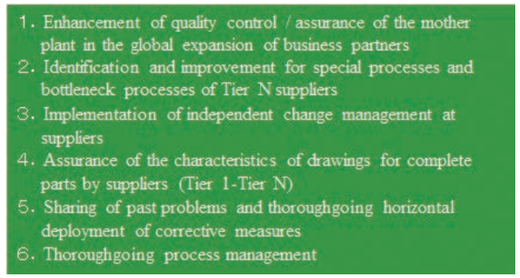

Fig. 3 Focal points

以下に，活動の内容を説明する.

(1) 対象サプライヤの選定

過去に国内親会社では管理できている項目が，海外拠点に転写されておらず，納入品不良が発生した経緯があった．また，ジヤトコからの仕様提示部品に関し，当方での確認事項も不足して，納入品不良に繋がることが起きた.

そこで今回は，サプライヤ毎の，国内，海外の生産拠点数，品質実績，対象部品（部品難易度等）から，活動対象の絞込みを実施した.

(2) 活動内容

対象となる，本社機能を有するサプライヤと，活動内容を計画する.

本社機能を有する親会社が，どのように子会社と連携を取っているか？本社機能の確認と，子会社での対応状況を確認する.

（活動期間は原則半年．ジヤトコ独自の品質評価ツールを用い，活動開始時，終了時に評価を行い，目標に達すれば活動は終了，未達の場合は活動継続となる.）

only with local suppliers but also with overseas suppliers that are increasing in number. Improvement efforts are undertaken centered on the assembly plants based on firm agreements with suppliers concerning the objectives of the activity. There has been a steady expansion of suppliers capable of executing the PDCA cycle by themselves.

3. Purchased Parts Quality Assurance Improvement Activity, Effective for Improving Work Processes

3.1. Overview

JATCO has been increasing production volumes at overseas plants accompanying the growth of the global vehicle market. Production of purchased parts is also being localized overseas based on existing parts manufactured in Japan. Our partner suppliers are also setting up their own overseas production plants.

In localizing production operations, we have demanded that quality levels equal to those of existing parts to be achieved. Naturally, that involves close teamwork between our assembly plants in Japan and the overseas plants. In addition, a clear division of responsibility has been defined for head office functions, and it has been absolutely necessary for the mother plant in Japan to provide guidance and support to overseas plants as shown in Fig. 2.

This activity also involves checking the organization and systems of suppliers. Using JATCO's original evaluation tool, we conduct quantitative evaluations, identify the strengths and weaknesses of suppliers, and provide support for helping them to undertake continuous improvement activity.

One point that is important for suppliers who have established operations overseas is that they must transfer the systems and know-how of their domestic plants to their overseas facilities and ensure that they are managed effectively. Figure 3 summarizes the key points for evaluating this mother plant function.

Detail this activity is given below.

(1) Selection of suppliers

In the past, there were instances where defective parts were delivered because the quality assurance criteria that the parent companies properly managed in Japan were not transferred to their overseas plants. In addition, there were cases where we did not fully confirm detail specification designed by supplier based on specification requirement issued by JATCO, which also led to the occurrence of

①グローバルマネージメント力評価シート
（Fig. 4）に基づく，体制組織の評価を実施.
サプライヤの“強み”“弱み”の抽出を行なう.
②活動画書の作成，実行
ジヤトコとサプライヤでの活動の合意
③改善項目の反映を，サプライヤの組織図，基準書等で確認し，活動の浸透を図る.

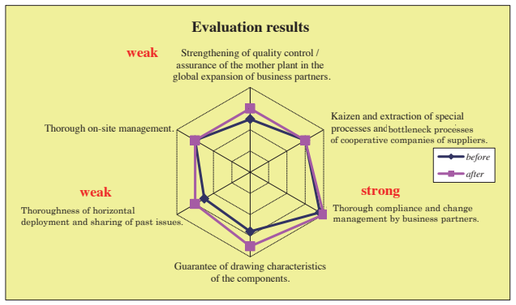

Fig. 4 System diagnosis

（4）活動終了
上記，実活動での実施状況を確認し，改善が認められた時点で，活動をクローズさせる.
活動のクローズについては，サプライヤ責任者，ジヤトコ責任者の合意の上で，判断する.

3.2. 活動の成果

今年度（FY14）よりスタートした活動で，まだ手探りの段階ではあるが，効果は得られ始めている．本活動を基に，サプライヤ独自での活動に移行しているところも出始めている.
（従来の水平展開の仕組みに加え，各工場間への横展開を精査し，監査を行ない，効果の確認を実施する専任部署を立上げたサプライヤもある.）
今後は対象範囲を広げ，部品難易度，国内外対象を問わず，全てのサプライヤと連携して，品質向上に努めていく.
特に海外に本社拠点を置くサプライヤについては，仕組みも含め国内との違いもあるので，本活動を広め，品質向上に努めていきたい.

defects. Therefore, we selected suppliers for this activity based on the number of production plants each supplier has in Japan and overseas, their quality assurance performance and the candidate parts to be improved, including manufacturing difficulty level of parts and other aspects.

(2) Details of the activity
The details of the activity are planned together with the head office members of partner suppliers. A check is made how head office of suppliers work together with their subsidiaries. Their head office functions are confirmed along with verifying the status of measures to be implemented at their subsidiaries.
In principle, the activity is conducted for a period of six months. Evaluations are made at the beginning and end of the activity using JATCO's original quality evaluation tool. If the quality targets are achieved, the activity is concluded; if they are not achieved, the activity is continued.
(1) The organization and work processes of a supplier are evaluated based on a form for evaluating global management capabilities (Fig. 4). The strengths and weaknesses of the supplier are identified on the basis of the evaluation results.
(2) An activity plan is prepared and executed according to an agreement between JATCO and the partner supplier concerning the details of the improvement activity.
(3) A check is made to confirm that the items to be improved are included in the supplier's organizational chart or standards documents and other documents, and efforts are made to thoroughly penetrate the activity.

(4) Activity conclusion
At the end of the activity, a check is made to confirm that the improvement measures have been implemented during the course of the activity. If it is recognized that improvements have been made, the activity is concluded. The person in charge at the supplier and the JATCO person in charge decide whether to conclude the activity based on a mutual agreement.

3.2. Results of the activity

This activity was initiated in the current fiscal year (FY14) and has already begun to produce results even though it is still at the trial-and-error stage. There are some suppliers that have started to transition to their own independent efforts based on this activity. Some

4. 謝辞

最後に本活動にあたり，多大なるご協力，ご理解を頂いているサプライヤの関係の皆様ならびに社内の関係者に感謝いたします.

suppliers have also formed a dedicated department that carefully checks and monitors the lateral deployment of improvement measures at each plant, in addition to the traditional system for horizontal deployment, and confirms the results obtained.
In the future, we intend to expand the scope of this activity and work vigorously with all suppliers to improve quality. This will be done regardless of the manufacturing difficulty level of parts and whether supplier is located in Japan or overseas.
We especially want to extend this activity to suppliers whose head office is located overseas and strive to improve quality with them. This is because their organizations and work processes differ from those of suppliers in Japan.

4. Acknowledgments

Finally, we would like to thank everyone involved at the partner suppliers and also within JATCO for their understanding and tremendous cooperation with these quality improvement activities.

■ Authors ■


Takefumi SUZUKI


Mutsuhiro TAHARA

『JATCO Standard Line』(JSL)の構築

Global CVT Line 加工･熱処理･組立の実例

Establishing JATCO Standard Line

—Global CVT Line, Example of Machining, Heat Treatment and Assembly—

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抄　録　2012 年より生産技術革新として JATCO Standard Line（以下 JSL）の構築に着手し，2020 年には，世界一のフレキシビリティをもった第 4 世代 JSL 実現を目指し，部品・工法毎に推進中である.

本稿では，加工，熱処理，組立の JSL 活動内容および設備本体・周辺機器の構想を実現した第 2 世代 JSL のグローバル展開状況について紹介する.

Summary　JATCO Standard Line (hereafter JSL) was initiated in 2012 to reform production engineering. Activities are being promoted to develop JSL for each part and process with the target of building the fourth generation of JSL, aiming the world's highest flexibility by 2020. This article details the JSL activities undertaken for the machining, heat treatment and assembly lines and describes the global deployment status of the second-generation JSL that embodies the concepts envisioned for the equipment proper and peripheral devices.

1. はじめに

トランスミッション(T/M)グローバル No1 企業を目指すには，生産拠点のグローバル拡大や，既存の生産拠点における更なる増強やモデルチェンジが必要になることが想定される.

このような環境の中，生産ラインを各リージョン最適，プロジェクト最適，デマンド最適など，グローバル視点での統一性を欠いたコンセプトのままで展開していくと，投資，生産準備期間，習熟期間，生産開始（以後，SOP）後のランプアップなどが一過性となり，それぞれのスパイラルアップが期待できず，各々個別対応が必要となり，設備投資やエンジニアリングリソースは増大する一方となる.

そこで，グローバルに通用し競争力のある革新的なスタンダードラインを構築する必要性が生じてきた.

2012 年，生産技術を中心に「JSL ワーキング活動」をスタートさせ，2013 年生産開始したジヤトコタイランド（以下　JTL）は「JSL 第 1 世代」を反映し，2014 年 8 月に生産開始した最新拠点ジヤトコメキシコ第 2 工場（以下 JMEX#2）は「JSL 第 2 世代」を実現した工場である.

1. Introduction

To become the Global No. 1 Transmission Manufacturer, it is envisioned that JATCO must expand its production plants globally and further intensifying its existing production plants capability as well as undertaking production line model changes.

Amid this environment, if we had introduced new production lines without any consistency from a global perspective with regard to regional, project and market demand optimization, the results would only be transitory, and we could not expect any significant improvement with regard to capital investment, production preparation lead time, training of skilled employees and ramping up of production volumes following the start of production (hereafter SOP). Consequently, we would have to deal with these issues individually, which would only increase capital investment and the unnecessary usage of engineering resources.

For that reason, it became necessary for us to construct an innovative standard production line that has ample competitiveness and can be deployed globally.

In 2012, Production Engineering was principally responsible for initiating the JSL Work Activity. The first-generation JSL was installed in the plant of JATCO Thailand (hereafter JTL) where production began in 2013. The second-generation JSL was installed in JATCO Mexico's Plant No. 2 (hereafter JMEX #2), the latest production facility that launched production operations in August 2014.

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2. JSL ワーキング活動　概要

JSL のコンセプトは，以下の 3 本柱である.

①設備のダウンサイジング化

②設備能力と投資の比例化

③多機種対応の設備開発

その 3 本柱を，より具体化するため JSL ワーキング活動は，以下 6 つの評価指標を設定し活動を進めた.

1. ラインモジュール（ラインあたりの生産量）
2. 投資
3. フレキシビリティー（ラインあたりの生産可能機種数）
4. 生産準備工数
5. OEE（設備総合効率）達成期間
6. 面積

また，JSL の姿は，Fig. 1 のように第 1 世代から第 4 世代までのステップごとにそのシナリオを描き，そこに向かい推進中である.

ワーキング活動で生み出された新技術など，新たなチャレンジもフレキシブルに取り込み，シナリオを修正しながら，JSL ワーキングにて情報を共有化し，また，バリデーションしながら方向性を明確にし，活動を進めた.

