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2ペダル・トランスミッションが提供する『価値』

The Value Provided by Two-pedal Transmissions

副社長 薄葉 洋
Executive Vice President Yo USUBA

ジヤトコが開発・生産している2ペダル・トランスミッション(以下「TM」とする．)は，個人の移動手段：Personal Mobilityに分類される小型自動車(Light Duty Vehicle)に提供されています．しかし，世界規模でCO_2排出削減が求められている現在，Personal Mobilityが抱える矛盾をどう解決するかが，自動車業界の課題となっています．

CO_2排出削減を目的とするならば，電車・バスといった大量輸送手段：Mass Transportationが有効な手段です．しかし，大量輸送手段は，個人が自由に移動する要求を満たすことはできません．

Personal Mobilityは，『個人の自由な移動』と，それに伴い増加する『CO_2排出量の削減』をどのように両立させるかという問いに答えを出さなければならないのです．ジヤトコはこの問いに，2ペダルTM技術と製品の提供を通じて取り組んでいます．

さて，自動車のCO_2排出量は，モード燃費という形でお客さまに提供されています．今から四半世紀前は，良燃費車はマニュアルミッション(以下「MT」とする．)仕様であることが当たり前でした．しかし現在は2ペダルTMが良燃費車としての前提条件となっています．2ペダルTMは，ドライバーの期待を理解し駆動力(Driving Force)を変化させるアダプ

The 2-pedal transmissions that JATCO develops and manufactures are supplied for use on light-duty vehicles categorized as being a means of personal mobility. However, today when there are strong demands to reduce carbon dioxide (CO_2) emissions on a global scale, the automotive industry is faced with the challenge of how to solve the contradiction inherent in personal mobility.

If the aim is to cut CO_2 emissions, then forms of mass transportation such as trains and buses are effective solutions. However, these means of mass transportation cannot satisfy the desire of individuals to be able to move about freely.

The dilemma in personal mobility is to resolve the question of how to reconcile the desire of individuals for freedom of movement with the need to reduce the attendant increase in CO_2 emissions. At JATCO, we are striving to address this question by supplying 2-pedal transmission technologies and products.

Data on the CO_2 emissions of vehicles are given to customers in the form of statistics obtained in fuel economy tests. A quarter of a century ago it was taken for granted that a fuel-efficient vehicle was one equipped with a manual transmission. Today, however, a 2-pedal transmission is the prerequisite specification of a fuel-efficient vehicle. Moreover, 2-pedal

ティブ変速制御など『個人の自由な移動』を支援する技術をも提供してきています．これらは，Personal Mobilityの矛盾の解決に2ペダルTMが貢献してきた成果です．

2ペダルTMには，ステップAT･CVT･DCTなど様々なタイプが存在しています．北米ではステップATが，日本ではCVTが主流となっています．欧州はいまだにMT仕様を購入されるお客さまが大半ですが，近年はAMTやDCTといった2ペダルTMが増加してきています．このように，地域によって2ペダルTMのタイプ･技術に違いが出る背景には，各地域で道路･交通環境や，お客さまの『Driving』に対する期待が異なるのに対し，すべての運転環境やお客さまの期待に答えられる2ペダルTM技術がまだ存在しないことを示しています．

一方，新興国の自動車保有は伸張を続け，交通インフラの整備も進んでいます．このような地域では，初めてクルマを運転されるお客さまが増加しています．これらのお客さまにとっては，私たちが提案する『Driving』が今後の期待値を作っていくことになります．

このように成熟市場･新興市場のPersonal Mobilityへの期待に答えるためには，2ペダルTMがどのような『価値』を提供できるのか?を今一度考える必要があります．

2ペダルTMの価値は，自動車の動力源からの駆動力を効率よくタイヤに伝え，意のままに走らせることだけでは有りません．Personal MobilityのCO_2削減のために，『車全体で使われるエネルギーをマネージメントする』．個人の移動手段としてドライバーが期待する加速性能だけでなく，『車の挙動に関わる駆動力をマネージメントする』．その実現のために，車両技術，交通社会との連携も含めた技術開発を通じ，価値を提供したいと考えています．

本号のテーマである『Jatco CVT8』は，私たちジヤトコの目指す価値実現の重要なマイルストーンとなるものです．このテクニカルレビューで，ジヤトコの目指す価値の一端を紹介したいと思います．

transmissions have also come to incorporate advanced technologies for supporting the freedom of movement that people desire. One good example is Adaptive Shift Control that can detect the driver's intention and vary the driving force accordingly. This is one result of the contributions of 2-pedal transmissions to resolving the contradiction inherent in personal mobility.

There are many different types of 2-pedal transmissions on the market today, including stepped automatic transmissions (ATs), continuously variable transmissions (CVTs) and dual-clutch transmissions (DCTs), among others. Stepped ATs are predominant in North America, while CVTs are dominant in Japan. In Europe, the greater majority of customers still prefer to buy vehicles with a manual transmission, though 2-pedal transmissions like automated manual transmissions (AMTs) and DCTs have been increasing in recent years. The preferred 2-pedal transmission type and technology thus tend to differ from one geographical region to another. One reason for this is the fact that road conditions, traffic environments and customers' expectations of driving performance are different in each market. This situation indicates that there is still no single 2-pedal transmission technology today that is suitable for all driving environments and can meet customers' diverse expectations.

Meanwhile, vehicle ownership in emerging markets is continuing to increase and the construction of road transportation infrastructure is steadily moving forward. The number of customers who are driving their own vehicle for the first time is continually increasing. Therefore, the type of driving performance that we propose to such customers will likely form their future expectations of vehicles.

In order to respond to people's expectations for personal mobility in both mature and emerging markets, it is necessary to consider once again the type of value that 2-pedal transmissions can provide.

The value of 2-pedal transmissions does not lie solely in their ability to transfer driving force efficiently from a vehicle's power source to the drive wheels for obtaining driving performance matching the driver's wishes. For the purpose of reducing CO_2 emissions in personal mobility, two-pedal transmissions can also assist in managing all the energy used in a vehicle. Moreover, in facilitating individual freedom of moment, 2-pedal transmissions can assist in managing the driving force that affects vehicle behavior, in addition to delivering the acceleration performance expected by the driver. This represents the type of value that we want to achieve and provide by developing the requisite technologies, including coordination with vehicle technologies and the traffic infrastructure.

The focus of this issue of the JATCO Technical Review is the Jatco CVT8, a key milestone product for achieving our targeted value. The articles in this issue of the Technical Review explain in general terms the value that JATCO aims to provide through our two-pedal transmissions.

Jatco CVT8 の企画

Planning of the Jatco CVT8

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Corporate Vice President Shinji MORIHIRO

抄 録 弊社は2012年02月より，幅広い領域をカバーする中大型車向けJatco CVT8（以降「CVT8」とする.）の生産を開始した．本稿ではCVT8の開発にいたった背景について，弊社のラインナップの考え方･グローバル市場での自動変速機の動向･自動車の需要の拡大･環境規制や経済性の観点から紹介する．

Summary In February 2012, JATCO launched production of the new Jatco CVT8 series designed to cover a wide range of applications from midsized to large vehicles. This article describes the background leading to the development of this new CVT8 series, specifically with regard to JATCO's product lineup philosophy, transmission trends in global markets, expansion of vehicle demand, environmental regulations and economy.

1．はじめに

企画すべきスコープとして，ユニットの小型･軽量化･性能向上を目的に，中大型用CVTを1ラインナップに統合するという方針のもと，新CVTの企画を目指した．（Fig. 1）

ジヤトコ，および外部で行っている市場動向調査･環境要件調査などの結果から，中大型車は先進国においては台数ボリュームの多いマーケット，新興国ではインフラ整備充実や所得増加に伴い，急激に拡大しているマーケットである．

1. Introduction

This new CVT series was planned under a policy of unifying two existing CVT units used on midsized and large vehicles into a single lineup (Fig. 1). The scope of the planning activity was aimed at reducing the size and weight of the new series and improving its performance.

The results of market trend surveys, research into environmental requirements and other studies indicated that the planned torque capacity range would cover a vehicle market with large sales volumes in developed countries. In emerging economies, it would cover a vehicle market that was expected to expand rapidly accompanying the construction of road infrastructure and rising personal incomes.

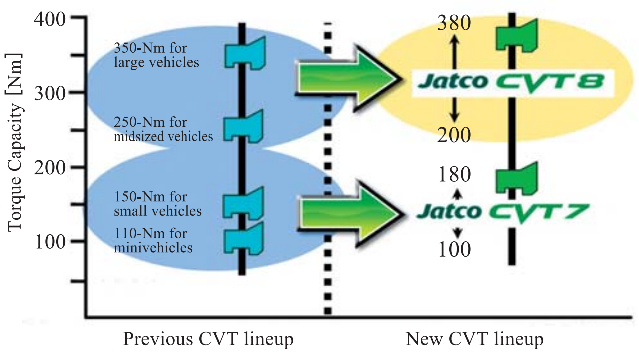

Fig. 1 CVT Lineup for front-drive vehicles

2. グローバルなFFトランスミッション動向 ～DCTの台頭への対抗～

次にグローバルマーケットに於ける台数を分析し，CVT8の主要マーケットを想定した．

新CVTのトルク帯である200～380Nmでは，台数規模が大きいのが北米と中国である．これにより新CVTの最重要マーケットを北米，中国とおいた．北米マーケットはDCTが台頭し始め，中国マーケットでもDCT化･AMT化が進む．これによりこのマーケットで優位に立つためにDCTを超える性能を持つユニットを開発する必要があった．

Fig. 2，Fig. 3に企画時に行なった，トルク帯ごとのグローバルな生産台数と予測を示す．

2. Global Transmission Trends for Front-drive Vehicles: Countering the Rise of DCTs

Principal markets for the CVT8 series were then envisioned by analyzing vehicle volume trends in global markets. The markets having the highest vehicle volumes in the torque range of 200-380 Nm planned for the new CVT series are North America and China. Accordingly, North America and China were selected as the most important markets for the new CVT series. It was seen that dual-clutch transmissions (DCTs) were beginning to increase their share in the North American market, and that DCTs and automated manual transmissions (AMTs) were advancing in the Chinese market. Therefore, it was necessary to develop a CVT with performance exceeding that of DCTs in order to gain a competitive advantage in these markets. Figure 2 shows a breakdown of the global production volume of front-wheel-drive vehicles fitted with a 2-pedal transmission in the 200-380 Nm torque range in various markets around the world and forecasts of the production volumes of different transmission types in the U.S. and Chinese markets.

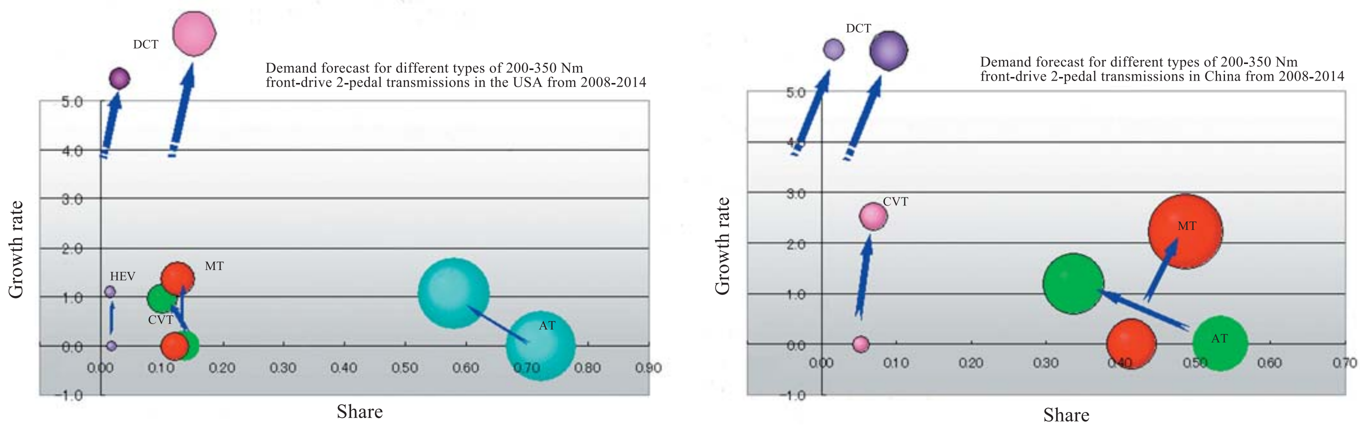

Fig. 2 Global production breakdown for 200-380 Nm front-drive 2-pedal transmission vehicles by country/region and demand forecasts for U.S. and Chinese markets

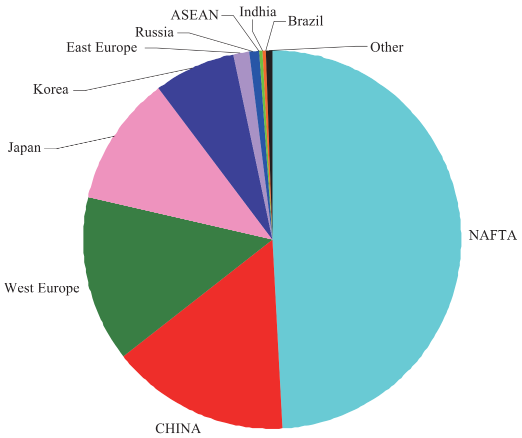

Fig. 3 Global production breakdown for 200-380 Nm front-drive 2-pedal transmission vehicles by country/region