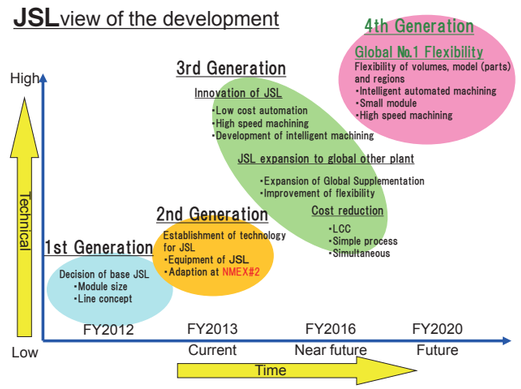

Fig. 1 The road map of JSL

2. Overview of JSL Work Activity

The JSL concept consists of the following three concept.

(1) Downsizing of equipment

(2) Capital investment proportional to equipment capacity

(3) Development of equipment capable of handling multiple models

In order to specify these three concepts more concretely, the JSL Work Activity defined the following six evaluation indexes and proceeded with efforts to develop JSL.

1. Line module (production volume per line)
2. Capital investment
3. Flexibility (number of models producible per line)
4. Production preparation man-hours
5. Time needed to achieve the targeted overall equipment efficiency (hereafter OEE)
6. Area

As shown in Fig. 1, a scenario was created for evolving JSL through each stage from the 1st generation to the 4th generation, and efforts have been under way to achieve the configuration envisioned for each step.

New challenges that have emerged have been tackled flexibly, including the new technologies created during the course of the JSL Work Activity. Information has been shared in the JSL Work Activity while modifying the scenario as necessary. Moreover, the future direction of the work has been made clear in the process of validating the results, and the activities have continued to move forward.

3. 活動事例

以下に，CASE 加工，熱処理，組立の活動事例を紹介する.

3.1. CASE 加工

CASE 加工での面積 1/2 への取り組みを紹介する.
グローバル化に向けた生産ラインの重要課題の 1 つとして，各海外拠点における建屋を含むエリアの確保がある. 占有面積を縮小できると建屋の投資も小さく抑制することができ，多くの拠点に展開する際のリードタイムも大幅に短縮できる. 建屋と土地を小さくすることは多拠点での生産対応にとって重要な課題である. この課題を設備ダウンサイジングによって解決した.

Fig. 2, 3 に，トランスミッションケースの加工設備面積を半減化した事例を示す.
加工設備（汎用マシニングセンタ）を横型から縦型にすることにより，投影面積（必要エリア）を約半分にできた.

これまでトランスミッションケースのような大物部品は，加工ストローク不足，設備剛性不足，送り速度が上げられない，熱歪の影響を受け易い，切粉による品質問題を起こし易いなどの課題から縦型マシニングセンタを採用できなかった.

しかし，近年ダウンサイジングを実現するために設備メーカー各社が，加工領域を効率よく拡大可能なベッドレスタイプの新規開発を行い，長ストローク，高剛性，高速を実現した縦型マシニングセンタを開発した. その開発設備をベースに設備メーカーと連携し切粉などの品質課題をクリアし，また，側面作業廃止，タンク構造見直しなどライントータル面積の削減に取り組んだ結果，縦型採用によるライン面積を半減することに成功した.

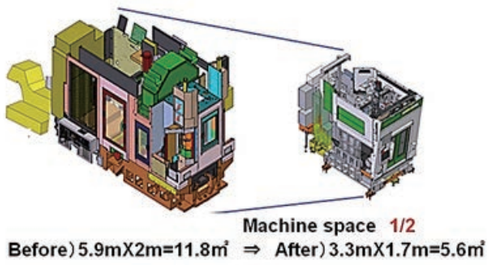

Fig. 2 Downsized case machining center

3. Examples of Activities

This section describes examples of the activities undertaken for case machining, heat treatment and assembly.

3.1. Case machining

The challenge of reducing the area for case machining by half is described here. One critical issue for the global deployment of production lines is to secure a sufficient area, including the building floor space, at each overseas location. Reducing the floor space occupied by the lines also holds down the capital investment in the plant building as well as substantially reducing the necessary lead time when lines are built at many plants. Reducing the area of the land and building is a crucial issue for facilitating production at many plants. This issue was resolved by downsizing the equipment.

Fig. 2 and 3 present examples of transmission case machining equipment that was downsized by one-half. By changing the machining facility (general-purpose machining center) from a horizontal machine to a vertical one, the projected area, i.e., necessary floor space, was approximately halved.

Previously, vertical machining centers could not be adopted for large parts like transmission cases because of various issues, including insufficient cutting tool movement stroke and stiffness and inability to increase cutting feed rates. Conventional vertical machines were also susceptible to the effects of thermal distortion and chips after cutting were apt to cause quality issues.

However, for the purpose of downsizing equipment, in recent years machine tool makers have developed new headless-type vertical machining centers that can efficiently expand the machining area. The newly developed vertical machines achieve longer movement strokes, higher stiffness and faster cutting speeds. Based on these new machines, we worked together with machine tool makers to resolve the quality issue caused by chips and also reduced the total line area by eliminating work operations at the side of the machines and revising the fluid tank structure, among other changes. As a result, we succeeded in halving the line area by adopting vertical machining centers.

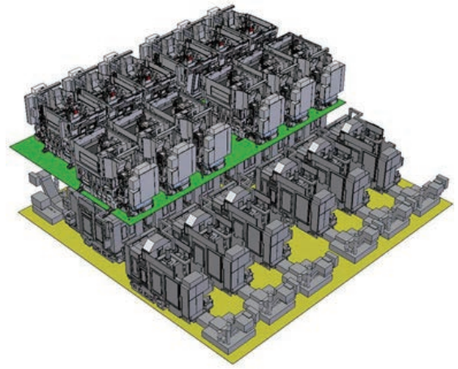

Fig. 3 Downsized JSL case machining line

3.2. 熱処理

熱処理設備における JSL を Fig. 4 に示す.

Fig. 4 は浸炭設備の事例である. 従来の生産モジュールとしては 12 セルが一式となった生産モジュールであり，生産量の増大への対応は，この 12 セル揃ったモジュールを順次追加していく方式であった. しかしこのような方式では，多くの海外拠点で同時に生産能力を増強する必要性が発生した場合には必要な投資が高額となる課題が生じていた.

そこで，Fig. 4 に示すように，連続浸炭方式からバッチ処理方式の考え方を導入することにより，12 セルから 2 セル単位で順次追加できる浸炭設備とすることによって，生産能力を段階的に増加させることを可能とした.

さらに，生産能力増強にかかる設備準備リードタイムも削減とすることが可能となった. また，生産台数が減ったときにも，適正なセル単位で設備稼働，中止できるような設備仕様とすることも JSL の基本コンセプトに取り入れ，需要に応じた生産能力のきめ細かい調整も可能とし，CO_2 排出削減にも貢献する仕様とした.

3.2. Heat treatment

The JSL configured for heat treatment equipment is shown in Fig. 4. The example in this figure is for carburizing equipment. Previously, one complete production module consisted of twelve cells. Increases in production volumes were handled by successively adding more 12-cell modules. However, this approach gave rise to the issue that large capital investments were required when it was necessary for many overseas plants to expand their production capacity simultaneously.

Therefore, instead of a continuous carburizing system, we introduced the concept of a batch processing system as shown in Fig. 4, which allows the successive addition of two cells at a time to the original twelve cells. The adoption of this carburizing equipment makes it possible to increase the production capacity in incremental steps.

Moreover, it also allows a shorter lead time for preparing the equipment needed to expand the production capacity. The basic JSL concept also includes the idea of adopting equipment specifications that allow operation with the optimal number of cells and suspending the use of some cells when the production volume declines. This enables the production capacity to be fine-tuned to match demand, and the equipment specifications thus also contribute to reducing CO_2 emissions.

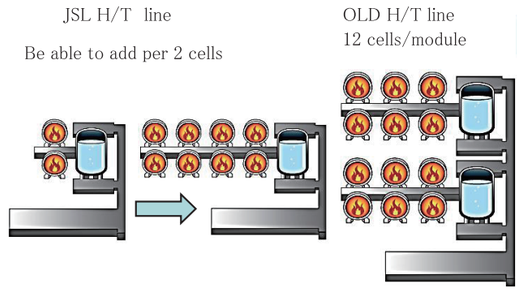

Fig. 4 JSL heat treatment line with flexible modules

3.3. 組立

組立ではフレキシビリィティについて紹介する.

グローバル化に向けた生産ラインの重要課題の一つとして，多機種の生産を同一の設備で生産できるようにすることがある．各拠点にて納入先が増加するにつれて生産機種数の増加も発生し，その対応のため，異なる仕様を同一の設備で生産できるようにするニーズが高い．さらにグローバルな各拠点においては同一仕様が大量に流れることはむしろ少なく，かつ商品のライフサイクル短縮によって，モデルチェンジも早期化してきているため，単一機種向け専用の設備では適正な生産量が確保できずに生産効率が極端に悪くなるおそれも高まった.

そこで，スタンダードラインにおいては，多機種対応できる設備開発を掲げ，活動を実施している．Fig. 5 に圧入設備における具体的事例を示す.

従来の組立てラインでは圧入工程においては，機種毎に圧入装置を準備していたが，圧入治具を固定部と変動部とに分ける構造とすることにより，多機種対応可能な設備とすることができた．その結果，圧入装置の機械要素および制御部の 98%が共通する標準装置の開発ができ，スタンダードラインの柱の 1 つである総設備面積の縮小にも貢献できた.

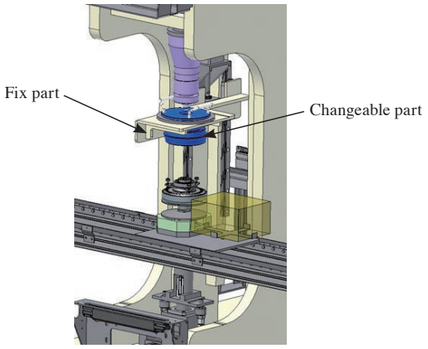

Fig. 5 Flexible press machine

4. まとめ

JSL 活動の成果について，6 つの指標の改善結果を Table 1 にまとめる.

現時点は第 2 世代までの成果であるが，6 つの指標とも大きな改善効果が出ている．継続して活動し，さらなる改善を進める.

3.3. Assembly

The incorporation of flexibility in the assembly line is described here. One key issue in building production lines suitable for global deployment is to have equipment that can produce different models simultaneously on the same line. As the number of customers at each plant increases, it becomes necessary to increase the number of models produced. To accomplish that, there is a strong need to be able to produce models with different specifications using the same equipment. Moreover, there is rather less chance that any one of the globally located plants would have to produce extremely large volumes of the same specifications, and the shortening of product life cycles is also resulting in quicker model changes. Therefore, having dedicated equipment designed to produce only one model would not secure optimal production volumes, and there would be a greater risk that production efficiency would decline drastically.

Therefore, for the JSL assembly line, we undertook activities to develop flexible equipment capable of handling multiple models. Fig. 5 shows a specific example of a flexible press-fit machine developed for that purpose.

For the press-fit process of previous assembly lines, we used to prepare separate press-fit machines for each transmission model. However, by adopting a machine structure that separated the fixed and changeable parts of the press jigs, we were able to build press-fit machines capable of handling different models. As a result, 98% parts and control unit of press-fit were developed as common for different models. That also contributed to reducing the total equipment area, which is one of the concepts of the JSL.

4. Conclusion

The results of the JSL Work Activity are summarized in Table 1 in terms of the effects of the improvements achieved for the six indexes. At this point, these results extend as far as the second-generation, but it is clear that all six indexes show the effects of large improvements. We are continuing our efforts to pursue further improvements.

Table 1 Effects of six JSL indexes

6 indexes	The effect of 6 indexes in JSL (Base ; the old line is 100%) 50% 100%
	Example ＪＳＬ effect by the JSL ▲２１％
1．Line module (volume / line)	▲１５％
2．Total investment	▲６％
3．Production flexibility	▲３３％(Improvement)
4．Production preparation manpower	▲２６％
5．Achievement term of OEE	▲２２％
6．Space efficiency	▲２４％

5. 終わりに

本稿では JSL 事例の一部を紹介した．今回紹介出来なかった鋳造，鍛造，プーリー，ギヤラインも，グローバル展開の都度，JSL 化を拡大していく.

JSL 活動を通じて，JSL の 6 つの指標の劇的な改善はもとより，生産技術員のスキル・マインドも著しい成長を遂げており，今後も生産技術部門の根幹の活動として継続していく.

最後に，JSL 活動を進めるにあたり，ご協力いただいた設備メーカーの皆様，社内の関係者各位に感謝の意を表します.

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5. Final Remarks

This article has described some typical examples of the activities undertaken to establish JSL. Though not described here, we plan to expand the JSL concept also to the casting, forging, pulley assembly and gear lines for global deployment.

Besides the dramatic improvements achieved in the six JSL indexes, the JSL Work Activity also helped to markedly heighten the skills consciousness of Production Engineering employees. It will be continued in the coming years as a core activity of the Production Engineering Department.

Finally, we would like to thank the machine tool makers and everyone concerned at JATCO for their tremendous cooperation in promoting the JSL Work Activity.

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生産情報 ICT 化による品質向上

Quality Improvement by ICT (Information and Communication Technology) in Manufacturing

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抄　録　ジヤトコは，グローバル化推進のための生産方式の進化として，2010 年 4 月より統合情報アプリケーション（株式会社ワイ・ディ・シー社製 SONAR）を利用した社内品質関連情報の一元管理化を進めている．このシステムは，開発・生産・市場の品質情報を全社的に幅広く活用し，当社品質の維持・向上を図るために導入したシステムである．

本稿では，生産部門における生産情報 ICT（Information and Communication Technology）による品質向上の取組み内容を報告する．

Summary　Since April 2010, JATCO has been promoting centralized processing of internal quality-related data using SONAR, a comprehensive information application developed by YDC Corporation. This is being done to advance the production system for promoting globalization of the company's operations. This quality improvement system enables company-wide use of quality information coming from development, manufacturing and global markets. It was implemented in order to maintain and improve the quality of JATCO products.

This article describes in detail activities undertaken to improve quality through the use of Information and Communication Technology (hereafter ICT) for handling manufacturing information in the manufacturing Division.

1. はじめに

ジヤトコの生産ラインでは，部品加工データや組立データを，主として品質トレーサビリティや品質管理として活用している．

これらのデータを最大限活用し，品質改善スピードを飛躍的に向上するため，徹底的な見える化を行い，誰でも活用できる新たな品質システムを構築したのでその内容について報告する．

2. ICT 化の取組み

2.1. 課題と方策

生産品質向上のための課題とその対応方策を Table 1 に示す．

1. Introduction

Parts machining data and assembly data are used mainly for quality traceability and quality management on JATCO's manufacturing lines. Such data must be thoroughly visible in order to make maximum use of it for dramatically increasing the speed of quality improvements. This article describes the new quality improvement system we have built that anyone can use.

Table 1　ICT issues and measures for improving production

	Issues	Measures
①	To reduce searching time. Part number ⇕ Applied unit number	On-line automatic search system. Two type of search option. Part No. to Unit No. Unit No. to Part No.
②	To control deviation of unit assembly performance by watching part spec. deviation.	One-by-one monitoring system. Relationship between parts spec. deviation and unit assembly performance are connected by it.
③	To make automatic control tool for daily deviation control, that is easy to use for operators at line.	Deviation data on-line accumulation and on-line monitoring system for various control items.
④	To make rapid quality analyze by utilizing past know-how.	On-line quality data analyzing system in which expert know-how is automatically applied.

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Project Promotion Section, Engineering Management Department

2.2. 新品質システムの構成

各工場の独立している加工及び組立の品質データをつなぎ，各種データが組合せて分析できるように統合情報アプリケーション（SONAR）を導入した（Fig. 1）．

【特徴】
①異なるデータベースでのデータを関連付けた分析の容易化
②大量データの高速処理による，グラフやデータの見える化

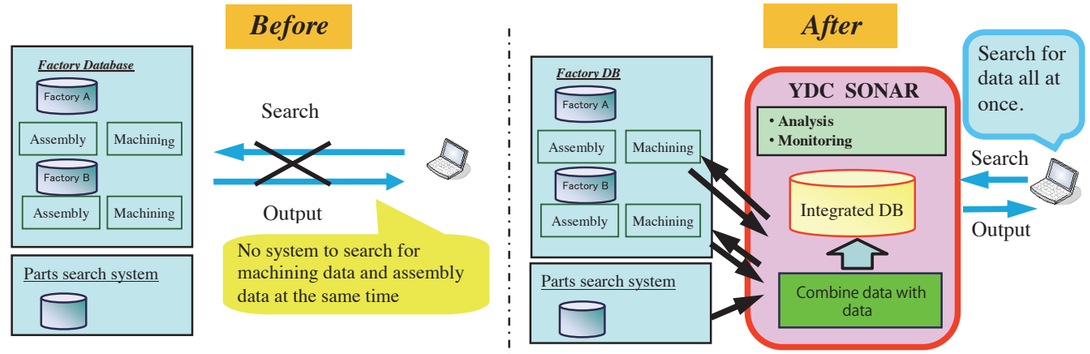

Fig. 1 Configuration of new quality system

3. 主な事例紹介

3.1. 対象品の絞込み時間の短縮

工程内で異常が発生すると，「対象品の絞込み」を行なうが，部品検索システムとの繋がりがなく，対象の絞込みに時間が掛かっていた．ここでは，YDC SONAR の導入と活用により「異常部品」→「対象ユニット」→「対象部品ロット」を短時間で探索できるようにした（1.0h/ 件 → 0.1h/ 件）．（Fig. 2）

3.2. 組立と部品間のトレーサビリティのプロセス造り

ここでは，起振力異常の組合せ要因の分析事例を説明する．

ユニットにはギヤ対で組込まれ，その性能テスト結果が起振力データとして記録される．

起振力の安定化には，ギヤ部品の組合せの影響が大きいことから，起振力データと加工・組立データの 1 対 1

2. Activities for ICT Implementation

2.1. Issues and Solutions

Table 1 lists the issues involved in improving manufacturing quality and the solution applied to resolve them.

2.2. Structure of a new quality improvement system

We implemented a comprehensive information application called SONAR as shown in Fig. 1. This system links together the quality data of the machining and assembly processes performed independently at each plant and enables various types of data to be combined for analysis.
Features of SONAR
(1) It facilitates easy analysis of related data in different databases.
(2) It supports high-speed processing of large volumes of data, enabling data to be visualized or represented in graphs.

3. Introduction of Main Usage Examples

3.1. Faster identification of parts concerned

Previously, action was taken to identify the parts concerned whenever a defect occurred in a production process. However, because there was no link to the parts search system, it took great amount of time to identify the parts involved. YDC SONAR makes it possible to search for a defective part, the transmissions concerned and the parts lot concerned in a short period of time 1.0 h/item to 0.1 h/item (Fig. 2).

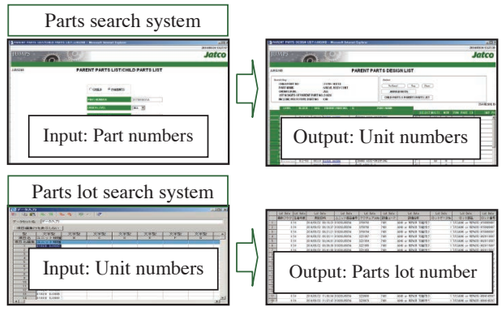

Fig. 2 Search for unit numbers and parts lot number

で追跡できるシステムとした．(Fig. 3)

その結果，起振力データと組込まれたギヤの精度データとをつなぎ，ギヤ組合せと起振力との相関解析が可能となった．また，構成部品毎の変化点を起振力データと全数関連付けて監視することが可能となり，変化点を起点に起振力異常の原因特定が迅速にできる様になった．(Fig. 4)

更に，蓄積されたデータを基に工程改善を行い，起振力を小さく且つバラツキ幅が小さくなるギヤ精度を実現している．(Fig. 5)

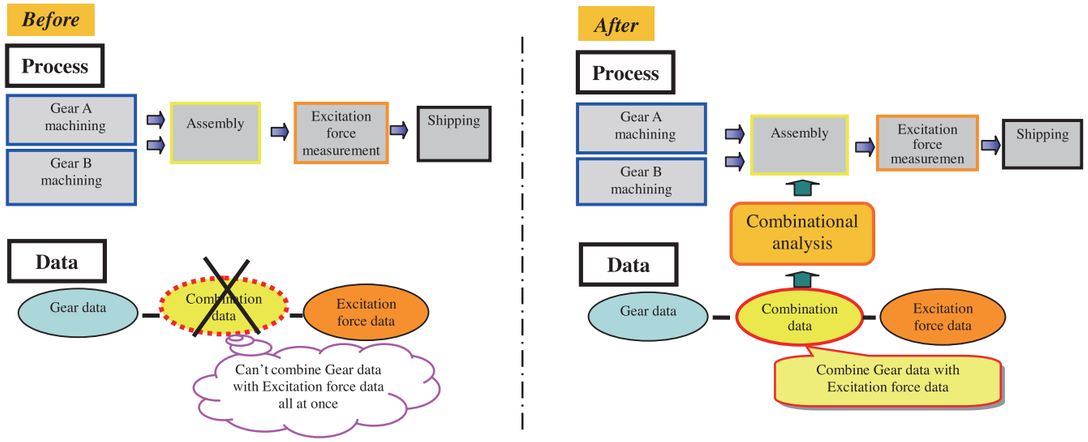

Fig. 3 Improvement of traceability process

3.2. Process to obtain traceability between final assembly data and parts data

Here we will present an example of an analysis of combined factors against out of specification of gear noise excitation force. Noise excitation test is conducted with unit assembly in which certain gear pairs incorporated and generally gear parts have a large effect on noise stabilizing excitation force. Therefore, we designed the system so that noise excitation force data and machining data of gear can be traced on a one-to-one basis (Fig. 3).

As a result, excitation force data can be linked to the accuracy data of paired gears, making it possible to analyze the correlation between gear accuracy and unit assembly noise excitation forces. In addition, it is also possible now to monitor changes made to each component part in relation to the noise excitation force data for all units. This makes it possible to quickly identify a particular change as the source of an out of specification of gear noise excitation force (Fig. 4).