3.求められる商品性

北米，中国マーケットは，2ペダルトランスミッションタイプもCVT･ステップAT･DCT･AMTと幅広く，またカーメーカー内製に加えて，トランスミッションメーカーが多数参入しており，競争が非常に激しいマーケットである．お客さまに貢献できる2ペダルトランスミッションの性能には，

- ● 環境性能（CO_2削減）
- ● 運転性（走りの楽しさ）
- ● 快適性（イージードライブ，静粛性，スムーズ）
- ● 動力性能（発進性能，加速性能，最高速，登坂性能等）
- ●経済性（購入価格，ランニングコスト）

等様々だが，中でも最も重要な性能は経済性や環境性能の大きな要因となる燃費性能であると考えた．また，燃費向上を最優先項目としながらも，各性能についても市場競争力のあるものとして企画した．

4.競争力分析

企画時ジヤトコは軽用，小型用，中型用，大型用とCVTのフルラインナップメーカーとして，各CVTの量産を行っていた．同時にCVT8を企画するために徹底的な競争力分析を実施した．

DCTが世間に認められるようになったこともあり，CVT/ステップATのみならず，DCTも重要な競合と見なし，競争力分析を実施しCVT8の企画へと繋げた．

3. Essential Product Qualities

There is a wide variety of 2-pedal transmissions available in the North American and Chinese markets, including CVTs, stepped automatic transmissions (ATs), DCTs and AMTs. Competition among the different types is extremely fierce, as vehicle manufacturers produce transmissions in-house and many transmission manufacturers are active in these markets. Two-pedal transmissions have various performance attributes that benefit customers including:

- ● Environmental performance (reduction of CO_2 emissions)
- ● Drivability (driving pleasure)
- ● Comfort (driving ease, quietness, smoothness)
- ● Power performance (start-off acceleration, acceleration performance, top speed, hill-climbing performance, etc.)
- ● Economy (purchase price, running cost)

Among them, the most important attributes were assumed to be economy and fuel economy, which is a major factor determining environmental performance. While putting top priority on improving fuel economy under the U.S. combined driving cycle and the New European Driving Cycle (NEDC), the new CVT series was planned so as to have market competitiveness in every performance attribute.

4. Competitiveness Analysis

At that time JATCO had already developed a full lineup of CVTs for use on minivehicles, small cars, midsized vehicles and large vehicles and was mass producing each CVT model. A thoroughgoing analysis of competitiveness was made simultaneously with the planning of the CVT8 series. Since DCTs had also come to be accepted in the marketplace at that time, they were regarded as a serious competitor of CVTs, in addition to stepped ATs. The results of the competitiveness analysis were incorporated in the planning of the CVT8 series.

4.1. Fuel economy

Both wet and dry clutch versions of advanced DCTs were assumed to be CVT competitors with respect to fuel economy. The results of a marketing study indicated that the U.S. combined driving cycle was the most important fuel economy test mode. Accordingly,

4.1. 燃費性能

燃費競合としては，進化型DCT（Wet and Dry）を想定した．またマーケティングの結果より，燃費モードは北米（US comb）が最重要であると考え，競争力分析を行った．結果として，燃費性能で勝つためには，既に優位なフレキシビリティの更なる向上（レシオカバレッジの拡大）に加えて，効率の大幅な向上（フリクション低減）が必要であると考えた（Fig. 4）

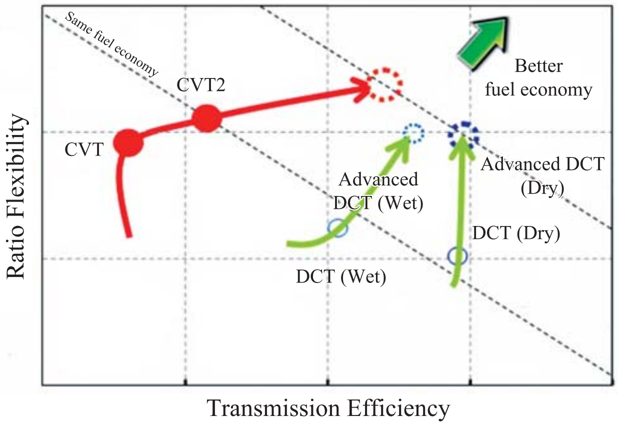

Fig. 4 Analysis of fuel economy competitiveness

4.2. レシオカバレッジ

レシオカバレッジは，燃費性能，動力性能に大きく起因する項目である．ターゲット燃費性能達成のために必要なレシオカバレッジ，および動力性能への寄与度も十分に考慮しターゲットを設定した．

4.3. フリクション

フリクションは，CVT8の最優先性能である燃費性能向上に大きく起因する性能であるため，大幅なフリクション低減策を講じる必要があると考えた．ターゲットとしては，CVT/ステップATでトップ性能になるだけでなく，進化型DCTに勝つために必要なフリクション値をターゲットとして設定した．

4.4. 製造原価

製造原価については，燃費性能と同様に重要と考えて，競合に対してトップになるターゲットを設定した．

5.商品コンセプト

既に述べた項目を考慮しCVT8のコンセプトをまとめた．

competitiveness in fuel economy was analyzed for operation under this driving cycle. Based on the results shown in Fig. 4, it was concluded that improvements would be needed in two aspects in order to remain superior to DCTs in fuel economy as the latter continued to progress. One was to expand ratio coverage so as to further improve ratio flexibility, for which CVTs already enjoyed an advantage. The other was to reduce friction in order to improve transmission efficiency substantially.

4.2. Ratio coverage

Ratio coverage is one factor that markedly influences both fuel economy and power performance. The ratio coverage target was set by fully considering the ratio coverage needed to attain the targeted fuel economy level as well as its contribution to power performance.

4.3. Friction

Friction was assumed to be a major factor affecting improvement of fuel economy, which was regarded as the top priority performance attribute of the CVT8 series. Accordingly, it was concluded that various measures had to be taken to reduce friction significantly. The target set for friction reduction was not simply to attain the best performance among existing CVTs and stepped ATs, but rather to achieve a level of friction necessary for being superior to advanced DCTs.

4.4. Manufacturing cost

Manufacturing cost was regarded as being as important as fuel economy. The target set was to achieve the lowest cost level among rival transmission types.

5. Product Concept

The following product concept was defined for the CVT8 series, taking into account the aspects explained above.

1. To reduce costs by sharing components in common between the CVT8 for midsized vehicles and the CVT8HT (High Torque) for large vehicles.
2. To reconcile higher fuel economy with the desired power performance by improving ratio

1. 中型車向けCVT8と大型車向けCVT8HT（High Torque）の構成部品の共用化によるコスト低減
2. ワイドレシオ化によるフレキシビリティの向上による低燃費と動力性能の両立
3. フリクション低減による効率向上
4. 走りの楽しさの追求

以上をコンセプトとして開発に取り掛かった.

flexibility through wider ratio coverage.

3. To improve transmission efficiency by reducing friction.
4. To pursue enhanced driving pleasure.

Based on this product concept, we set about to develop the new CVT8 series.

環境性能を向上したJatco CVT8の技術紹介

Introducing the Fuel Economy Improvement Technologies of the Jatco CVT8

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抄　録　ジヤトコは，2012年2月にJatco CVT8（以下「CVT8」とする．）の生産を開始した．このCVTは従来の2.0Lクラス FF車用CVTと3.5Lクラス FF車用CVTを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た．本稿ではこのCVT8の商品概要と主要技術を紹介する．

Summary　JATCO began manufacturing the Jatco CVT8 series in February 2012. This new CVT series unifies two existing CVTs used heretofore on 2.0-3.5L-class front-drive vehicles, enabling it to cover a wide range of vehicle applications. Moreover, it also substantially improves fuel economy as a result of an extensive review made of the parts of the existing CVTs. This article presents a product overview of the Jatco CVT8 series and describes the major technologies it embodies.

1. はじめに

ジヤトコは，2012年2月にCVT8の生産を開始した．このCVTは従来の2.0LクラスFF車用CVTと3.5LクラスFF車用CVTを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た．

地球環境が課題視されて久しいが，自動車業界では燃費向上が環境維持への貢献とされ，電気自動車などゼロエミッション車両も普及し始めている．しかし現時点でレシプロエンジン車の割合はまだ大きく，CVTはその燃費を向上させる有力な環境技術の一つとなっている．

弊社は早くからCVTに着目し，他社に先駆けてフルラインナップ化の取り組みをおこなってきた．1997年に当時世界初となる2.0LクラスFF車用CVTを発表して以来，軽自動車用から3.5LクラスFF車用まで幅広い車両に対応したCVTを実用化し，好評を得ている．

今回，新規に開発したCVTは，2.0LクラスFF車から3.5LクラスFF車まで幅広く搭載していく予定である．本稿ではCVT8の商品概要と主要技術を紹介する．（Fig. 1）

1. Introduction

JATCO launched production of the Jatco CVT8 series in February 2012. This new Jatco CVT8 series has a broad range of application that unifies the coverage of two existing units used so far on 2.0L-class to 3.5L-class front-drive vehicles. In addition, it also improves vehicle fuel economy significantly as a result of making an exhaustive review of the parts of the existing units.

Global environmental protection has been viewed as a priority for many years. The automotive industry has been contributing to environmental protection through concerted efforts to improve vehicle fuel economy. Electric vehicles and other types of zero-emission vehicles released by the automakers are beginning to gain popularity. However, vehicles fitted with a reciprocating engine still account for a large proportion of the vehicle population at this point, and CVTs are an effective environmental technology for improving the fuel economy of such vehicles.

JATCO began to focus attention on CVTs early on and undertook activities to develop a full CVT lineup ahead of other manufacturers. In 1997, we announced the world's first CVT for use on 2.0L-class front-drive vehicles. Since then, we have developed CVTs for

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Project Promotion Office

** 実験部
Experiment Department

Fig. 1 Jatco CVT8

2. 商品

2.1. 商品コンセプト

CVT8は以下のコンセプトで開発を行った．

(1) 変速比幅拡大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

2.2. 商品ラインナップ

弊社は軽自動車用から3.5LクラスFF車用までのCVTフルラインナップを実現しており，当初トルクレンジを4機種でカバーしてきたが，軽自動車用と1.5LクラスFF車用CVTを統合する副変速機付CVT（Jatco CVT7）を2009年に発表して現在は3機種構成となっている．今回生産を始めたCVT8により2.0LクラスFF車用と3.5Lクラス車用CVTを共通として2機種構成とした．（Fig. 2）その結果，適用領域で台数規模が拡大して大幅なコスト低減に貢献した．

今回開発したCVT8の諸元をTable 1に示す．

Table 1 Major specifications

Item			For 2.0L-class FWD vehicles		For 3.5L-class FWD vehicles	
			Existing CVT	CVT8		Existing CVT
Torque capacity			250	250	380	350
Gear Ratio	Ratio coverage		6.0	7.0	6.3	5.4
	Pulley ratio		2.35~0.39	2.64~0.38	2.43~0.38	2.37~0.44
	Final gear ratio		5.1~6.4	4.8~6.4	4.7~5.8	4.8~6.3
	Planetary gear ratios	Forward	1.00	1.00	1.00	1.00
		Reverse	0.75	0.75	0.75	0.75
Through low ratio			12.0~15.2	12.7~16.8	11.3~14.1	11.6~15.0
Weight (kg)			91.5	91.5	98.5	103.5
Overall length (mm)			340	345	356	372.6
Distance between pulley shafts (mm)			**171**	**173**	**173**	**178**
Distance between 1st and 4th shafts (mm)			197	197	205	205

application to a wide range of vehicles, extending from minivehicles to 3.5L-class front-drive models. Our CVTs enjoy an excellent reputation in global markets.

The newly developed Jatco CVT8 series is designed for use on a broad range of front-drive vehicles, from 2.0L-class to 3.5L-class models. This article presents a product overview of the new Jatco CVT8 series and describes its major technological highlights (Fig. 1).

2. Product Overview

2.1. Product concept

The Jatco CVT8 series was developed around the following concept.

(1) To achieve both improved fuel economy and better power performance by expanding ratio coverage

(2) To increase fuel economy by reducing friction

(3) To create a CVT series for common use on 2.0-3.5L-class front-drive vehicles by downsizing the unit

2.2. Product lineup

JATCO has a full CVT lineup, ranging from units for use on minivehicles to ones used on front-drive vehicles with a 3.5L-class engine. Four CVT models previously covered the entire engine torque range from minivehicles to large cars. The model mix was integrated into three series when the Jatco CVT7 with an auxiliary transmission was released in 2009, which integrated two existing units used on minivehicles and 1.5L-class front-drive small cars. With the launch of the new Jatco CVT8 series for common use on both 2.0L-class and 3.5L-class front-drive vehicles,

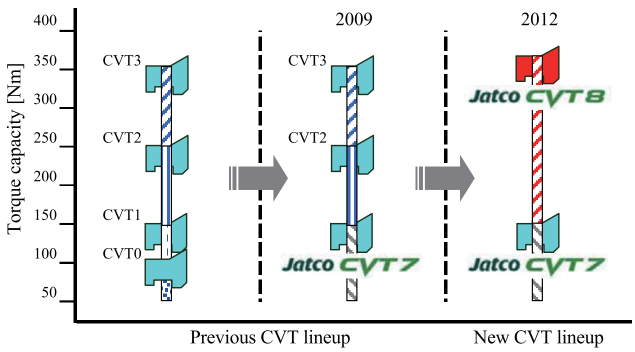

Fig. 2 CVT Lineup for front-drive vehicles

2.3. 開発の狙い

CVT8は，従来型CVTに対し以下の視点で燃費性能の向上を図った．（Fig. 3）

(1) 変速比幅拡大による，高速燃費の改善
(2) 部品見直しによる，フリクションの低減
(3) 新制御採用による，トルクコンバータ損失および油圧損失の低減

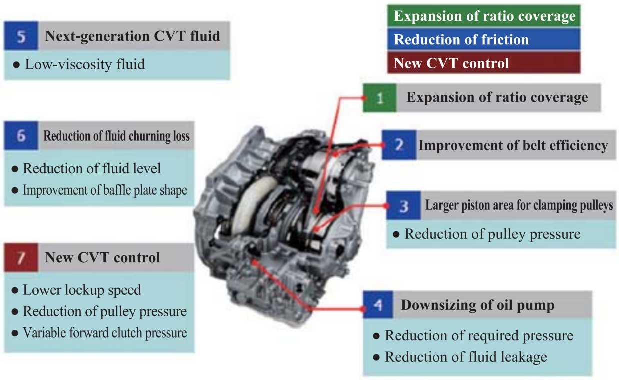

Fig. 3 Key measures for improving fuel economy

2.4. 構造

発進要素はトルクコンバータを採用し，エンジンからの入力トルクは，このトルクコンバータからインプットシャフトを介し，変速機構であるプーリーシステムへ伝達される．リダクションギヤ列を介して，ディファレンシャルギヤにより左右の駆動輪を駆動する．

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

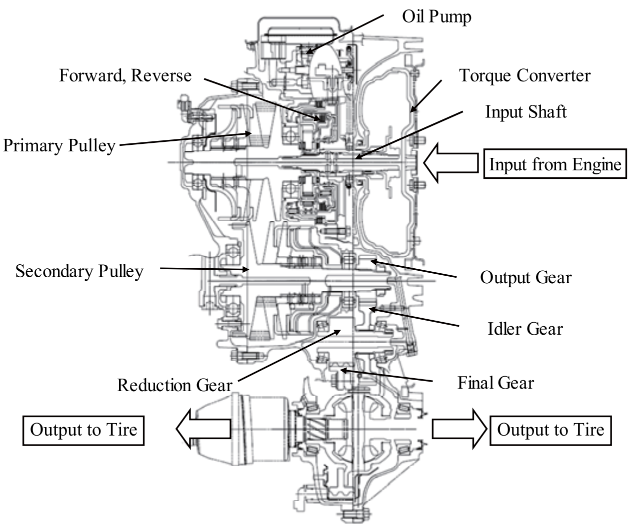

Fig. 4 Main cross section

the model mix has now been unified into two series. The wide range of application of each CVT series will mean larger production volumes, thereby contributing to substantially lower costs (Fig. 2).

The specifications of the new Jatco CVT8 series are given in Table 1 in comparison with the existing base models.

2.3. Development aims

The CVT8 achieves better fuel economy than the existing base CVTs because of the measures taken with regard to the points below (Fig. 3).

(1) Fuel economy at high driving speeds was improved by substantially expanding the ratio coverage.
(2) Reduction of friction by thoroughly improving the constituent parts
(3) Reduction of torque converter loss and pressure-related loss by adopting new control features

2.4. CVT Structure

The Jatco CVT8 series adopts a torque converter as the start-off element. Torque input from the engine is transferred from the torque converter via an input shaft to the belt-pulley system that serves as the shift mechanism. It is then transferred through the final reduction gear to the differential gear and from there to the right and left drive wheels.

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

2.5. Technologies for accomplishing fuel economy improvement

A target was set for improving fuel economy by 10% under the U.S. combined driving cycle compared with the existing base CVTs by adopting the measures shown in Fig. 3. The strategy devised for achieving that goal is shown in Fig. 5.

While inheriting the same structure as the existing base CVTs, the CVT8 reduces friction by approximately 40% as a result of thoroughly redesigning the fine details of various parts (Fig. 6).

2.5. 目標達成技術

先に述べた低燃費技術の採用により，従来型CVT比でUS-Combで燃費10%の向上を目標に企画した．（Fig. 5）

従来構造を踏襲した今回のCVT8では細部まで徹底的に部品を見直すことで，約40%のフリクション低減を達成した．（Fig. 6）特に，オイルポンプ駆動トルクおよび攪拌抵抗の低減が寄与している．

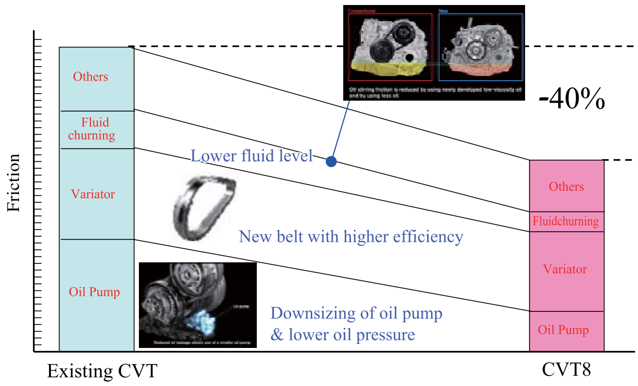

Fig. 6 Breakdown of friction reduction

新型ベルトの適用と設計要件の見直しによるプーリーシャフト径の細軸化，ならびに軸間2mmUPにより変速比幅を従来から17%拡大した．（Fig. 7）

3. 主な採用技術の詳細

3.1. オイル攪拌抵抗の低減

CVT8では，主としてリングギヤ，およびディファレンシャルギヤによるオイル攪拌抵抗の改善を目的に，油没部を全包囲した形状のバッフルプレートの追加（Fig. 8），オイルレベルの低減，および低粘度オイルの採用によりフリクションを低減した．

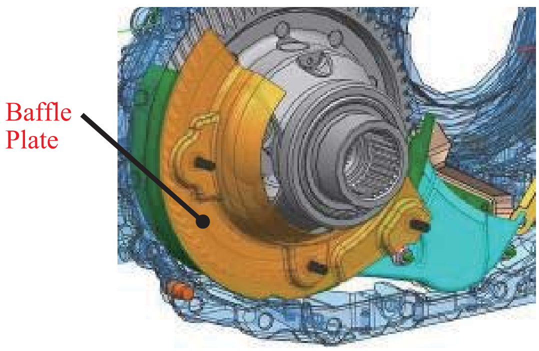

Fig. 8 Structure of baffle plate

バッフルプレートの終端形状は，リダクションギヤへの潤滑を考慮して決めた．また，バッフルプレー

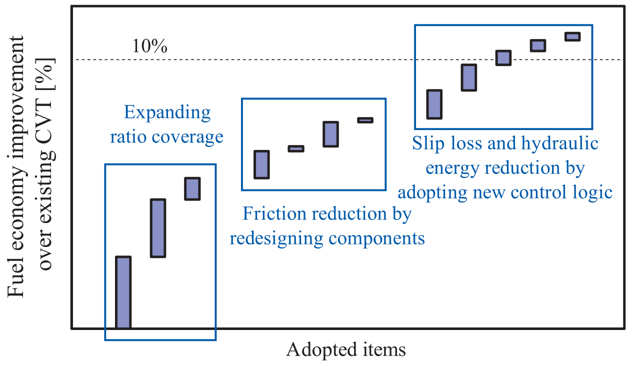

Fig. 5 Strategy for achieving goal

Two major factors in particular that contributed to reducing friction were the reduction of oil pump drive torque and fluid churning.

Ratio coverage was expanded by 17% over the existing base CVTs by adopting a new belt, narrowing the pulley shaft diameter based on a review of the design requirements, and increasing the distance between the pulley shafts by 2 mm (Fig. 7).

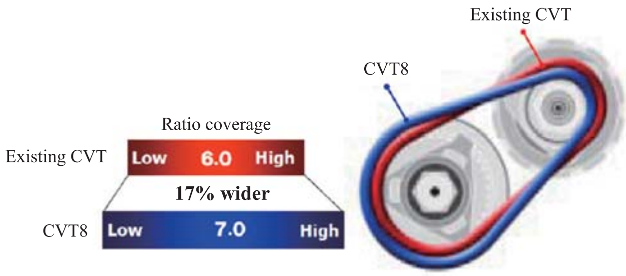

Fig. 7 Expanded ratio coverage of the CVT8
for midsized vehicles

3. Details of Major Technologies Adopted

3.1. Reduction of fluid churning

Baffle plates were added to the ring gear and the differential gear of the CVT8 mainly for the purpose of reducing fluid churning caused by their rotation. The baffle plate shape was designed to cover the entire submerged portion of the gears (Fig. 8). That measure along with the reduction of the fluid level and the adoption of a low-viscosity CVT fluid worked to reduce friction.

The shape of the end portion of the baffle plates was determined by taking into account the dispersion of fluid for lubricating the reduction gear. In addition, the installation clearance of the parts composing the baffle plates was determined so as to ensure good assembly line productivity and fluid drainage from inside the baffle plates.

トを構成する各部品の組み付け部クリアランスは，生産性とバッフルプレート内の油の排油性から決めた．

Fig. 9に流体解析に拠るバッフルプレート有無での油かき上げ量の違いを示す．バッフルプレート有りは無しと比べて，狙い通り油の飛散量を低減していることが確認できた．

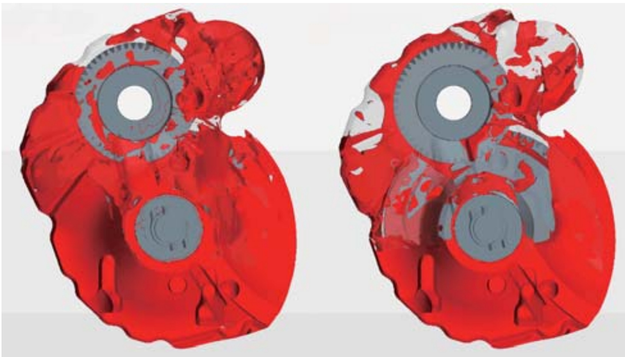

Fig. 9 Aspects of agitation without and with baffle plate

入力回転数毎のバッフルプレート有無による攪拌抵抗の低減効果をFig. 10に示す．特に高回転領域での低減に大きく寄与している．

3.2. バリエータ効率の向上

CVT8では，下記2つの特性を改良した新型スチールベルトを採用した．

(1) リング幅の低減

(2) ベルト剛性の最適化

高強度材を採用により，リング幅を狭くし，スチールベルトのトルク伝達メカニズム上避けられないリングとエレメント間の摩擦損失を低減した．また，エレメントの形状を見直すことで剛性を最適化して走行半径を理想に近づけることで，摩擦損失を低減した．(Fig. 11)

3.3. オイルポンプ駆動トルクの低減

CVT8では，

(1) コントロールバルブからのオイルリーク低減

(2) ライン圧の低減

によりオイルポンプ駆動トルクを低減した．

大容量3方ソレノイドの採用により，従来12本使っていたスプールを8本に削減することと，スプールとバルブボディのクリアランスを最適化して，コントロールバルブからのオイルリークを低減した．これにより，

Figure 9 presents the results of a computational fluid dynamics (CFD) analysis showing the difference in the amount of fluid churning with and without the baffle plates. The results confirm that the addition of the baffle plates reduces the amount of fluid dispersion as was intended, compared with the condition without the baffle plates.

Figure 10 shows the effect of the baffle plates on reducing fluid churning at two different input speeds in comparison with the results without the baffle plates. The baffle plates markedly reduce fluid churning especially in the high-speed range.

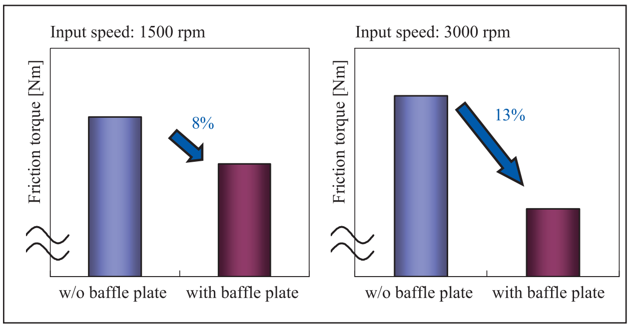

Fig. 10 Effect of baffle plate

3.2. Improvement of variator efficiency

The CVT8 adopts a new steel belt featuring improvements in the following two characteristics.