Moreover, accumulated data are used for making process improvements so as to obtain gear accuracy that reduces noise excitation force and achieves a small range of variability (Fig. 5).

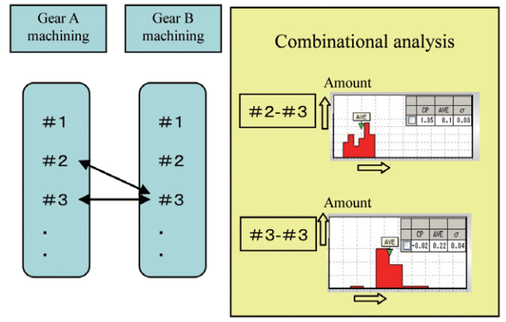

Fig. 4 Combinational analysis

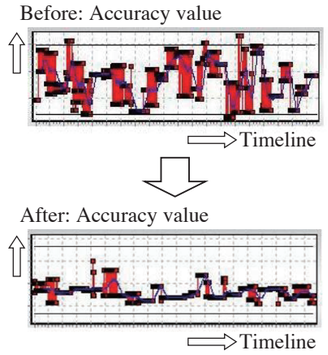

Fig. 5 Improvement of gear accuracy

3.3. 管理項目の常時監視化

品質データを手作業で集計していたが，常時自動検索することで工程内異常情報の共有が即時にできる．また，部品ロットデータの 4M（Man，Machine，Material，Method）情報の要因分析が迅速にできるようにした．

Fig. 6 は管理特性値の週別の異常件数の推移を表し，下図は同じ管理特性値を「加工設備別」・「部品サプライヤ別」に分析した結果の一例を示す．例えば，ある特性値について No.1 のマシンと No.2 のマシンを比較して平均値や標準偏差，Cp 値を自動算定することにより，No.1 マシンと No.2 マシンの工程能力差を日常的に自動検定することが可能となった．この図の事例はマシン差がないことが判明したデータ例であり，マシンごとの能力の同等性がライン内のオペレーターからも容易にその場で確認できるようになった事例である．

3.3. Continuous monitoring of quality control items

Quality data used to be compiled manually, but now we can immediately share information on defects in manufacturing processes by conducting an automatic search at any time. Factor analyses of parts lot data can also be conducted quickly with respect to 4M (manpower, machine, material, method) information.

Figure 6 shows the weekly change in the number of out of specification factors seen in control characteristic values. The lower graphs show an example of the analysis results by machine and by parts supplier for the same control characteristic values. As an example, auto detection for process capability difference on daily bases has been made possible by automatic calculation of average value or standard variation, Cp index by comparing machines such as No. 1 and No. 2, example mentioned below clarifies, that there is no machine difference and operator on assembly line can also confirm the difference between two machines easily.

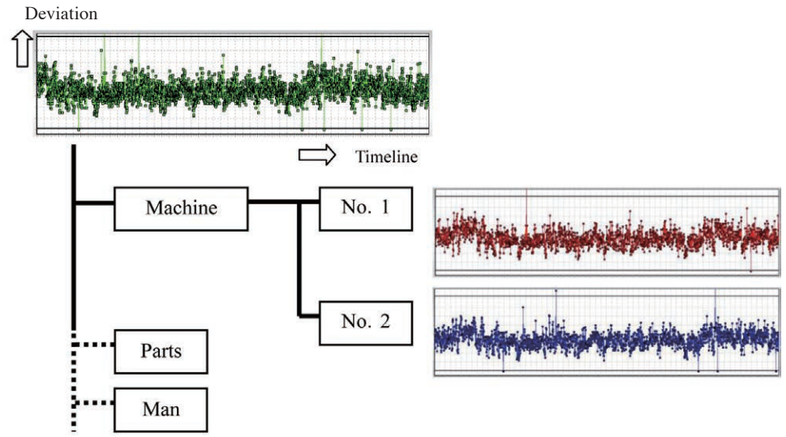

Fig. 6 Monitoring factor analysis results

3.4. 品質分析の標準化

日々稼働している生産設備では，設備の駆動トルクや，振動データ，油圧や電流の状況，等を分析することによって生産の安定度の確認や異常な傾向を早期に自動で発見することが品質確保の観点で大変重要である．そのような品質分析においても多量のデータを分析する必要がある．

しかしながら，そのような品質分析の手法はベテランのエキスパートに頼って分析を行なっていたため，分析に時間が掛かっていた．そこで品質分析の徹底的な見える化を図り，分析プロセスを定型化した．

Fig. 7 は，品質分析のパターンを層別したメニューである．

その結果，品質分析が誰でも同じやり方で即座に活用でき，品質分析のメニューを国内・海外工場へ展開することでノウハウの共有も図れる．

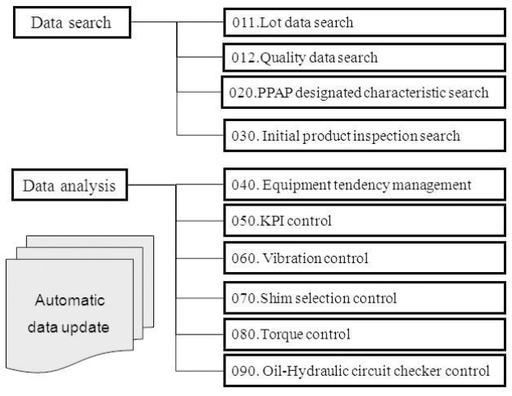

Fig. 7 Quality analysis menu

4. まとめ

YDC SONAR システムの導入により，生産現場にあるデータを徹底的に層別し，見える化を図ることにより，品質分析が飛躍的に速まり，品質分析の標準化にも貢献できた．更に現場のオペレータにも日々のデータ変化の見える化によって種々の気づきが与えられ，品質向上活動の推進力とすることができた．

今後の展開として，国内工場に留まらず Global へ拡大，並びに更なる品質向上活動を目指して，システムを発展させたい．

3.4. Standardization of quality analysis

Analysis of driving torque, excitation force, hydraulic pressure or current flow of the production facilities which are operational on daily bases are highly important to assure quality because it automatically facilitates confirmation of production stability or abnormal trend in early stage. There is a need to analyze a large amount of data for quality analysis.

However, in the past, it took great amount of time to conduct a quality analysis because the methods employed depended on experienced experts. Therefore, a standard analysis process was established in order to completely visualize the quality analysis procedure.

Fig. 7 shows the quality analysis process in the form of a hierarchical menu. As a result, anyone can promptly conduct a quality analysis using the same procedure. The sharing of this know-how will be promoted by deploying the quality analysis menu at both domestic and overseas plants.

4. Conclusion

With the utilization of YDC SONAR system, this quality improvement system thoroughly stratifies and visualizes the data at manufacturing workplaces, which dramatically speeds up quality analyses. It has also contributed to the standardization of quality analyses. In addition, visualization of daily data fluctuation has made operators more conscious and it has become driving force for promoting quality improvement activities.

We intend to deploy this quality improvement system not only in domestic plants but also expand its application globally. Moreover, we want to continue to develop the system for the purpose of promoting activities to improve quality even further.

Finally, we would like to thank YDC Corporation and all of the people involved at JATCO for their tremendous cooperation regarding the implementation of this quality improvement system.

最後に，本システム導入に際しての多大なご協力を頂いた株式会社ワイ・ディ・シー様，及び社内関係各位に感謝の意を表したい．

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三菱自動車向け RVR用Jatco CVT8（JF016E）の紹介

Introducing Jatco CVT8 (JF016E) for Mitsubishi RVR

三菱自動車のコンパクトSUV「RVR」15年型にJatco CVT8（JF016E）が搭載され，2014年1月にロシア向けに発売されました．

その後，北米，国内，豪州等に拡大採用されています．

JF016Eの特徴である低フリクションやワイドレシオカバレッジにより高い燃費性能と動力性能を両立しました．

特に北米向けについては，加速性能を重視した高い運転性ニーズに応え，三菱自動車と共同で変速性能をきめ細かく適合することで目標性能を達成することができ，お客様に好評を得ております．

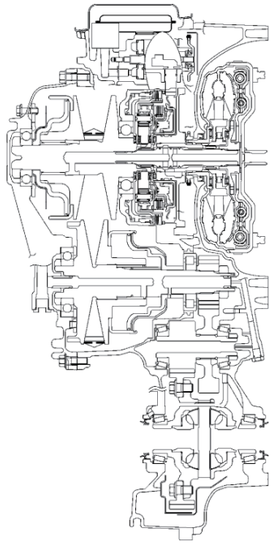


Fig. 1 Main cross-sectional view

The 2015 Mitsubishi RVR compact SUV, adopted Jatco CVT8 (JF016E), was released in Russia in January 2014. Subsequently, it is expanded to car models sold in North America, Japan, Australia and other markets.

The JF016E features low friction and wide ratio coverage, which deliver both high fuel economy and excellent power performance. For use in the North American market in particular, Mitsubishi Motors and JATCO worked together to fine tune the shift performance in response to the need for high driveability with emphasis on acceleration performance. As a result, the performance target was attained, and this transmission is highly popular with customers.

Table 1 Specifications of Jatco CVT8 (JF016E)

Torque capacity	190.9 Nm
Control system	Electronic
Torque converter size	236 mm dia.
Pulley ratios	Low 2.631
	High 0.378
Ratio coverage	7.0
Final gear ratio	6.026
No. of selector positions	4 (P, R, N, D) + Sporty mode
Overall length	366 mm
Weight (wet)	91.5 kg

■ Typical model fitted with the JF016E CVT ■

RVR

スズキ向け Celerio用Jatco CVT7（JF015E）の紹介

Introducing Jatco CVT7 (JF015E) for Suzuki Celerio

2014年5月にタイで発売されたスズキ株式会社の「Celerio」に，当社製Jatco CVT7（JF015E）が搭載されました．

副変速機構を備えた独自の機構を採用することで世界トップクラスの変速比幅を実現し，レスポンスの良い発進と加速性能を確保しつつ，高速走行時の静粛性向上および低燃費を両立して，タイのエコカープロジェクト適合車の燃費条件である5L/100kmの達成に貢献しました．

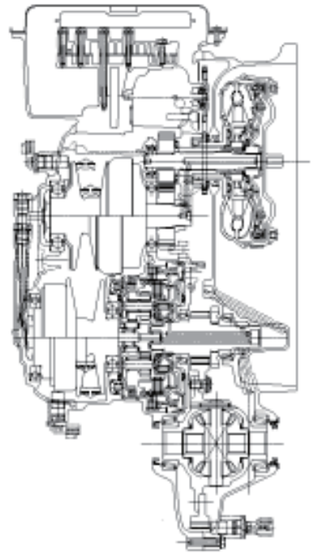


Fig. 1 Main cross-sectional view

The Jatco CVT7 (JF015E) is mounted on the new Suzuki Celerio that was released in Thailand in May 2014.

Built with a unique structure that incorporates an auxiliary transmission, the Jatco CVT7 features the world's widest ratio coverage. It provides both enhanced quietness during high-speed cruising and excellent fuel economy, while also ensuring quick start-off response and outstanding acceleration performance. The Jatco CV7 greatly helps the Celerio achieve fuel efficiency of 5 L/100 km, thereby complying with the fuel economy requirement of Thailand's eco-car project.