(1) Reduction of the band width

(2) Optimization of belt stiffness

The use of a high-strength steel allowed a narrower band width for reducing the friction loss between the bands and the elements, which is unavoidable in the

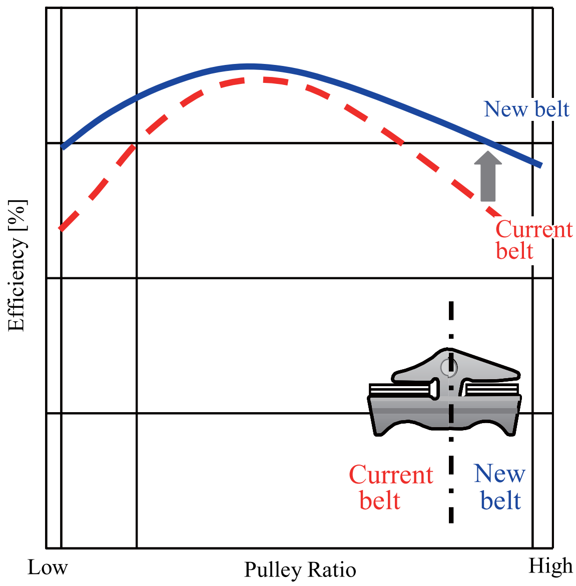

Fig. 11 Belt efficiency

オイルポンプサイズを約30%低減した．

これらの相乗効果によりオイルポンプ駆動トルクを低減した．（Fig. 12）

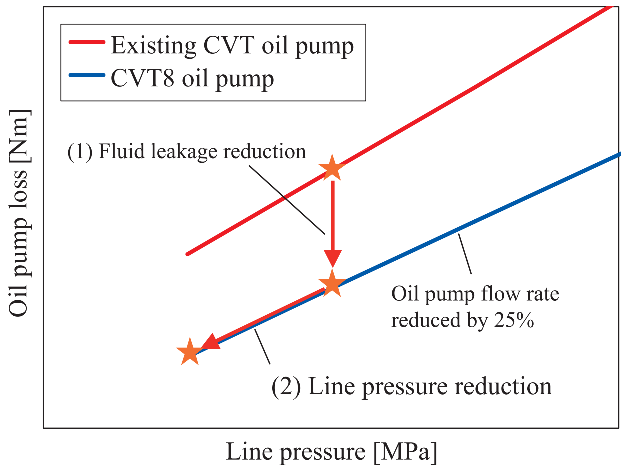

Fig. 12 Oil pump torque loss

4. 燃費効果の検証結果

モータベンチによるCVTユニット単体でのモード走行シミュレーションを行い，入出力エネルギー，油圧などを測定し，燃費向上効果を検証した．（Fig. 13）

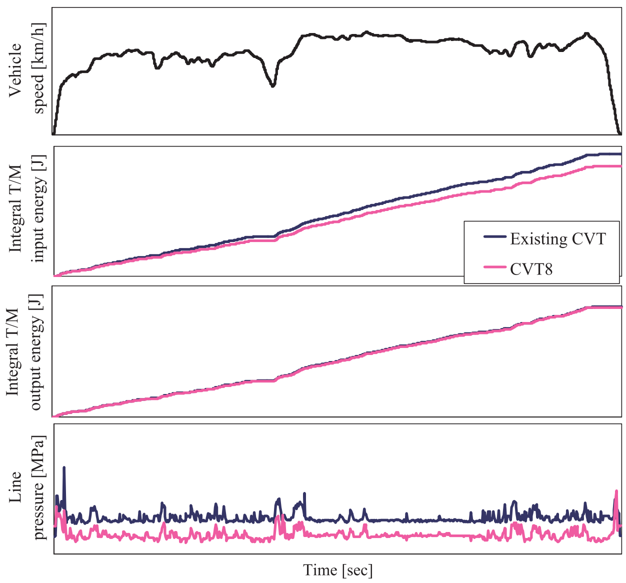

Fig. 13 Comparison of input/output energy behavior in U.S. highway driving cycle

トランスミッションの出力エネルギーは，同一車両を模擬した負荷で走行しているため，同等であるが，入力エネルギーはCVT8の方が低い．これは，CVT8でトランスミッションのフリクションが低減していることを意味する．

また，測定結果の解析より，モード平均でフリクショ

torque transmission mechanism of a steel belt. The element geometry was also revised to optimize the belt stiffness and bring the belt's running radius closer to the ideal. That also worked to reduce friction loss (Fig. 11).

3.3. Reduction of oil pump drive torque

The drive torque of the CVT8 oil pump was reduced as a result of (1) reducing fluid leakage from the control valve and (2) reducing the line pressure.

The adoption of a large-capacity three-way solenoid made it possible to reduce the number of valve spools from 12 in the existing base CVTs to 8 in the CVT8. The clearances between the spools and the valve body were also optimized. These two measures reduced fluid leakage from the control valve, enabling the oil pump to be downsized by approximately 30%.

The multiplier effect of these improvements allowed the oil pump drive torque to be reduced (Fig. 12).

4. Verification of Fuel Economy Improvement Effects

Motor benches were used to simulate the conditions of regulatory test driving cycles at the level of CVT operation. Measurements were made of the input/output energy, pressure and other parameters to investigate the effect of the adopted technologies on improving fuel economy in comparison with the existing base CVT (Fig. 13).

The output energy waveforms of the two CVTs were the same because they were operated under an applied load that simulated identical vehicle specifications. However, input energy was lower for the CVT8, which signifies that the friction level has been reduced in this transmission.

An analysis of the measured data confirmed an improvement in the drive torque transmission efficiency of the CVT8 owing to reduced friction and an improvement in the brake thermal efficiency of the engine attributable to the expanded ratio coverage. As a result of those cycle-averaged improvements, it was verified that the CVT8 is effective in improving fuel economy by approximately 10% in both the U.S. city and highway driving cycles (Fig. 14).

ン低減によるトランスミッションの伝達効率の向上代，および変速比幅の拡大によるエンジンの正味熱効率の向上代を確認した．その結果，City，Highwayとも約10%の燃費効果があることを検証できた.（Fig. 14）

5. 走りの楽しさ

CVTはステップATにはない，スムーズな変速に特徴を持つ．CVT8でもその特徴を最大限に生かして車が本来持つ『走る楽しさ』に貢献すべく変速制御を進化させた．（Fig. 15）

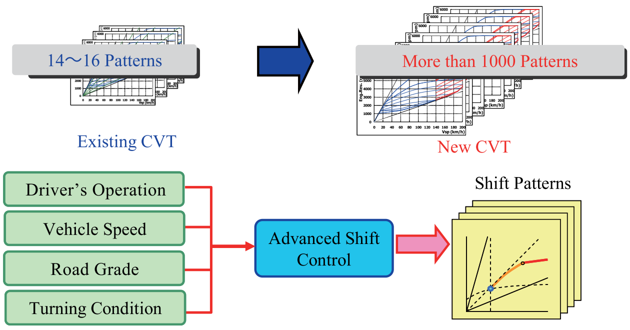

Fig. 15 Improvement of transmission control

CVT8では変速パターンを従来の14〜16から1000以上として運転シーンに合わせてきめ細やかに変速を制御できるようにした．加えて車両状況と車の操作からお客さまの運転意図を読み取りできるようにした，変速パターンを都度変更．

これらの進化により高速道路合流時の力強い加速や，ワインディングロードでの安定した走りを実現した．（Fig. 16-1, 16-2）

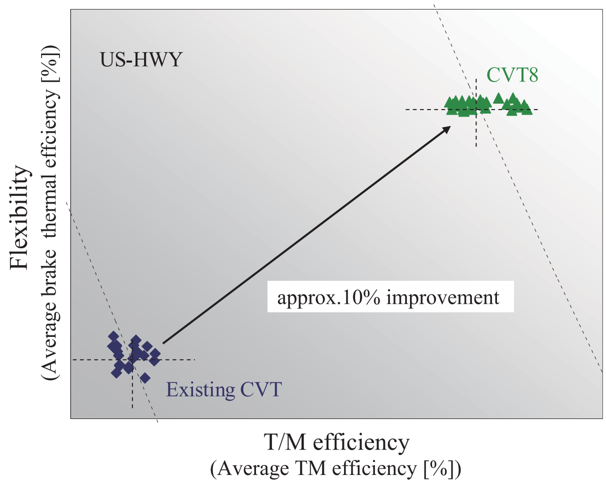

Fig. 14 Measured results for fuel economy improvement

5. Driving Pleasure

CVTs feature smooth, seamless shifting, an attribute that stepped automatic transmissions (ATs) do not have. That characteristic was fully exploited in further advancing the shift control of the Jatco CVT8 so as to contribute to the inherent driving pleasure of vehicles (Fig. 15).

The Jatco CTV8 incorporates more than 1,000 shift patterns, compared with 14-16 for the existing CVTs. This facilitates fine-tuned shift control matching diverse driving situations. Moreover, the shift control infers the driver's intention from the vehicle state and driving operation inputs and varies the shift pattern accordingly.

The shift control improvements enable the vehicle to deliver powerful acceleration when merging with freeway traffic as well as stable driving performance when traveling on winding roads (Figs. 16-1 and 16-2).

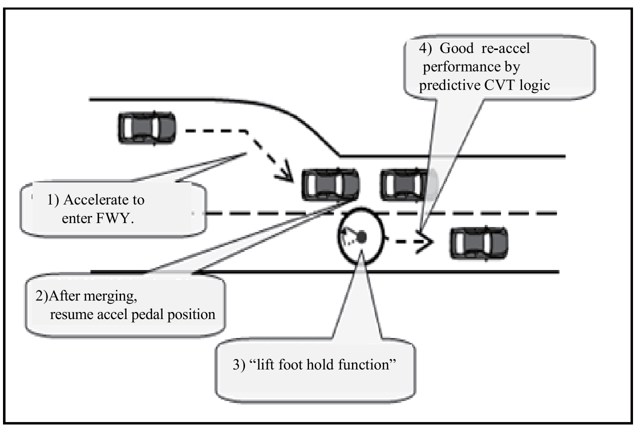

Fig. 16-1 Driveability performance

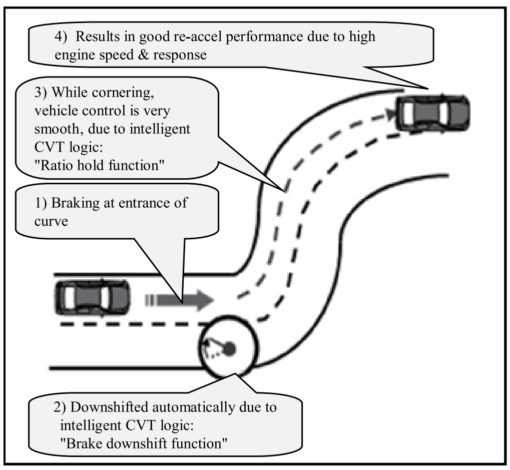

Fig. 16-2 Driveability performance

6. 競争力分析

CVT8の燃費競争力の分析結果をFig. 17に示す．CVT8の伝達効率は，ステップATを凌駕する実力を有しており，変速比幅および無段変速による燃費効果を考慮すると，トランスミッションが寄与するトータルのエネルギー効率はクラストップである．

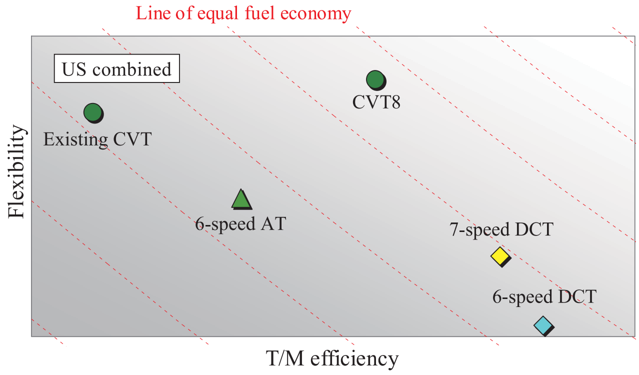

Fig. 17 Fuel economy competitiveness of CVT8

7. まとめ

CVT8の開発により以下の効果を得られた．

(1) ワイドレンジ化による動力性能と燃費の両立

プーリーシステムの最適化を行うことでユニットサイズの拡大や，適用トルクの低下なく従来型CVTに対して17%のレシオカバレッジの拡大を達成した．これにより発進性能の確保と巡航走行時の低回転走行が可能になり，低燃費化，加えて低騒音化が達成できた．

(2) フリクションの低減

従来と同様の構造をとりつつも主として油圧システムやプーリーシステムを改善，最適化することで，攪拌抵抗を低減し，従来型CVTに対して40%のフリクション低減を達成することができた．これは適用車両にもよるが燃費効果で最大10%の貢献となる．

(3) 走りの楽しさの追求

変速制御を進化させることでCVTの持つスムーズな変速でお客さまの意図通りの走りを実現することができた．

6. Analysis of Competitiveness

Figure 17 shows the results of an analysis of the fuel economy competiveness of the CVT8. The effective drive torque transmission efficiency of the CVT8 is markedly superior to that of stepped ATs. Taking into account the effect of the expanded ratio coverage and stepless shifting on fuel economy, the plots in the graph indicate that the CVT8 achieves class-leading total energy efficiency.

7. Conclusion

The newly developed CVT8 series provides the following benefits.

(1) Improved fuel economy combined with power performance through wider ratio coverage

Optimization of the pulley system expanded ratio coverage by 17% over that of the existing CVTs without increasing the transmission size or reducing the applicable torque range. Wider ratio coverage provides excellent start-off acceleration and allows a lower engine speed for improved fuel economy and quieter operation during highway cruising.

(2) Reduced friction

The CVT8 series has 40% less friction than the existing CVTs, which translates into a fuel economy gain of up to 10%, depending on the vehicle application. This friction reduction was achieved primarily by improving and optimizing the hydraulic and pulley systems, while retaining the same basic CVT structure as that of the existing units.

(3) Pursuit of driving pleasure

Shift control improvements deliver the smooth, seamless shifting characteristic of CVTs and provide driving performance matching the driver's wishes.

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レシオカバレッジ拡大プーリーの開発

Development of New Pulleys for Expanding Ratio Coverage

辻　洋一*
Yoichi TSUJI

抄　録　ジヤトコはJatco CVT8（以下「CVT8」という．）を2012年2月に生産を開始した．

CVT8はドライバーの要求に応じた動力性能の実現やエンジンの効率の良いポイントを使用し燃費への貢献できるようレシオカバレッジ（以下レシカバという）の拡大を行った．

本原稿は，CVT8のレシカバ拡大に大きく寄与したプーリーの主要技術について紹介する．

Summary　In February 2012, JATCO began producing the CVT8 series that achieves higher vehicle fuel economy. The ratio coverage of the CVT8 series was expanded to provide the power performance demanded by the driver and also to contribute to improving fuel economy by enabling the engine to operate in a range of high efficiency. This article describes the key pulley technologies that were developed for significantly expanding the ratio coverage of the CVT8 series.

1. はじめに

近年，エネルギーおよび地球環境への配慮や原油価格の上昇等から自動車の燃費向上，コスト低減，小型軽量化がこれまで以上に求められている．加えて静粛性やドライビング性能の向上も望まれている．

これらを実現するためにコンパクトで，かつレシカバを拡大したプーリーが必須である．そこで，

（1）FEMによる応力解析技術の精度
（2）過渡運転時の挙動
（3）疲労強度設計の精度
（4）生産性を考慮した形状

でそれぞれの限界を見極め，新たに設計の見直しを行った．

ここでは2.0L～3.5L適用のCVT8用に開発したプーリーの技術解説を行う．

1. Introduction

In recent years, there have been greater demands than ever before for improvement of vehicle fuel economy, lower costs and size/weight reductions owing to heightened concerns about energy, the global environment and rising oil prices, among other things. In addition, there are also desires for enhanced vehicle quietness and driving performance.

In order to meet these diverse requirements, it is necessary to have CVT pulleys that are more compact in size and can contribute to expanding the ratio coverage. Therefore, we reviewed the pulley design once again, paying careful attention to the limits of the following aspects.

(1) Accuracy of the FEM stress simulation program
(2) Pulley behavior under transient operating conditions
(3) Accuracy of the fatigue strength design
(4) Pulley shape taking into account productivity

The following sections describe the pulley technologies developed for the CVT8 series intended for application to 2.0L-3.5L-class vehicles.

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2. プーリー主要諸元

Table 1にCVT8とJF010E，JF011Eのプーリー主要諸元を示す．

Table 1 Major specifications of pulley

		CVT8		JF010E	JF011E
Torque capacity		350	250	350	250
Ratio coverage		6.3	7.0	5.4	6.0
Pulley ratio	Low	2.41	2.64	2.37	2.35
	High	0.38	0.38	0.44	0.19
Shaft diarmeter		48-49.8	48	52.6-59	49.8
Center distance		173		178	171

3. レシオカバレッジの拡大

CVTのレシオは駆動側（以下プライマリとする）と従動側（以下セカンダリとする）のベルト巻付き径の比であるから，レシカバを大きくするためにはLow・Highレシオ共にこの比が大きくなる様に配置する（Fig. 1）．シーブ径を拡大するとプライマリとセカンダリの軸間（Center distance）が広がりユニットが大きくなる．逆に軸径を小さくするとユニットをコンパクトにできるが軸強度が課題となる（Fig. 2）．

CVT8はコンパクト，かつレシカバを拡大するためにプーリー軸の細軸化にチャレンジすることとした．しかし，より厳しい条件となることから課題を小さなところまでブレークダウンし限界を見極めたうえで設計する取組みを実施した．

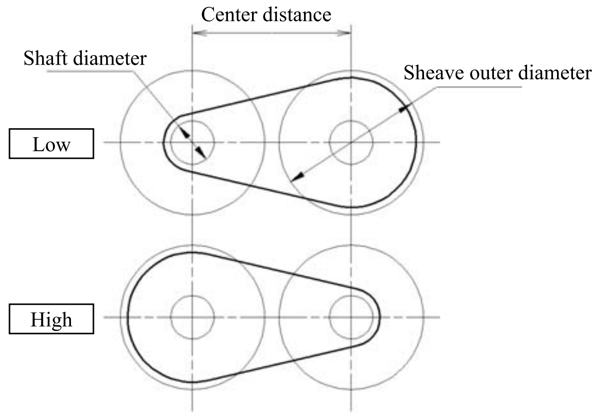

Fig. 1 Pulley layout

3.1. 発生応力，およびFEM応力解析の精査

プーリーへの主要入力に油圧，および軸間力による曲げがある．CVT8のプーリーを成立させるために実験で入力モードを丹念に測定し，発生する応力を把握した．

まず，ジヤトコの全てのCVTで静的および動的に

2. Pulley Specifications

Table 1 compares the major specifications of the pulleys used in the CVT8 series, JF010E and JF011E.

3. Expansion of Ratio Coverage

The CVT ratio represents the ratio of the diameter of belt contact on the drive-side primary pulley to that on the driven side secondary pulley. Therefore, in order to expand the ratio coverage, the pulleys must be positioned so that this ratio increases on both the Low and High ratio sides (Fig. 1). If the sheave diameter is increased, it expands the center-to-center distance between the primary and secondary pulley shafts, resulting in a larger unit. Conversely, if the shaft diameter is reduced, the unit becomes more compact, but the shaft strength becomes an issue of concern (Fig. 2).

In order to downsize the CVT8 while still expanding the ratio coverage, it was decided to undertake the challenge of reducing the pulley shaft diameter. However, because that would subject the pulley shafts to more rigorous operating conditions, the pulley design was developed by breaking down the issues involved into small details and analyzing the limits of each one thoroughly.

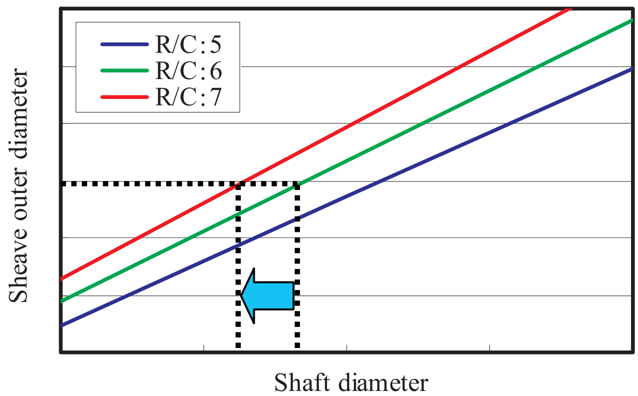

Fig. 2 Pulley layout relationship

3.1. Careful investigation of actual stress and accuracy of FEM stress simulation

The principal force inputs to the pulleys include hydraulic pressure and bending induced by axial force. In order to ensure the feasibility of the CVT8 pulleys, the actual stress that occurs was ascertained by carefully measuring the force input modes experimentally.

発生する応力の再取得を実施した．つぎに同一CVTで軸径を変化させながら発生する応力の取得を行い変化と傾向を把握した．

さらに，実験結果を基に全ての評価モードでFEMによる応力解析を行い，精度向上を図ったアセンブリ解析モデルを構築することができた．Fig. 3に油圧，および軸間力によるシーブ付け根の曲げ応力の測定結果，およびFEM解析の一例を示す．

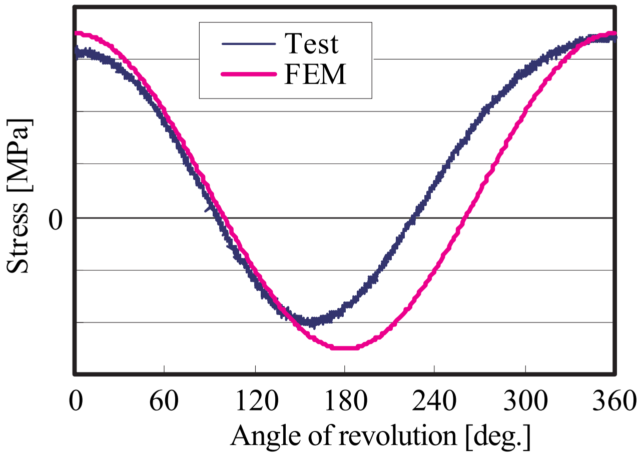

Fig. 3 Pulley shaft stress

3.2. 過渡運転時の挙動

厳しい入力がプーリーへ入るのは車両の運転条件で言えば発進ストール，および変速過渡なので，この2つを評価する．

発進時は停止している車両を必要な車速に到達させるためにエンジンとトルクコンバータの性能を最大限に活用することから大きなトルクが入力される．この入力トルクを伝達するためには大きな油圧が必要となり，プーリーの曲げモーメントが大きくなる．

一方，変速するためにはプライマリとセカンダリの力のバランスを変える必要がある．ベルト滑りを防止するためには入力トルクに応じたクランプ力を保持しながら釣合う力より大きな力を片側のプーリーにかける必要がある．このとき，逆側のプーリーには短時間ではあるがその反力がかかるため，プーリーの曲げモーメントが大きくなる．Fig. 4に概念を示す．

さらにこの力は変速レスポンスを向上するために複雑なチューニングが行われるため性能設計，制御設計，部品設計が連携し注意深く決定した．

First, measurements were made of the static and dynamic stresses that occur in all of JATCO's CVTs. Then, using the same CVT, the stress that occurred in relation to various shaft diameters was measured to ascertain the change in the stress level and the tendency.

Based on the experimental results, an FEM stress simulation was then conducted under all of the evaluation modes. A pulley assembly simulation model was successfully built for the purpose of improving simulation accuracy. Figure 3 shows an example of the measured and FEM simulation results for bending stress at the base of the sheave induced by hydraulic pressure and axial force.

3.2. Pulley behavior under transient operating conditions

Examples of vehicle operating conditions that apply severe force inputs to the pulleys include stall upon vehicle launch and transient ratio changes. Therefore, pulley evaluations were conducted under these two conditions.

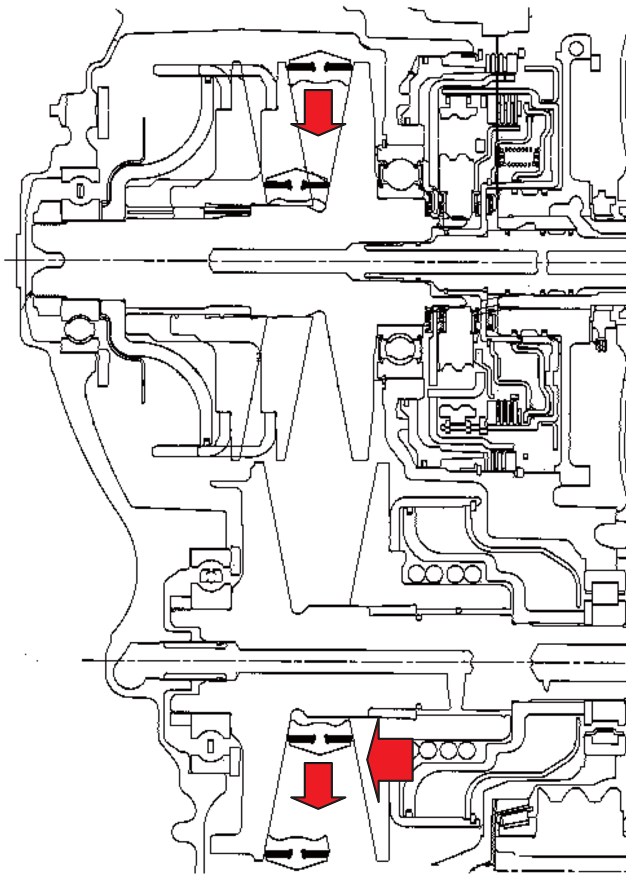
Fig. 4 Ratio change mechanism

3.3. 疲労強度設計の精度

前述のようにプーリーは大きな曲げと，トルクによるねじりの入力を受ける．

ところで，金属材料の疲労限度線図は一般的に修正Goodman線が成立するといわれている．そこでCVT8プーリーの材料でも成立するかを確認するため，実際のプーリーを用いてTable 2に示す疲労試験を行った．

Table 2 Types of fatigue tests

No.	Test piece	Fatigue type
1	Pulley only	Bending fatigue
2	CVT-ASSY	Rotary bending fatigue