Table 1 Specifications of Jatco CVT7 (JF015E)

Torque capacity	100 Nm
Control system	Electronic
Torque converter size	UUF 185 mm dia.
Counter gear ratio	0.968
Pulley ratios	2.200-0.550
Ratio coverage	7.3
Auxiliary transmission 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	349.2 mm
Weight (wet)	64 kg

■ Typical model fitted with the JF015E CVT ■

Celerio

日産自動車向け NP300 Navara用 7速AT JR711Eの紹介

Introducing JR711E 7-speed AT for Nissan NP300 Navara

2014 年 7 月に発売された新型 1 トンピックアップトラック「NP300 Navara」に当社 7 速 FR AT JR711E が搭載されました．NP300 Navara は「優れた燃費性能,加速性能」を主な特徴としており，1 トンピックアップトラックでは，クラス最高レベルとなる燃費性能を実現しております．

低剛性ロックアップダンパーと最新制御技術を採用した JR711E は新型 4 気筒ディーゼルエンジンとの組合せにより，低速域での燃費の良さや加速性能の向上，幅広い速度域を実現するギヤ比の拡大のほか，滑らかな加速と変速フィーリングを実現し，お客様から好評を得ております．

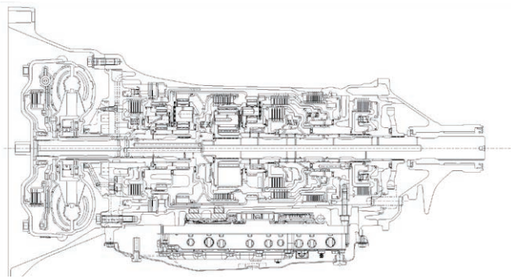


Fig. 1 Main cross-sectional view

The NP300 Navara, a new 1-ton pickup truck released in July 2014 adopted JR711E 7-speed AT for RWD models. Offering outstanding fuel economy and acceleration performance as its primary features, the NP300 Navara ranks at the top of the 1-ton pickup truck class in fuel efficiency.

The JR711E, featuring a low-stiffness lockup damper and the latest control technology, is mated to a new 4-cylinder diesel engine. This powertrain combination provides excellent fuel economy and improved acceleration performance in the low-speed range and wider gear ratio coverage for obtaining broad speed ranges. Additionally, it delivers seamless acceleration and a smooth shift feel. These qualities have drawn enthusiastic praise from customers.

Table 1 Specifications of JR711E

Torque capacity	600 Nm
Control system	Electronic
Torque converter size	260 mm dia
Gear ratios	1st 4.887 2st 3.170 3st 2.027 4st 1.412 5st 1.000 6st 0.864 7st 0.775 Rev 4.041
Ratio coverage	6.31
No. of selector positions	4 (P, R, N, D) + manual shift mode
Overall length	765 mm
Weight (wet)	101 kg

■ Typical model fitted with the JR711E AT ■

NP300 Navara

日産自動車向け ジューク用Jatco CVT8（JF016E）の紹介

Introducing Jatco CVT8 (JF016E) for Nissan Juke

日産自動車の「ジューク」に Jatco CVT8（JF016E）が搭載され，2014 年 8 月に欧州向けを始め，日本向け，北米向けマイナーチェンジして発売されました．

前モデルに搭載されていた JF011E に対し，JF016E ではその特徴である低フリクションやワイドレシオカバレッジにより，更なる燃費向上に大きく貢献しています．

また，ターボエンジンの改良に伴う低回転からの高トルク化と合わせて，ステップ変速制御（D-STEP）を採用することにより，更に気持ちの良い加速フィーリングを実現し，お客様の好評を得ております．

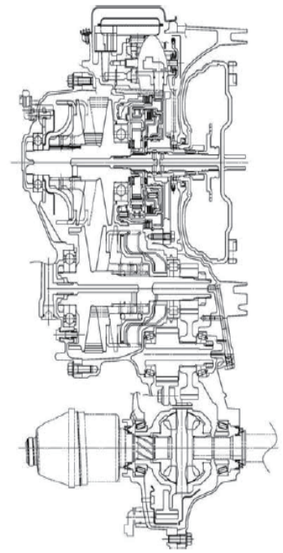


Fig. 1 Main cross-sectional view

The Jatco CVT8 (JF016E) is fitted on the Nissan Juke that was released first in Europe in August 2014 after the execution of a minor model change, followed by launches in Japan and North America.

Thanks to its distinctive features of low friction and wide ratio coverage, JF016E contributes greatly to a further improvement in fuel economy compared with the JF011E that was mounted on the previous Juke model. The Juke's turbo engine has been improved to deliver higher torque from the low speed range. Together with that improvement, the new Dynamic Step Shift Control (D-STEP) software adopted for the JF016E provides a much more enjoyable feeling of acceleration, which is highly popular with customers.

Table 1 Specifications of Jatco CVT8 (JF016E)

Torque capacity	240 Nm
Control system	Electronic
Torque converter size	236 mm dia.
Pulley ratios	2.631-0.378
Ratio coverage	7.0
Reverse gear ratio	0.745
Final gear ratio	5.694
No. of selector positions	4 (P-R-N-D) + Manual shift mode
Overall length	362.9 mm
Weight	90.5 kg

■ Typical model fitted with the JF016E CVT ■

Juke

日産自動車向け Qashqai用Jatco CVT7（JF015E）の紹介

Introducing Jatco CVT7 (JF015E) for Nissan Qashqai

2014 年 10 月に発売された，日産自動車の SUV「Qashqai」に当社副変速機付 Jatco CVT7（JF015E）が搭載されました．Qashqai は，ステップ変速制御（D-STEP）により，感性にマッチした変速が実現でき，スリップロックアップを活用した発進時のダイレクト感向上制御により，レスポンスの良い発進加速性を得ています．

また，アイドルストップ制御により，トップクラスの燃費も実現でき，好評を得ています．

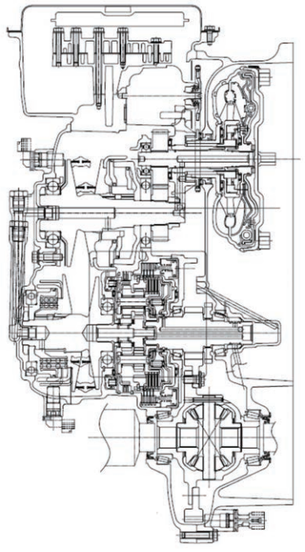


Fig. 1 Main cross-sectional view

The Qashqai SUV, released by Nissan in October 2014, is adopted with the Jatco CVT7 (JF015E) featuring an auxiliary transmission. Fitted with Dynamic Step Shift Control (D-STEP), the Qashqai provides a shift feel matching human sensibilities. Slip lockup control is used at start-off to improve the directly connected feel of highly responsive acceleration performance. In addition, stop/start control also achieves class-leading fuel economy. These qualities are highly popular with customers.

Table 1 Specifications of Jatco CVT7 (JF015E)

Torque capacity	165 Nm
Control system	Electronic
Torque converter size	205 mm
Pulley ratios	Low 2.200
	High 0.550
Ratio coverage	7.3
Final gear ratio	3.882
No. of selector positions	7
Overall length	361.2 mm
Weight (wet)	68.9 kg

■ Typical model fitted with the JF015E CVT ■

Qashqai

日産自動車向け Murano/Quest用Jatco CVT8（JF017E）の紹介

Introducing Jatco CVT8 (JF017E) for Nissan Murano and Quest

日産自動車の「Murano」と「Quest」に Jatco CVT8 High Torque（JF017E）が搭載され，北米向けに 2014 年 10 月に Quest がマイナーチェンジ，12 月に Murano がフルモデルチェンジして発売されました．

前モデルに搭載されていた JF011E に対し，JF017E ではその特徴である低フリクションやワイドレシオカバレッジにより，高い燃費性能と動力性能を両立させています．

また，ステップ変速制御（D-STEP）を採用することにより，更に気持ちの良い加速フィーリングを実現し，お客様の好評を得ております．

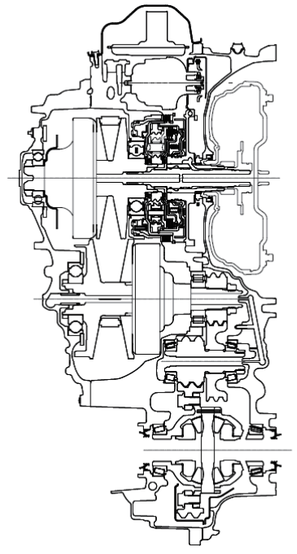


Fig. 1 Main cross-sectional view

The Jatco CVT8 High Torque (JF017E) unit is fitted on the updated Nissan Quest released in North America in October 2014 and on the new Nissan Murano released in the same market in December last year. The Quest underwent a minor model change while the Murano underwent a full model change.

Thanks to its distinctive features of low friction and wide ratio coverage, the JF017E achieves both high fuel economy and excellent power performance compared with JF011E that was adopted in earlier model. In addition, it also adopts the new Dynamic Step Shift Control (D-STEP) software that provides a markedly more enjoyable feeling of acceleration, which is highly popular with customers.

Table 1 Specifications of Jatco CVT8 High Torque (JF017E)

Torque capacity	350 Nm
Control system	Electronic
Torque converter size	250 mm dia
Pulley ratios	2.413-0.383
Ratio coverage	6.3
Final gear ratio	Murano: 4.688 Quest: 5.250
No. of selector positions	Murano 4 (P-R-N-D) + Manual shift mode Quest 5 (P-R-N-D-L)
Overall length	370 mm
Weight	101.3 kg

■ Typical models fitted with the JF017E CVT ■

Murano

Quest

スズキ向け アルト用Jatco CVT7(JF015E)の紹介

Introducing Jatco CVT7 (JF015E) for Suzuki Alto

2013 年 12 月発売のスズキ株式会社ハスラー以降に搭載された Jatco CVT7（JF015E）は，電動ポンプレスアイドルストップシステムの採用により，燃費向上と発進性能の両立を実現することが出来，お客様に好評を得ています．

2014 年 12 月発売のアルト向け JF015E には，『世界初の新工法と効率向上のための改良を加えたベルト』と『ファイナルギヤ比ハイ化』を採用し，更なる低燃費に貢献しています．

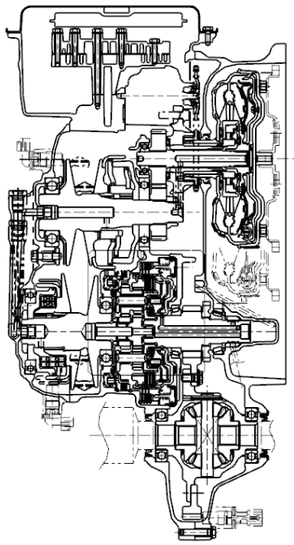


Fig. 1 Main cross-sectional view

The Jatco CVT7 (JF015E) has been adopted on Suzuki's FWD models since the Hustler was released in December 2013. This is CVT is used with a stop/start system without an electric oil pump, thereby providing both improved fuel economy and excellent start-off acceleration performance, which have been highly praised by customers.