Fig. 5に示すようにCVT8プーリーは修正Goodman線に一致する良好な結果を得られた．

これより，修正Goodman線を用いて検討を行えばよいことを再確認した．

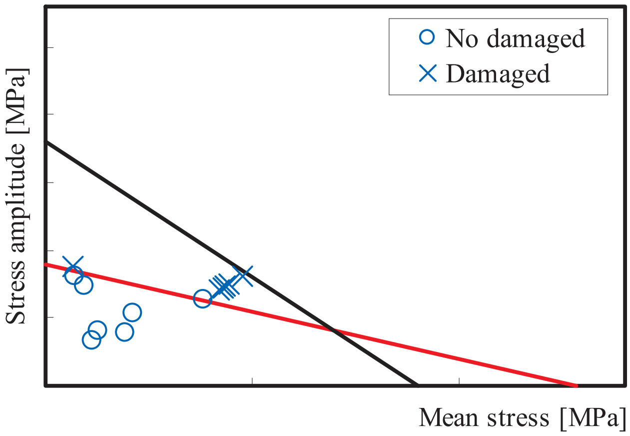

Fig. 5 Fatigue limit diagram

一方，ベルトの巻き付き径を小さくした場合，巻き付くエレメント数が減少する．したがってエレメント1枚当りが受け持つ荷重が大きくなり，接触するシーブ面の面圧が高くなる．ベルトとシーブ面は摩擦で力を伝達しているため，面圧が高くなると繰り返し入力による表面の疲労剥離が起こる．（Fig. 6）

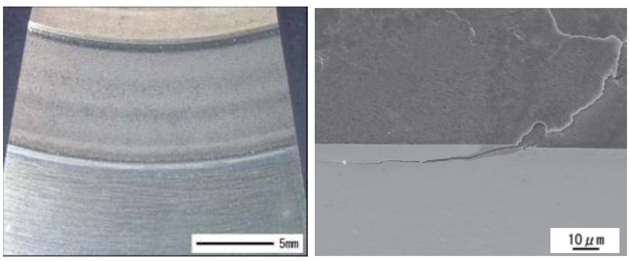

Fig. 6 Wear of pulley sheave

Accelerating a stopped vehicle to the necessary vehicle speed requires full use of the maximum performance of the engine and the torque converter, which inputs large torque to the CVT. A high level of pressure is needed to transmit the input torque, resulting in a large bending moment in the pulley shafts.

On the other hand, shifting the transmission requires a change in the balance of force between the primary and secondary pulleys. In order to keep the belt from slipping, it is necessary to apply a force larger than the force balance to one pulley, while maintaining pulley clamping force commensurate with the input torque. At that moment, the resultant reaction force acts briefly on the other pulley, causing the bending moment of the shaft to increase. This concept is illustrated in Fig. 4.

Moreover, because complex tuning is performed regarding this force in order to improve shift response, special care was taken to coordinate the determination of the performance design, control system design and part designs.

3.3. Accuracy of fatigue strength design

As mentioned above, pulley shafts are subjected to large bending moments and torsional moments caused by the input torque. It is reported that a modified Goodman diagram generally applies to the fatigue limit curve of metal materials. To confirm whether this would apply to the CVT8 pulley material, the fatigue tests indicated in Table 2 were conducted using actual pulleys.

As shown in Fig. 5, good results were obtained for the CVT8 pulleys that were consistent with the modified Goodman diagram. This result reconfirmed that fatigue strength could be investigated using the modified Goodman diagram.

On the other hand, reducing the diameter of belt contact on the pulleys would reduce the number of elements in contact with the pulleys. As a result, the force borne by each element would increase and the contact pressure on the sheave face in contact with the elements would increase. Because drive torque is transmitted by the friction force between the belt and the sheave face, the sheave face might suffer fatigue delamination due to repeated force inputs at higher contact pressure (Fig. 6).

Figure 7 shows the results of a durability test that

シーブ面の疲労剥離を耐久実験にて確認した結果をFig. 7に示す．この結果から表面硬さの上昇シーブ面の疲労剥離強度向上対策として被害度が大きくなる範囲にマイクロショットピーニングを採用した．

3.4. 生産性を考慮した形状

FEMでの応力解析精度が向上したことで詳細形状を検討し，生産-開発共同検討の中で加工ツールの動きや形状をより精度良くフィードバックしたプーリーの設計が可能となった．

Fig. 8にローラーを位置決めするプレートのストッパー機能を有し，かつ応力集中部位の改善例を示す．

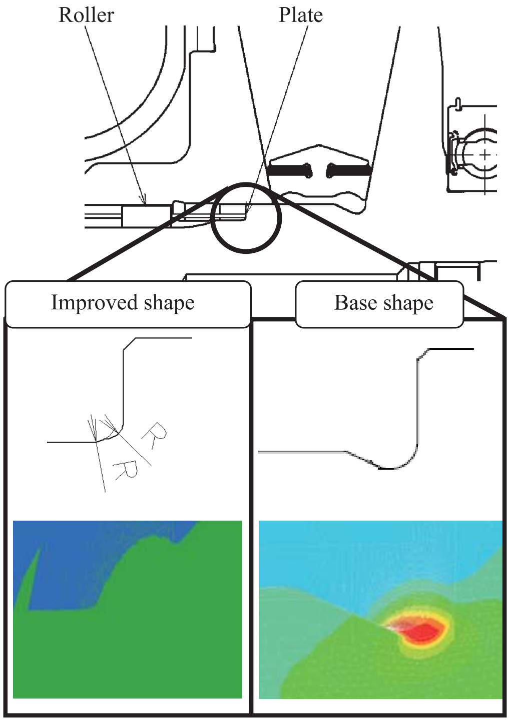

Fig. 8 Shape of pulley shaft

4. CVT8プーリーの開発拠点について

ジヤトコグループの開発拠点は，日本の他にJATCO Korea Engineering（以下「JKE」とする.）がある．両拠点に分かれてリアルタイムにフィードバックをしながら開発を行ったのは，プーリーでは今回が初であり，それぞれの強みを発揮してCVT8の開発ができた．

was conducted to confirm the fatigue delamination of the sheave face. Based on these results, micro-shot peening was applied in the area of large damage as a measure for increasing surface hardness and improving the fatigue delamination strength of the sheave face.

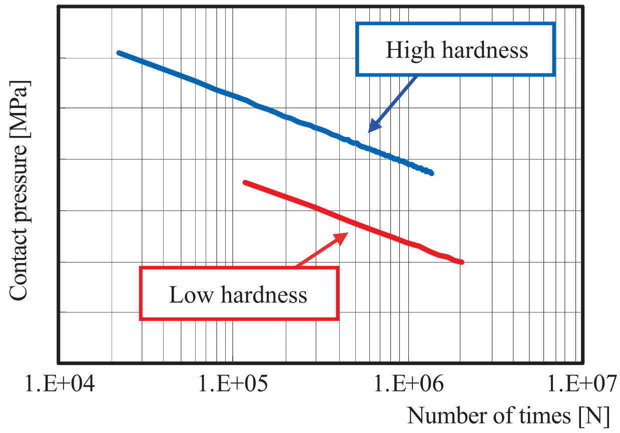

Fig. 7 P-N diagram of sheave wear

3.4. Pulley shape designed for good productivity

Having improved the accuracy of the FEM stress simulation, a study was made of the detailed pulley shape, which was conducted jointly by the manufacturing and R&D divisions. Thanks to that collaboration, the cutting tool motions and pulley shape were fed back more accurately and used in developing the pulley design.

Figure 8 shows a stopper plate that was added for positioning the roller, along with an example of an improved shape for an area of stress concentration.

4. CVT8 Pulley Development Locations

In addition to the company's engineering center in Japan, JATCO has established JATCO Korea Engineering Corporation (JKE) in Korea. The work of developing the CVT8 series was carried out at both locations with real-time feedback of information. This was the first time that this approach was used for developing CVT pulleys. The CVT8 series was successfully developed by both centers making the most of their respective strengths.

5. まとめ

CVT8の要求に対応するレシカバ拡大プーリーを開発し，燃費性能向上を実現することができた．

（1）FEMによる応力解析技術の精度
実験による計測技術とアセンブリモデルにより精度の向上ができた．

（2）過渡運転時の挙動精度
プーリーの推力と反力の関係をマップ化することで全てのシーンでプーリーに必要な耐力を明確にすることができた．

（3）疲労強度設計の精度
実プーリーを用いて実験し，基本理論と一致することが確認できたことにより，限界設計が可能となった．

（4）生産性を考慮した形状
難しい形状を，生産技術検討のフロントローディングにより開発段階から工具の動きや形状を考慮することにより，より簡素で造り易い形状を決定することができた．

CVTのレシカバ拡大は車両の燃費，および動力性能の向上に非常に大きく貢献できると共に，多くの期待が寄せられている技術である．本開発を基礎とし今後も更なる技術の向上に努めていきたい．

5. Conclusion

This article described the development of pulleys for expanding the ratio coverage required of the JATCO CVT8 series and the associated contribution to improving vehicle fuel economy.

(1) Accuracy of FEM stress simulation program
The accuracy of the FEM stress simulation program was improved by developing better measurement techniques based on experimental work and by applying a pulley assembly model to conduct simulations.

(2) More accurate understanding of pulley behavior under transient operating conditions
By mapping the relationship between the pulley thrust force and resultant reaction force, the strength required of the pulleys was made clear in all types of driving situations.

(3) Accuracy of fatigue strength design
Tests were conducted with actual pulleys to confirm consistency with the fundamental theory of fatigue strength, making it possible to develop a pulley design at the performance limits.

(4) Shape designed for productivity
A front-loading approach was taken to examine the production engineering requirements for manufacturing the complex pulley shape. Cutting tool motions and shapes were taken into account from the early stage of development, making it possible to determine a simpler and easy-to-manufacture pulley shape.

Expanding the CVT ratio coverage contributes greatly to improving vehicle fuel economy and power performance. There are strong expectations of the technologies involved here. Based on the results achieved in this development project, we intend to continue our efforts to improve these technologies further in the future.

■ Author ■

Yoichi TSUJI

高効率油圧システムの開発

Development of a High-efficiency Hydraulic System

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抄　録　地球環境保護等のニーズにより，自動車に対する燃費改善要求が高まっている．Jatco CVT8（以下「CVT8」とする．）では，更なる燃費改善の要求と，運転性向上という相反する性能を両立するために，高効率油圧システムを開発した．

本稿では，CVT8におけるフリクション低減と，運転性向上を目的とした，高効率油圧システム開発の取組みについて紹介する．

Summary　There are growing demands to improve vehicle fuel economy in order to protect the global environment, among other needs. For the Jatco CVT8 series, we developed a new high-efficiency hydraulic system to meet the conflicting performance requirements for further fuel economy improvement and better driveability. This article describes the measures taken to develop this high-efficiency hydraulic system, aimed at reducing friction in the CVT8 series and improving driveability.

1. はじめに

ベルトCVTは，径の大きなプーリーピストンを作動させることで変速を実現する構造であるため，大流量と高いベルトクランプ圧力が必要となる．したがって，オイルポンプを始めとする油圧システムの仕事量が大きく，油圧システムの効率向上が，車両の燃費改善のために重要な課題となる．CVT8では，動力性能向上のためにプーリーピストンを弊社従来CVTに対し大型化する一方，油圧システムの高効率化に取り組むことで，オイルポンプを小型化し，運転性と燃費性能の高いレベルでの両立に取り組んだ．

2. 油圧制御回路構成

油圧制御回路の全体構成としては，弊社の従来CVTと同様に，使用油圧の高いプーリ圧系を上流，トルクコンバーター圧系を下流とした階層配置をとっている．（Fig. 1）

CVT8では，この油圧回路構成と新規開発した大容量三方リニアソレノイドを採用することにより，従来CVTに対して，クラッチReg弁，信号圧増幅弁を廃止する事を可能とした（Fig. 2）．これにより弁総本

1. Introduction

A steel-belt CVT is built such that ratio changes are made by actuating the hydraulic cylinder piston of the large diameter primary pulley, which requires a large fluid flow rate and a high belt clamping pressure. To accomplish that, the hydraulic system, especially the oil pump, must do a lot of work. Therefore, raising the efficiency of the hydraulic system is a key issue in improving vehicle fuel economy. For the CVT8 series, a larger primary pulley piston than that of our existing CVTs was adopted in order to improve power performance. On the other hand, the measures taken to improve the efficiency of the hydraulic system enabled the oil pump to be downsized. This made it possible to reconcile improved driveability with higher fuel economy.

2. Configuration of Hydraulic Control Circuit

The overall configuration of the hydraulic control circuit has the pulley pressure system, which requires high hydraulic pressure, positioned upstream of the torque converter pressure system that is located downstream (Fig. 1). This hierarchical arrangement is

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Hardware System Development Department

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Product Reliability Experiment Group Experiment Department

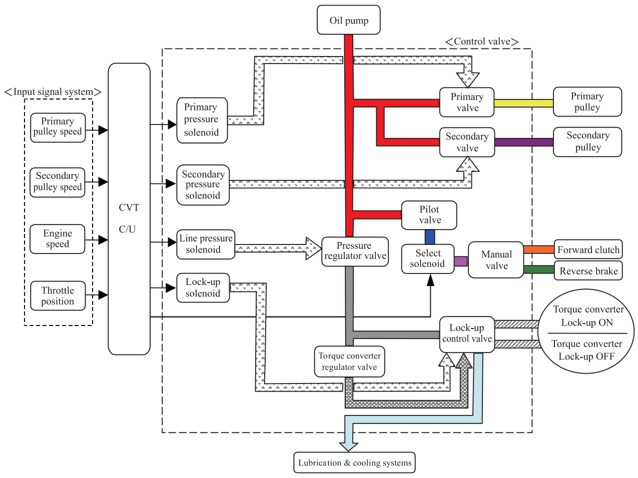

Fig. 1 Hydraulic system

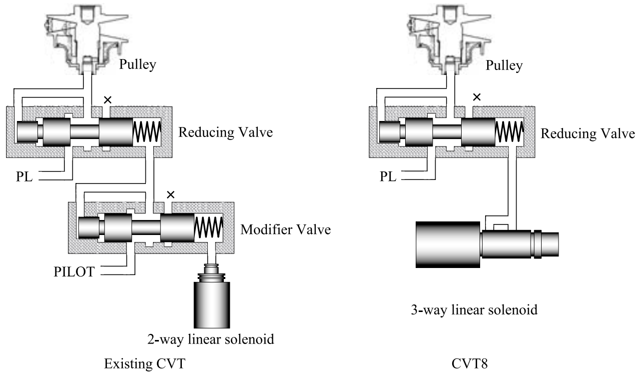

Fig. 2 Hydraulic circuit of primary pulley

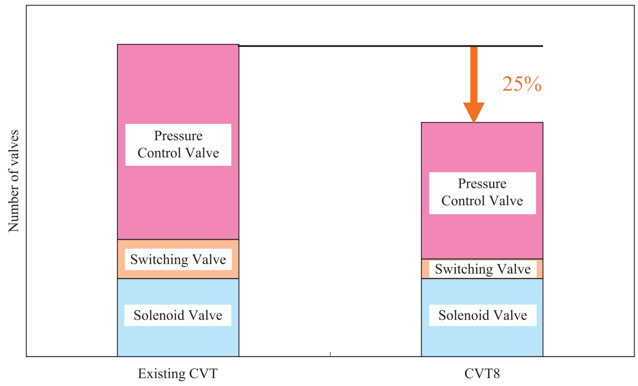

Fig. 3 Reduction of number of valves

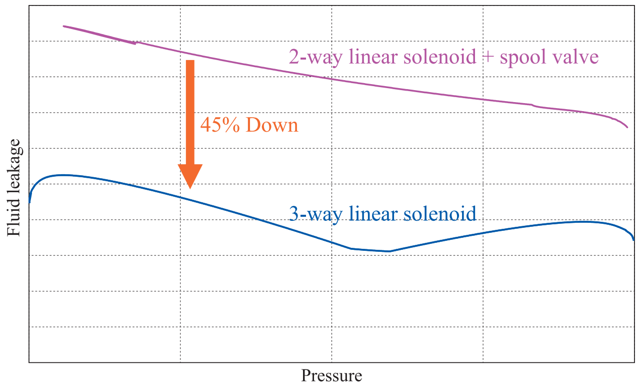

Fig. 4 Effect of 3-way linear solenoid on reducing fluid leakage

数を従来CVTに対して25%削減し（Fig. 3），コントロールバルブの小型化とリーク量の削減（Fig. 4）を実現した．

3. コントロールバルブ

3.1. 摺動部クリアランス縮小によるリーク量低減

コントロールバルブにおけるオイルリーク量は，コントロールバルブボディのボアとスプール間の摺動部からのリークが大部分を占めており，この部分でのリーク量の低減が重要となる．

そこでCVT8では，従来CVTに対して摺動部に必要なクリアランスを見直し，オイルリーク量の低減を実現した．

Fig. 5に示すようにスプールの幾何公差の精査，CAEによるコントロールバルブ組立時のボディ変形量，および熱膨張変形量の設計精度向上，スプールの作動限界確認により，摺動部クリアランスの縮小設計を可能とした．なお，縮小設計に際しては，夾雑

the same as that of our existing CVTs.

This hydraulic circuit configuration together with the use of a newly developed large-capacity three-way linear solenoid made it possible to discontinue the clutch pressure regulator valve and the signal pressure modifier valve used to date in existing CVTs (Fig. 2). That worked to reduce the total number of valves by 25% compared with an existing CVT (Fig. 3). As a result, the control valve was downsized and fluid leakage was reduced (Fig. 4).

3. Control Valve

3.1. Reduction of fluid leakage by narrowing sliding part clearance

Most of the fluid leakage from the control valve occurs from the sliding parts between the control valve body bore and the spool. Therefore, it is important to reduce the amount of leakage that occurs between these parts.

Toward that end, we reviewed the clearance needed

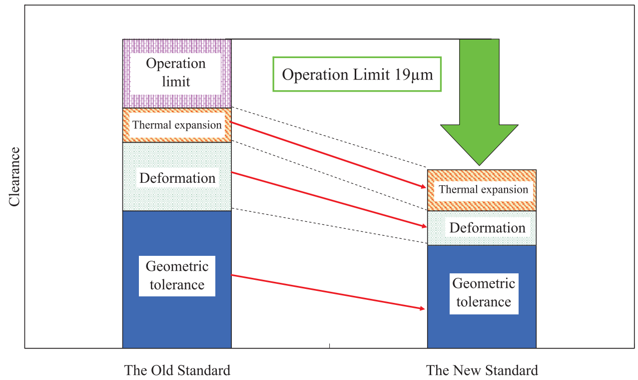

Fig. 5 Reduction of sliding part clearance

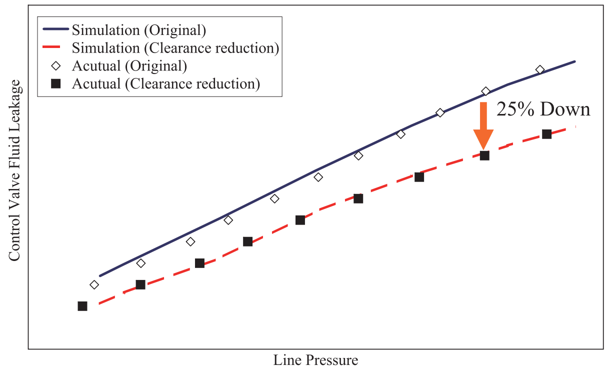

Fig. 6 Amount of fluid leakage

物によるスプールのスティック限界についても考慮して設定している．

摺動部クリアランスの縮小により，オイルリーク量を現行比で約25%低減することを実現できた．（Fig. 6）

3.2. アニール処理追加による熱成長防止

走行中のCVTでは，作動油が高温となるため，作動油に浸かっているコントロールバルブに熱負荷がかかり，スプール穴径が熱成長を起こし，クリアランスが拡大してしまう．

CVT8では，プレッシャーダイカスト品である粗材ボディへアニール処理を施すことで熱成長を防止し，クリアランス拡大によるリーク量の増加を改善することができた．その結果，オイルポンプを小型化したにも関わらず，経時変化後の運転性を確保することを可能とした．

Fig. 7にCVTの走行距離に対するスプール穴の熱成長量について，アニール処理実施品と未実施品とを比較した結果を示す．アニール処理を施したボディは熱成長し難いことが分かる．

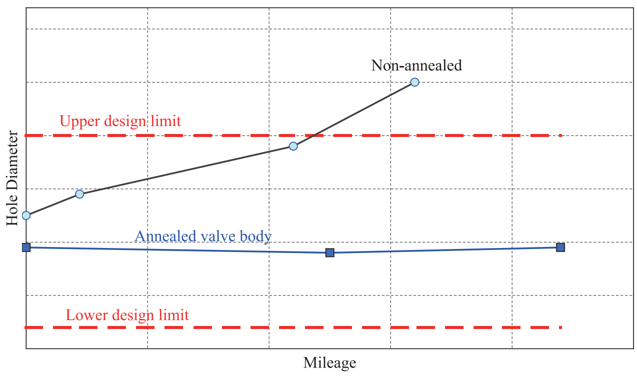

Fig. 7 Effect of annealing on preventing spool hole expansion

between these sliding parts and reduced the amount of fluid leakage by narrowing the clearance compared with that of an existing CVT.

As shown in Fig. 5, narrower clearance between these sliding parts was designed by carefully examining the geometrical tolerance of the spools, by applying a CAE tool to improve design accuracy with respect to the amount of body deformation and thermal expansion that occur when the control valve body is assembled, and by confirming the operation limit of the spools. The limit for spool sticking due to foreign matter incursion was also taken into account in determining the narrower clearance design.

Narrowing the clearance between sliding parts reduced the amount of fluid leakage by about 25% compared that of an existing CVT (Fig. 6).

3.2. Preventing thermal expansion by adding an annealing treatment

Because the CVT fluid reaches a high temperature during vehicle operation, a heat load is applied to the control valve immersed in the fluid. This causes the spool hole diameter to undergo thermal expansion, which increases the clearance.

Such thermal expansion has been prevented in the CVT8 series by applying an annealing treatment to the valve body casting that is a pressure die cast part. This works to prevent any increase in leakage that would otherwise occur due to the expanded clearance. Even though the oil pump has been downsized, the addition of this annealing treatment makes it possible to ensure satisfactory driveability even after the control valve ages with use.

Figure 7 compares the amount of spool hole thermal expansion for annealed and non-annealed control valve bodies in relation to the mileage

熱成長防止による，コントロールバルブリーク量の改善効果についてFig. 8に示す.

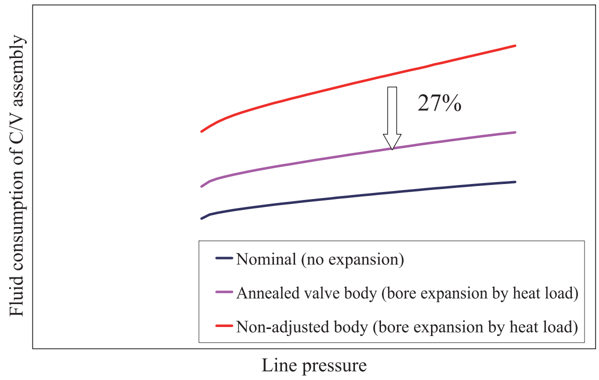

Fig. 8 Fluid leakage reduction by annealing treatment

4. オイルポンプ

コントロールバルブ等での消費流量の低減を行うことで，オイルポンプの固有吐出量を下げる事が可能となり，オイルポンプ駆動トルクを従来CVTに対して約25%低減することが実現できた.（Fig. 9）

また，オイルポンプ小型化とキャビテーション性能を両立させるため，Fig. 10に示すような流れ解析を用いた吸入経路形状の最適化を行う事で，吸入抵抗を低減し，ベーン室への充填性を向上，オイルポンプ小型化とキャビテーション性能を両立させる最適なオイルポンプを開発した.

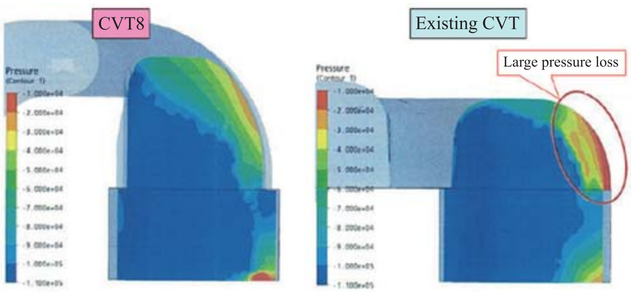

Fig. 10 Pressure loss at inlet port of oil pump

5. 油圧性能

5.1. 油圧シミュレーションの予測精度向上

コントロールバルブ系のオイルリーク量低減に伴い，油圧性能としては，過渡的な油圧応答が早くなることによる，跳ね返りが懸念される.

そこで，油圧シミュレーションモデルに，流体解析による回路圧損計算結果（Fig. 11）および，ノッチ等の複雑な形状まで考慮したモデルをシミュレーショ

accumulated by the CVT. The results indicate that the annealed valve body does not tend to experience thermal expansion.

The effect of preventing thermal expansion on reducing the amount of fluid leakage from the control valve is shown in Fig. 8.

4. Oil Pump

Reducing the fluid flow rate consumed by the control valve and other parts made it possible to lower the specific discharge rate of the oil pump. That allowed the oil pump drive torque to be reduced by approximately 25% compared with that of an existing CVT oil pump (Fig. 9).

A flow simulation like that shown in Fig.10 was also conducted to optimize the suction passage geometry in order to reconcile the downsizing of the oil pump with the avoidance of cavitation. As a result, suction resistance was reduced and fluid flow into the vane chamber was improved. The optimal oil pump was thus developed that allowed the pump to be downsized while at the same time avoiding cavitation.