JF015E adopted on Alto released in December 2014, have an improved belt for enhanced efficiency, which is built with world-first new manufacturing technique. It also features a higher final gear ratio. Both improvements contribute to a further fuel economy gain.

Table 1 Specifications of Jatco CVT7 (JF015E)

Torque capacity	100 Nm
Control system	Electronic
Torque converter size	UUF 185 mm dia.
Counter gear ratio	1.178
Pulley ratios	2.186-0.553
Ratio coverage	7.2
Auxiliary transmission gear ratios	1st Fwd: 1.821
	2nd Fwd: 1.000
	Rev: 1.714
Final gear ratio	3.45
No. of selector positions	5
Overall length	343 mm
Weight (wet)	62.5 kg

■ Typical model fitted with the JF015E CVT ■

Alto

Memo

ジヤトコ 一年間のトピックス
Highlights of the Past Year

1. 2014 SAE World Congress

4 月 8 日～ 10 日まで，SAE World Congress が米ミシガン州デトロイトで開催され，当社からも技術発表と技術展示ブースの出展を行った．当社社員による「Infiniti JX と Nissan Pathfinder 用 Jatco CVT8 HYBRID の開発」と「CVT の大トルク容量キャパシティ・バリエーターの開発」および「FTA 自動作成ツールの紹介」の技術講演も行われ，好評を得た．また，技術展示ブースの人気は高く，北米のカーメーカーの技術者を中心に 500 ～ 600 名ほどの来場があった．

2. 第 5 回日中トライボロジー先端フォーラムをジヤトコで開催

4 月 13 日･14 日,当社本社地区にて第 5 回トライボロジー先端フォーラム（日本トライボロジー学会，中国機械工程学会摩擦学分会主催）が開催された．

今回，ジヤトコでこのフォーラムが開催されたのは，世界文化遺産に登録された富士山の麓であり，なおかつ，ジヤトコがトライボロジー技術の代表例のひとつであるベルト&プーリーで動力伝達する CVT のトップメーカーであるためである．

フォーラムには　100 名以上の方が参加し，日本，中国共に各分野のエキスパートによる最先端の技術に関する講演 21 件，ポスター発表 3 件，企業展示 25 社があり，

1. 2014 SAE World Congress

JATCO employees gave technical presentations at the SAE World Congress held in Detroit, Michigan, USA from April 8-10, 2014 and JATCO set up a booth with technical exhibits. The technical presentations were entitled “Development of Jatco CVT8 Hybrid for Infiniti JX and Nissan Pathfinder,” “Development of High Torque Capacity Variator System for CVT,” and “Method of Computer-Aided FTA (Fault Tree Analysis) in Reliability Design and Development.” All of them were well received by the attendees. JATCO's booth was visited by many attendees during that period, attracting some 500-600 visitors, particularly engineers from U.S. automakers.

2. JATCO hosts The Fifth Japan-China Advanced Forum on Tribology

The Fifth Advanced Forum on Tribology 2014 was held at JATCO's head office, Japan on April 13-14, 2014, sponsored by the Japanese Society of Tribologists and the Tribology Institute of the Chinese Mechanical Engineers Society. This forum was hosted by JATCO at the foot of Mt. Fuji, which is registered as a World Heritage site, because the company is a leading manufacturer of CVTs that transmit power by means of a belt and pulley system, which is one typical example of tribological technology. Over 100 attendees participated in the forum, which featured 21 technical presentations and three poster presentations concerning cutting-edge technologies given

当社からも基調講演をはじめ技術講演や展示などを実施し好評を博した．

3. ソウル大学で CO_2 削減技術を講演

4 月 21 日，ソウル大学国際大学院でジヤトコ韓国エンジニアリング社（以下 JKE）の社長が講演を行った．この講演会は，韓国最大の日系コミュニティである Seoul Japan Club とソウル大学の日本研究所が連携して企画し，今回で 2 回目．講演者はソウルに所在している日本の企業のトップである．JKE 社長からは「自動車用トランスミッションによる CO_2 削減の取り組み」を主題に講演し，CO_2 削減に貢献しているジヤトコの技術を訴求した．

また，10 月 7 日には産学連携組織である LINC（産学協力先導大学連合）からの要請により，釜山のドンイ科学大学でもアイドルストップ技術等に関する講演を JKE 社長が実施した．

4. ジヤトコフランス，スペイン事務所を開設

ジヤトコフランス社がスペイン事務所（以下 JF スペイン事務所）を開設し，5 月 12 日に開所式を実施した．JF スペイン事務所は，バルセロナの Nissan Technical Center Europe の敷地内にオフィスを構え，欧州における CVT プロジェクトの実験業務，および品質業務を担当する．当初人員は 4 名．同事務所の開設により，顧客に対するさらにタイムリーな対応を可能にする体制を整えた．

by experts in related fields from Japan and China as well as company exhibitions displayed by 25 companies, JATCO also made plenary speech, technical presentation and exhibited it's products which was well received by other participants.

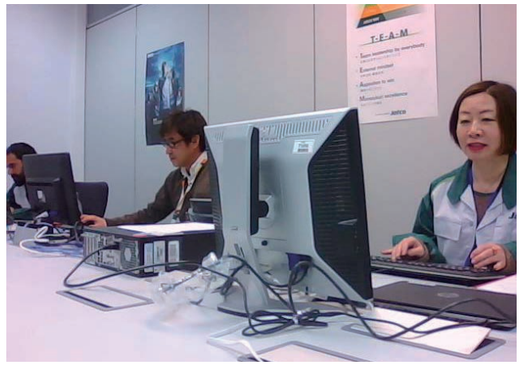
3. Lecture on CO_2 emission reduction technology at Seoul National University

President of JATCO Korea Engineering Corp. (JKE) gave a lecture at the Graduate School of International Studies, Seoul National University on April 21, 2014. This was the second lecture program to be organized cooperatively by the Seoul Japan Club (the largest Japanese community organization in South Korea) and the Institute for Japanese Studies at Seoul National University. The speakers were the chief executives of Japanese companies located in Seoul. JKE President's lecture was entitled “Efforts to Reduce CO_2 Emissions using the Automotive Transmission,” and he emphasized how JATCO's technologies are contributing to the reduction of CO_2 emissions.

He also gave a lecture concerning the stop-start system and other technologies at Dong-Eui University in Busan on October 7. He was invited to speak there by the Leaders in Industry-University Cooperation (LINC), an organization that promotes industry-academia collaboration.

4. JATCO France opens Spain Branch

JATCO France SAS held an opening ceremony for its newly established Spain Branch (hereafter JF Spain Branch) on May 12, 2014. JF Spain Branch has its office on the premises of Nissan Technical Center Europe in Barcelona and is responsible for testing and quality



5. FR 車用 5 速 AT 累計生産 500 万台達成

2000 年 11 月に生産をスタートした FR 車用 5 速 AT（JR507E/JR509E）が，5 月 19 日に累計生産台数 500 万台を達成し，6 月 16 日，富士宮工場で記念式典を行った．この間，富士宮工場は 2011 年の富士宮地震で設備倒壊や建屋損傷などの大きな被害を受けたが，日ごろの危機管理体制構築と訓練の成果もあり，約 2 週間という短期間で生産再開を果たすことができた．JR507E/JR509E は今でも NV350 キャラバン，アルマーダ，パトロールなど，使われ方の厳しい車両に搭載されており，品質の高さはお客さまからの信頼を得ている．

6. 中国における CVT 技術普及活動

ジヤトコ（広州）自動変速機有限公司（以下ジヤトコ広州）は今年も中国においてさまざまな CVT 技術普及活動を実施した．

6 月 12 日には，日産（中国）投資有限公司（以下 NCIC）と共同で中国国家知識産権局（以下 SIPO）蘇州センター向 CVT 技術説明会に参加．この説明会は 2012 年度の SIPO 北京本局向け，2013 年度の SIPO 広州センター向けに続く 3 回目の開催となる．さらに 7 月 11 日には，北京で開催された 21 世紀経済報道主催のパワートレイン技術フォーラムに参加，多くの中国の自動車有識者と主要メディアが招待される中，当社の CVT 技術が高い関心を集めた．また，10 月 30 日には，重慶大学で開催された BOSCH（中国）主催の第四回 CVT 大学技術セミナーに参加．「CVT の魅力を見つけ出せ」のテーマのもと，展示と技術講演を日産自動車とともに行い，CVT の魅力についての訴求を行うことができた．

assurance activities for CVT projects in Europe. The establishment of this branch, started with four employees, provides an organization capable of responding to customers in a timelier manner.

5. Cumulative production of 5-speed ATs for RWD vehicles reaches 5 million units

Cumulative production of the JR507E/JR509E 5-speed ATs, which went into production in November 2000 for use on RWD vehicles, reached five million units on May 19, 2014. A ceremony was held at the Fujinomiya Plant, Japan on June 16 to celebrate this milestone. During the intervening years, the Fujinomiya Plant suffered extensive damage in the 2011 Fujinomiya Earthquake, including the collapse of equipment and damage to the building. However, production was resumed in a short span of approximately two weeks owing in part to the results of persistent efforts to build a crisis management system and to conduct regular training. The JR507E/JR509E continue to be mounted today on vehicles used under tough conditions, including the NV350 Caravan, Armada and Patrol, among others, and their high quality has earned the trust of customers.

6. Activities to spread CVT technology in China

This year also JATCO (Guangzhou) Automatic Transmission Ltd. (hereafter JATCO Guangzhou) carried out various activities to spread CVT technology in China. Together with Nissan (China) Investment Co., Ltd. (NCIC), it participated in a CVT technology briefing held for the Suzhou Center of the State Intellectual Property Office (SIPO). This was the third briefing to be held following one in fiscal 2012 at SIPO's headquarters in Beijing and one for SIPO's Guangzhou Center in fiscal 2013. JATCO Guangzhou also participated in the Powertrain Technologies Forum sponsored by the 21st Century Business Herald in Beijing on July 11. JATCO's CVT technologies attracted strong interest among the Chinese automotive experts and representatives of major media companies who were invited to the event. Moreover, JATCO Guangzhou took part in the 4th CVT Technology University Seminar sponsored by Bosch China at Chongqing University on October 30. Technical presentations and an exhibition were carried out together with Nissan Motor Co., Ltd. on the theme of “Discovering

7. VDI トランスミッションカンファレンスに参加

6 月 24 日・25 日に独フリードリヒスハーフェンで開催された VDI（ドイツ技術者協会）トランスミッションカンファレンスにて，当社役員が当社初となる本会議講演（Plenary Lecture）を実施した．ステップ変速トランスミッションに対する CVT の優位性を具体的データをまじえて訴求した．技術発表では北米自動車メーカーの 1 社から同じ観点の講演があり，CVT の燃費に関する優位性の認識が定着しつつある．また，当社からは Jatco CVT8 HYBRID に採用された最新技術の紹介および CVT 出荷時の NVH 性能（音振性能）の検査のための最新技術について講演し，好評を得た．

8. 日産 XTRONIC CVT AUTOMAGIC —インドでの CVT イベント—

8 月 30 日～9 月 29 日の週末の土日，インド日産が CVT キャンペーンを実施，ジヤトコも協力した．これは，インドでの需要拡大時期である 9 月～ 10 月にあわせて開催したもので，西部:ムンバイ，南部:バンガロール，チェンナイ，コチ，北部:デリーの 5 都市で実施した．

インドの自動変速機搭載率は 10%以下と低いが，近年各社が新しい 2 ペダルのトランスミッションを採用しているのに伴い，自動変速機に関心が高まりつつある．イベントではジヤトコ社員が CVT のスムーズさ，燃費の良さ，CVT の作動原理や Jatco CVT7 の概要を説明し，来場者から熱い関心が寄せられた．

the Attractive Qualities of CVTs.” These activities emphasized the attractive features of CVTs to the seminar attendees.

7. Participation in the VDI Transmission Conference

A JATCO executive delivered JATCO's first Plenary Lecture at the VDI Transmission Conference held in Friedrichshafen, Germany on June 24-25, 2014. VDI stands for Verein Deutscher Ingenieure (Association of German Engineers). He presented concrete data to demonstrate the superiority of CVTs over stepped transmissions. An attendee from a U.S. automaker also gave a technical presentation from the same perspective. Recognition of CVT superiority in fuel economy is becoming well-established. Other JATCO presentations described the latest technologies adopted in Jatco CVT8 Hybrid and the latest techniques used in testing CVTs for noise, vibration and harshness (NVH) performance at the time of shipment. These presentations were well received by the attendees.

8. Nissan Xtronic CVT Automagic—CVT campaign in India

JATCO cooperated with Nissan India's CVT campaign that was held every weekend on Saturday and Sunday from August 30 to September 29, 2014. This campaign was conducted to coincide with the months of September and October when vehicle demand increases in India. Campaign events were carried out in five cities: Mumbai in the West; Bengaluru, Chennai and Kochi in the South; Delhi in the North.

The percentage of cars fitted with an Automatic Transmission (AT) is lower than 10%. In recent years, interest in AT has been rising as automakers have been

9. ジヤトコメキシコ第二工場開所式

ジヤトコメキシコ社（以下 JMEX）の第二工場が完成し，9 月 10 日に開所式を開催した．開所式には，メキシコの経済大臣や，アグアスカリエンテス州知事など，350 人のゲストと社員が出席した．

JMEX 第二工場はメキシコ日産の第二工場近くに位置し，Jatco CVT8 と Jatco CVT8 HYBRID を生産し，第一工場とあわせメキシコでの生産能力は年間 170 万台となる計画である．2005 年秋にジヤトコ初の海外拠点として稼働開始した JMEX は近年ジヤトコのグローバル生産における約 20% を占めるまでに拡大し，NAFTA 圏への CVT 供給において欠かすことのできない拠点となっている．

10. ジヤトコ広州が各賞受賞

2013 年の「広東省 500 強企業」受賞と「広東省功労企業」表彰につづき，2014 年も良き企業市民としてのジヤトコの活動が評価され，ジヤトコ広州が各種の表彰を受けた．

9 月 28 日に「2014 年中国自動車と部品業界発展創新賞」を受賞．この賞は中国の著名な自動車雑誌「自動車と部品」が主催し，環境にやさしい CVT が評価され「創新能力賞」を受賞した．同じ 9 月に「契約と信用遵守会社賞」を受賞した．この賞は広東省工商門に長期のモニタリング活動によって選ばれるもので，社会から信用されていることが評価された．11 月には広東省製造業協会，広東省現代サービス業連合会,広東省企業信用連盟より「広東省優秀信用企業賞」を受賞した．これは社会が誠実，自律，信頼される企業を育成するためのものである．

introducing new 2-pedal transmissions. At each event, JATCO employees explained CVT technologies with respect to their smoothness, excellent fuel economy and operating principle along with giving a general overview of the Jatco CVT7. The audience at each location expressed an enthusiastic interest in CVTs.

9. Opening ceremony for JATCO Mexico's second plant

JATCO Mexico (hereafter JMEX) held an opening ceremony on September 10, 2014 for its newly completed second manufacturing plant. Among the 350 guests and JMEX employees attending the ceremony were Mexico's Minister of Economy and the Governor of Aguascalientes State. Located close to Nissan's second vehicle assembly plant, JMEX's second plant produces the Jatco CVT8 and the Jatco CVT8 Hybrid. Total capacity of both plants will be 1.7 million units annually. JMEX is first overseas plant of JATCO group established in 2005 Autumn. JMEX is producing approximately 20% out of JATCO's total global production volume and it is an essential plant to supply CVTs in NAFTA region.

10. JATCO Guangzhou received several awards

In 2013, JATCO Guangzhou was named to the list of “Best 500 Companies in Guangdong” and won a “Guangdong Distinguished Company” award. In 2014 as well, JATCO Guangzhou received 3 other awards in recognition of JATCO's activities as a good corporate citizen.

First is “Innovation Capability Award” in the category of “2014 Innovation Award for Promoting Development of the Chinese Automotive and Parts Industries” given by “Cars and Parts,” a famous car magazine in China

11. パリモーターショー 2014 に初出展

10 月 4 日～ 19 日までの 16 日間，仏パリのポルト･ド･ヴェルサイユにて開催された「パリモーターショー 2014」にジヤトコが初出展した．来場者数は 125 万人にのぼり，ジヤトコブースにも大勢の来場者が訪れた．

当社ブースでは，主力商品である Jatco CVT7，Jatco CVT8，および Jatco CVT8 HYBRID などを展示．今後ますます厳しくなる欧州市場の CO_2 排出量規制対応するジヤトコの技術が社会に大きく貢献できることを訴求した．

12. GM Supplier Quality Excellence Award をダブル受賞

韓国 GM 社向けに FF 車用 4 速 AT（JF414E）を納入している掛川工場と，Jatco CVT7（JF015E）を納入している富士第 1 地区工場が，2014 年 GM Supplier Quality Excellence Award をともに受賞した．この賞は，非常に高い品質の製品とその品質を維持しているサプライヤーに贈られる賞であり，掛川工場は 3 年連続 3 回目，2013 年

On September 28 for high evaluation given to the environmental friendliness of CVTs. Second is, “Award for Company observing Contracts and Trust” also received in September. It was honored on the bases of monitoring carried by Commerce and Industry Department of Guangdong Province in a long-term. The trust given to JATCO Guangzhou by society was highly evaluated for this award. Third is , In November, “Award for Outstanding Trustworthy Company of Guangdong Province” by the Guangdong Province Association of Manufacturers, Guangdong Province Federation of Modern Service Industries and Guangdong Province Corporate Credit League. This award is given to encourage enterprises with integrity, self-sufficiency and trustworthiness.

11. JATCO's first exhibits at the Paris Motor Show 2014

JATCO participated for the first time in the Paris Motor Show held at Paris expo Porte de Versaille, France over a 16 days period from October 4-19, 2014. The show attracted over 1.25 million visitors and large numbers of people visited JATCO's booth.

On display at JATCO's booth were the company's leading products such as the Jatco CVT7, Jatco CVT8 and Jatco CVT8 Hybrid, among others. These exhibits emphasized to visitors that JATCO's technologies can contribute to society while meeting the European market's CO_2 emission regulations which are expected to become increasingly strict in the years ahead.

12. Double winner of General Motors Supplier Quality Excellence Award

The Kakegawa Plant that delivers the 4-speed AT for FWD vehicles (JF414E) and Fuji Area No. 1 Plant that delivers the Jatco CVT7 (JF015E) to GM Korea were presented with a General Motors Supplier Quality Excellence Award for 2014. This award is presented to suppliers for delivering products of exceptionally high quality and for maintaining good level of quality. Kakegawa Plant won its third award in three consecutive years. Fuji Area No. 1 Plant, which began deliveries in May 2013, received its first such award in its initial fiscal year of deliveries in recognition of the high quality of the Jatco CVT7.

5 月から納入を開始した富士第 1 地区は納入初年度の Jatco CVT7 の高品質が認められ初受賞となった.

13. CTI ベルリンで CVT の講演が好評

第 13 回国際 CTI シンポジウムが 12 月 8 日～ 11 日に独ベルリンで開催され，当社社長が本会議講演（Plenary Session）で講演を行った. CTI（Car Training Institute）は，自動車技術の最新トレンドに関するイベントとして 2003 年に創設され，ベルリンのほか，中国，米国でも開催されており，今回のシンポジウムには 20 か国から昨年比 20%増の 1300 名を超える参加者が訪れた.

当社社長の講演では CVT が環境性能に優れることはもちろん，スムーズでドライバーの意思のままのドライビングが楽しめるトランスミッションであることにより，欧州市場においても最新 CVT が好意的に受け入れられていること，さらに，CVT は将来クルマのエネルギーマネジメントにおいて中心的な役割を果たすと訴求し，来場者の好評を博した. 技術講演においても当社から CVT 技術に関する 2 件の発表を行った.また,当社役員が 3 つのセッションの座長を務め，トランスミッション業界の技術交流に貢献した.

14. 初開催の人とくるまのテクノロジー展 2014 名古屋に出展

12 月 11 日・12 日の 2 日間，ポートメッセ名古屋で開催された「人とくるまのテクノロジー展 2014 名古屋」（主催：公益社団法人自動車技術会）にジヤトコが出展した. 例年 5 月に横浜で開催されている展示会に加え，今回初めての名古屋開催であったが，来場者数は 2 日間で約 3 万人にのぼった. 当社ブースでは，主力商品である Jatco CVT7，Jatco CVT8 および Jatco CVT8 HYBRID を展示. 自動車関連企業の多い中京圏での開催ということもあり，多数のお客様が来訪. 熱心に説明員の話に耳を傾けるお客さまも見受けられ，当社製品へ高い関心が寄せられた.

13. Opening an avenue for CVTs at the CTI Symposium in Berlin

JATCO President and CEO Terry Nakatsuka delivered a presentation in the Plenary Session at the 13th International CTI Symposium held in Berlin, Germany from December 8-11 2014. The symposium was attended by over 1,300 attendees, an increase of 20% over the year before, from 20 countries. Initiated by the Car Training Institute (CTI) in 2003, this event focuses on the latest trends in automotive technologies. In addition to Berlin, the symposium is also held in China and the U.S.

His presentation focused on superior environmental performance of CVTs, as well their smoothness and that they deliver an enjoyable driving experience matching to drivers' wishes. These features are the reason why latest CVTs are being well accepted in the European market. Furthermore, he emphasized that CVTs can play a central role in energy management in vehicles in the future. His presentation drew high praise from the audience.

JATCO employees also presented two technical presentations about CVT technologies. Moreover, JATCO executives served as chairmen of three sessions, contributing to the exchange of technologies in the transmission world.

14. JATCO exhibits at the first Automotive Engineering Exposition held in Nagoya

JATCO presented a booth at the 2014 Automotive Engineering Exposition Nagoya, organized by the Society of Automotive Engineers of Japan, Inc. at the Nagoya International Exhibition Hall (Portmesse Nagoya) over a two-day period of December 11-12, 2014. In addition to the annual exposition held in Yokohama in May, this was the first time for the event to be organized in Nagoya. The number of visitors during the two-day period was around 30 thousand. Displayed at JATCO's booth were the Jatco CVT7, Jatco CVT8 and the Jatco CVT8 Hybrid, representing the company's leading products. Large numbers of visitors came to the booth because the event was held in Nagoya area where many automobile-related companies are located. Many visitors listened intently to the explanations given by the booth attendants and showing their deep interest in JATCO's products.

特　許　紹　介

Patents

1．無段変速機及びその制御方法

(Fig.1)

出願番号　:特願 2009-79679 号
出願日　:2009.3.27
特許番号　:特許第 5027179 号
登録日　:2012.6.29
発明の名称 :無段変速機及びその制御方法
発明者　:城崎建機，鈴木英明，野々村良輔，
井上真美子，高橋誠一郎（日産），
落合辰夫（日産），古閑雅人（日産），
内田正明（日産），門野亮路（日産）

1. Continuously-Variable Transmission and control method thereof

(Fig.1)

Application Number: 2009-79679
Application Date: 3.27, 2009
Patent Number: 5027179
Registration Date: 29.6,2012
Title: Continuously variable transmission and control method thereof
Inventors: Tateki Jozaki, Hideaki Suzuki,
Ryousuke Nonomura, Mamiko Inoue,
Seiichiro Takahashi (Nissan),
Tatsuo Ochiai (Nissan),
Masato Koga (Nissan),
Masaaki Uchida (Nissan),
Ryoji Kadono (Nissan)

【発明の概要】

本発明は，バリエータを有するベルト式無段変速機構に対して直列に設けられた副変速機構を有し，車両の急減速が判定された場合，前記副変速機構の変速段を Low 段に制御するとともに，前記バリエータを最 Low 変速比に向けて最大変速速度で，前記副変速機構の変速比が変化する方向と同じ方向に変速させる変速手段とを備えたことを特徴とする．この構成により急減速時にバリエータをできる限り最 Low 変速比に近づけることができるので，急減速で車両が停車したとしても，次回発進時に発進駆動力が不足することがなく，良好な発進性能が得られる．

【SUMMARY OF THE INVENTION】

A continuously variable transmission of the present invention includes a variator capable of varying a speed ratio continuously, and a subtransmission mechanism provided in series with the variator. When an actual through speed ratio passes a predetermined mode switch speed ratio, a transmission controller performs a coordinated shift in which a gear position of the subtransmission mechanism is changed and a speed ratio of the variator is varied in an opposite direction to a speed ratio variation direction of the subtransmission mechanism. When the rapid deceleration is determined, the transmission controller　controls the gear position of the subtransmission mechanism　to the first speed and shifts the variator toward the lowest speed ratio at a maximum shift speed.

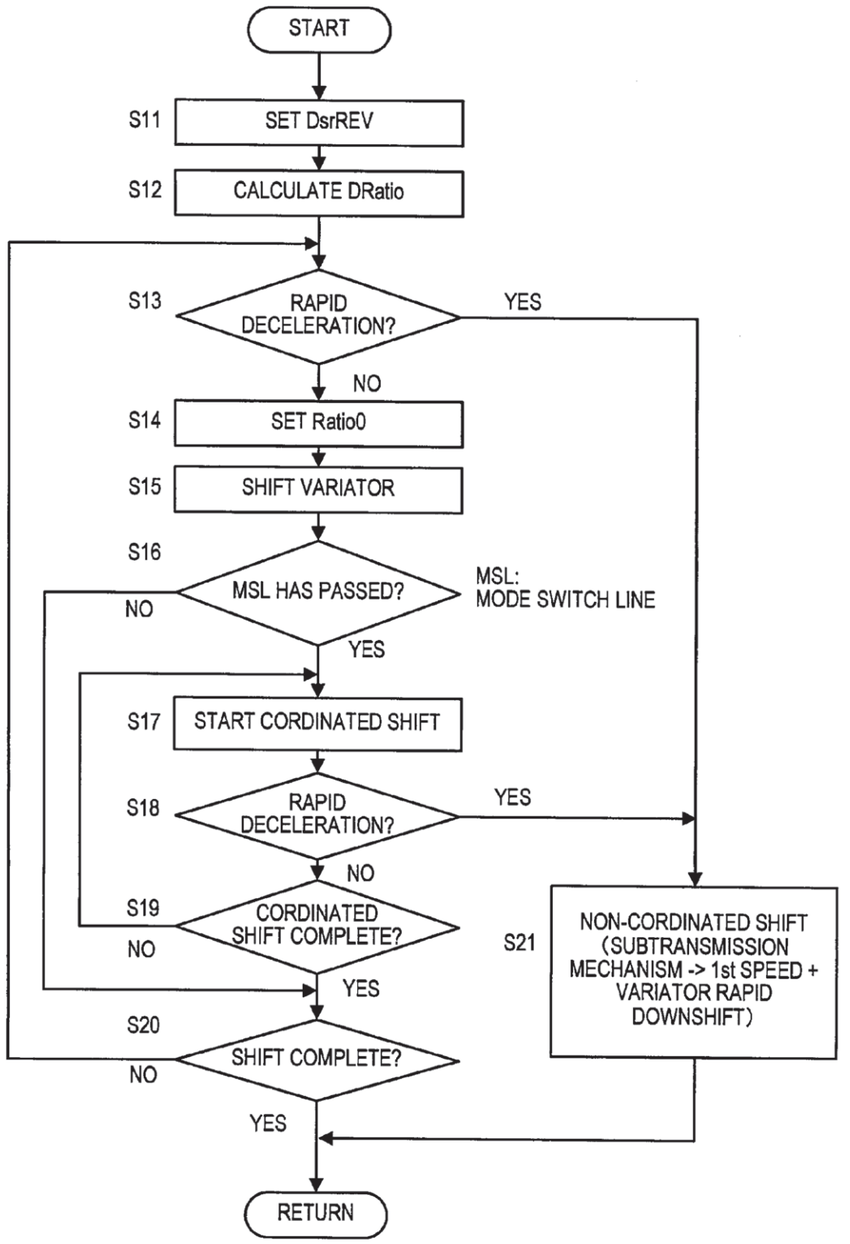


Fig. 1

2. 自動変速機の制御装置

（Fig.2）

出願番号　:特願 2009-194034 号
出願日　　:2009.8.25
特許番号　:特許第 4965611 号
登録日　　:2012.4.6
発明の名称 : 自動変速機の制御装置
発明者　　:土肥興治，石井実成

【発明の概要】

本発明の自動変速機は，摩擦締結要素が締結を開始したときから自動変速機の入力軸の回転速度の変化率が目標変化率となるように作動油圧の制御を行う回転速度変化率制御手段と，摩擦締結要素の締結が所定の進行状態と判定された後の締結後半から自動変速機の入力軸回転速度が目標回転速度となるように作動油圧のフィードバック制御を開始する回転数フィードバック制御手段とを有する．これにより，バラツキによる偏差の積分成分が蓄積されることを抑制でき，制御量の過度な増大を防止することができる．

2. Automatic Transmission Control Apparatus

(Fig.2)

Application Number:　2009-194034
Application Date:　8.25, 2009
Patent Number:　4965611
Registration Date:　4.6,2012
Title: Automatic Transmission Control Apparatus
Inventors: Koji Dohi, Minari Ishii

【SUMMARY OF THE INVENTION】

The automatic transmission of the present invention has a rotational speed change rate control section configured to control a hydraulic pressure so that a change rate of a rotational speed of an input shaft of the automatic transmission becomes equal to a target change rate, from when an engagement of a frictional engagement element is started; and a rotational speed feedback control section configured to perform a feedback control of the hydraulic pressure so that the rotational speed of the input shaft of the automatic transmission becomes equal to a target rotational speed, from when a progression state judging section judges a predetermined progression state. With this, it is possible to suppress an accumulation of an integral component of a deviation by a variation, and to prevent an excessive increase of the controlled variable.

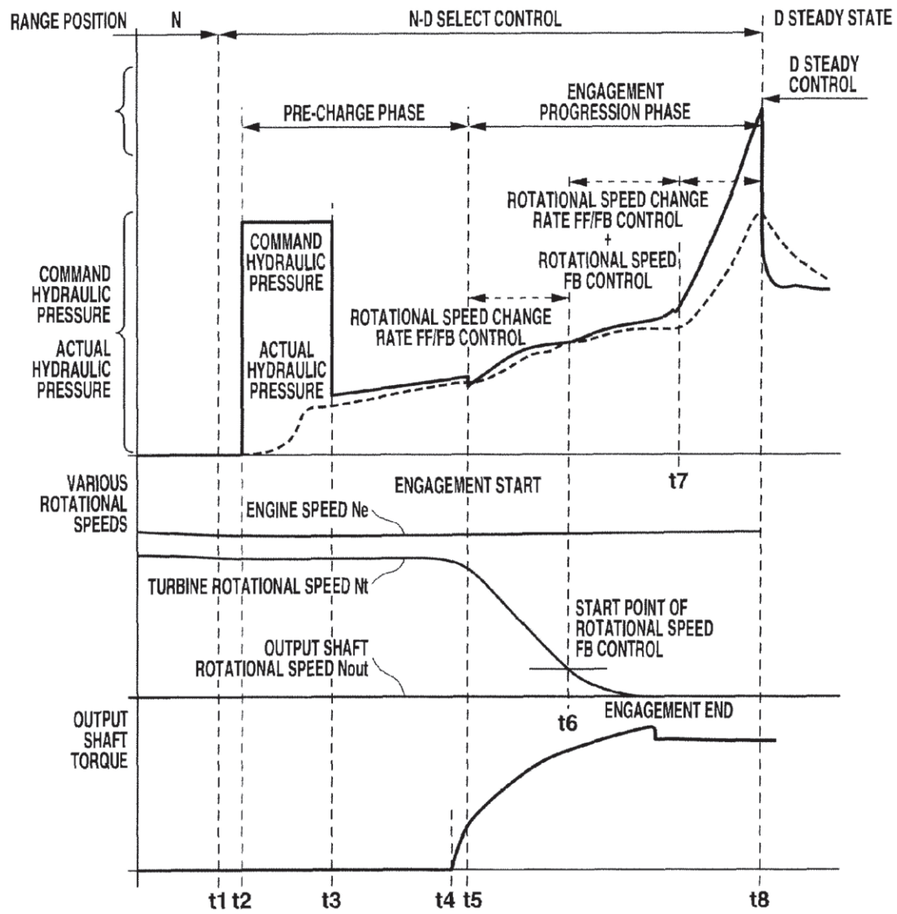


Fig. 2

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JATCO Technical review では Jatco CVT8 は CVT8 として記載.
Jatco CVT7 は CVT7 として記載.

In JATCO Technical review Jatco CVT8 is being mentioned as CVT8 and Jatco CVT7 as CVT7.

ジヤトコ・テクニカル・レビュー　No.14

JATCO Technical Review No.14

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発　　行	2015 年 3 月
発行・編集人	ジヤトコ・テクニカル・レビュー 編集局
発 行 所	ジヤトコ株式会社 商品市場戦略室 〒 243-0126 神奈川県厚木市岡津古久 560-2 TEL: 046-282-8926 FAX: 046-270-1751
印 刷 所	E−グラフィックス コミュニケーションズ株式会社 東京都三鷹市牟礼 6 丁目 25 番 28 号

	March, 2015
Publisher	JATCO Technical Review
(Editor)	Editorial Team
Distributor	Product Marketing Strategy Office JATCO Ltd 560-2 Okatsukoku, Atsugi City, Kanagawa 243-0126, Japan

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