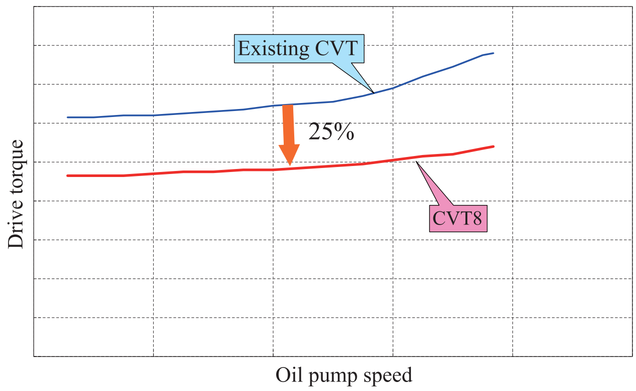

Fig. 9 Comparison of oil pump drive torque

5. Hydraulic Performance

5.1. Improvement of prediction accuracy of pressure simulation

In terms of hydraulic performance, reducing the amount of fluid leakage from the control valve had the effect of quickening the transient pressure response. There was concern that this might have repercussions on performance.

Therefore, steps were taken to improve the prediction accuracy of the pressure simulation model.

ンに織り込むことにより予測精度向上に取組んだ．

これにより，これまで予測が困難であった各油圧の過渡的な応答性を，シミュレーションにより検討可能となり（Fig. 12），仕様変更に対する事前の影響予測を実現した．

The hydraulic circuit pressure loss (Fig. 11) calculated by a computational fluid dynamics (CFD) simulation was incorporated into the model along with a model for considering various complex geometries, including notches. Simulations were then conducted with the improved model.

These measures made it possible to examine the transient response of each pressure by CFD simulation, something that has been very difficult to predict heretofore (Fig. 12).

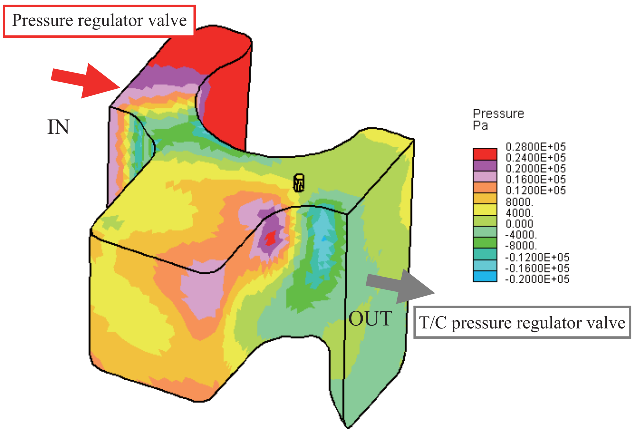

Fig. 11 Pressure loss simulation model

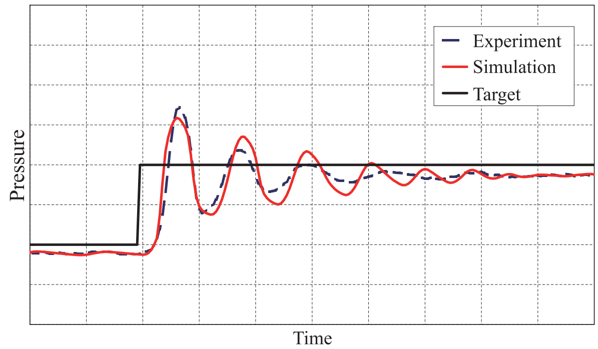

Fig. 12 Response of secondary pulley pressure

5.2. 油圧振動解析

上記油圧シミュレーションモデルにパワートレインモデル，および制御モデルを加え，実測が困難なパラメーターまで含めた油圧振動の達経路解析を行った．（Fig. 13）

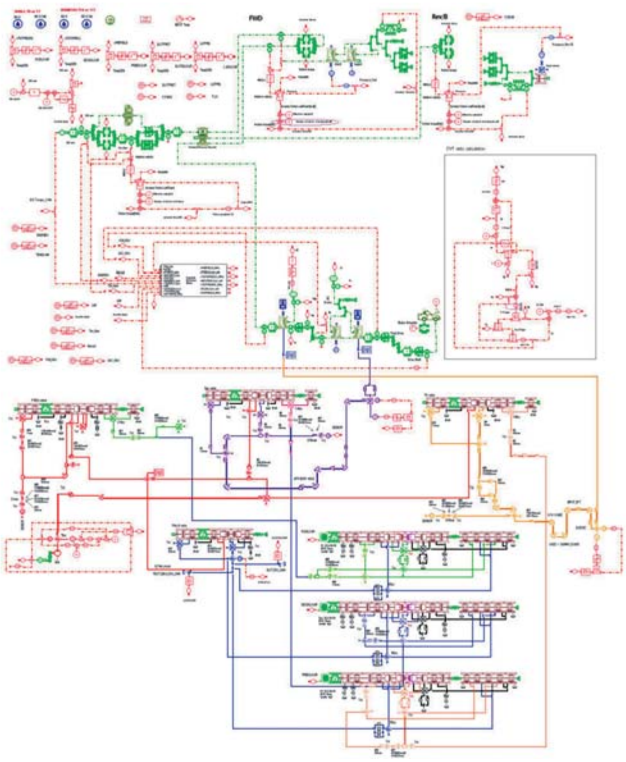

Fig. 13 Simulation model

5.2. Pressure oscillation analysis

A powertrain model and a control model were added to the pressure simulation model mentioned above, and a transfer path analysis of pressure oscillations was conducted that included even parameters difficult to measure experimentally (Fig. 13).

Parameter studies were also conducted, and the optimal specifications were determined by calculating the gain margin relative to the pressure oscillations that occurred with different specifications. Figure 14 shows the results of a steady-state analysis in which the damping orifice diameter of the control valve was used as the parameter.

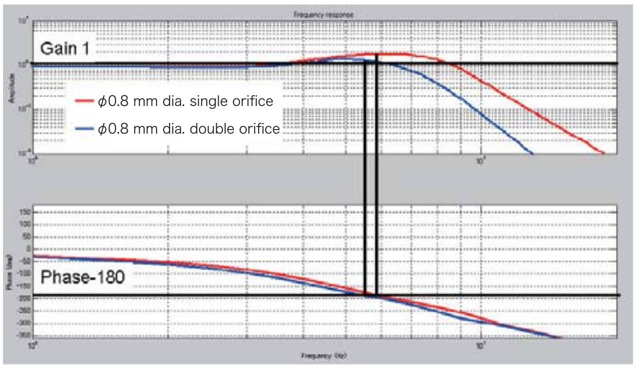

Fig. 14 Bode plots

また，パラメータースタディーを行い，各仕様の油圧振動に対するGain余裕を算出することで最適な仕様を決定した．以下に弁のダンピングオリフィス径をパラメーターとして安定性解析を行った結果を例として示す．（Fig. 14）

6.おわりに

CVTの競争力向上のためにはフリクション低減が不可欠である．油圧システムの高効率化はCVTのフリクション低減への寄与が大であり，今後もCVT8の開発で培ったシミュレーション精度の向上などにより，更なるCVTの効率改善に取り組んでいきたい．

最後に，本システムの開発に当たり，多大なるご協力を頂いた，社内外の方々に厚く感謝申し上げる．特に油圧振動解析に際しては，日産自動車㈱パワートレイン第一技術開発部の忍足主管には多大なるご協力を頂いた．心より感謝申し上げる．

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6. Conclusion

Reducing friction is indispensable to improving CVT competiveness. Increasing the efficiency of the hydraulic system contributes significantly to reducing CVT friction. In the future, we intend to continue to pursue measures for improving CVT efficiency further, including enhancing the accuracy of the simulation tools accumulated in the course of developing the CVT8 series.

Finally, we would like to express our deep appreciation to everyone inside and outside the company for their invaluable contributions to the development of this high-efficiency hydraulic system. Special thanks are due T. Oshidari, Senior Manager, Powertrain Product Development Department No. 1, Nissan Motor Co., Ltd., for his helpful cooperation with the pressure oscillation analysis.

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発進スリップ制御および技術開発

Development of Start-off Slip Control and Torque Converter

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Takateru KAWAGUCHI

抄　録　燃費向上に関する市場ニーズの高まりに応えるため，スリップ制御の高機能化と，その制御に対応するトルクコンバーター（以下「TC」とする．）の開発を行ない，Jatco CVT8（以下「CVT8」とする．）に採用した．本稿ではその技術を紹介する．

Summary　An enhanced start-off slip control function and a compatible torque converter were newly developed and adopted for the Jatco CVT8 series to meet heightened market needs for improved fuel economy. This article describes the details of these new technologies.

1. はじめに

TCは，流体を介してトルク伝達を行う発進デバイスである．流体により，エンジントルクを増幅させる機能や，入出力回転数に応じて駆動力を自動調整する機能等を持つ反面，流体の滑りによるロスで燃費を悪化させてしまう．

燃費を向上させるためには，滑り量をコントロールし，低車速からロックアップ（以下「LU」とする．）させることが重要な技術となる．

本稿では，発進直後からLUするための「発進スリップ」制御技術と，それに対応したTC技術開発について紹介する．

2. 発進スリップのメリットと課題

従来は，発進後所定車速以上になってからLU制御を行い，LUクラッチを締結させていた．

これに対し発進スリップでは，車速=0km/hからLU制御を行うこととした．これにより，エンジン回転の吹き上がりを抑え，更にLU締結を低車速化させることで，燃費向上を図った．コンセプトをFig. 1に示す．

本制御を行う上で，以下の性能を両立させることが発進スリップの課題となる．

1. Introduction

A torque converter functions as a start-off element that transmits torque by means of a fluid. Among other functions, it multiplies engine torque and also automatically adjusts the driving force according to the input and output rotational speeds. On the other hand, the loss resulting from slipping in the torque converter causes fuel economy to decline.

A key technique for improving fuel economy is to control the amount of slipping and to lock up the torque converter at a lower vehicle speed.

This article describes the start-off slip control for locking up the torque converter right after vehicle launch and a newly developed torque converter that is compatible with this enhanced control technique.

2. Advantages and Issues of Start-off Slip Control

Traditionally, lockup control has been actuated to engage the lockup clutch once the vehicle reached a certain specified speed following launch.

In contrast to that approach, start-off slip control engages the lockup clutch from a vehicle speed of 0 km/h. This works to suppress engine speed flare, and engaging the lockup clutch at a lower vehicle speed also improves fuel economy. The concept of this control strategy is outlined in Fig. 1.

One issue that must be addressed to execute start-off slip control is to ensure an acceptable balance of

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・動力性能
・こもり音
・運転性(ショック等)
・油圧性能
・ロックアップフェーシング耐力

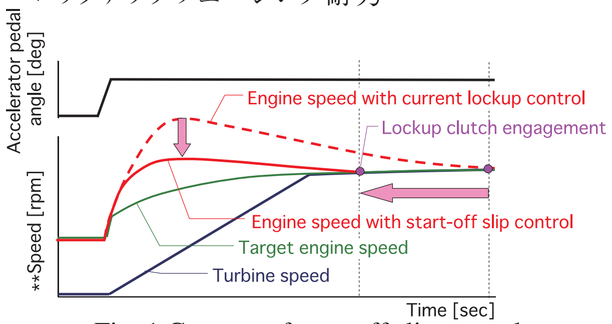

Fig. 1 Concept of start-off slip control

3. 課題の解決に対する方策紹介

3.1. 発進スリップ制御

発進スリップ制御は，2つのフェーズ(以下「フェーズ」とする．)を連続的にコントロールしている．

LUピストンをストロークさせて，ショックが出ないようにLUクラッチを締結させるフェーズA(以下「フェーズA」とする．)と名付け，「燃費」「動力」「こもり音」を成立させる，アクセル開度毎の目標エンジン回転線をトレースできるように，LUトルクを発生させる段階をフェーズB(以下「フェーズB」とする．)と定義する．この構成をFig. 2に示す．

発進スリップ制御時のLU指令圧のタイムチャートをFig. 3に示す．

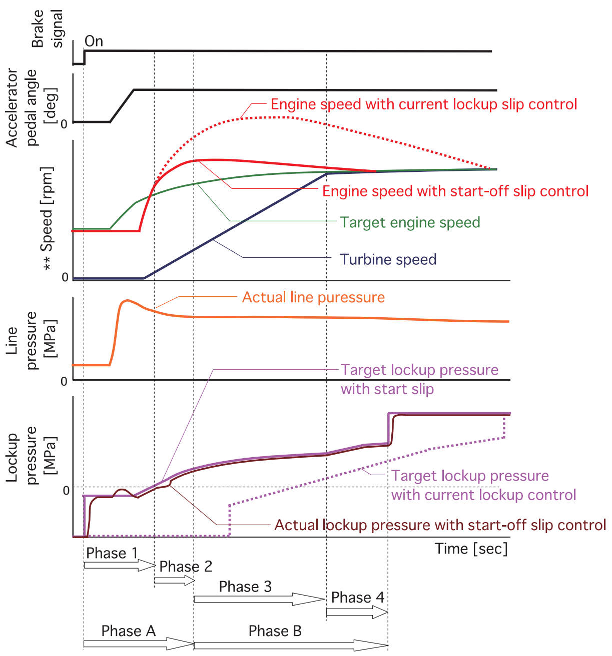

Fig. 3 Lockup pressure control time chart

the following performance attributes.

- Power performance
- Booming noise
- Driveability (shock, etc.)
- Hydraulic performance
- Lockup clutch facing durability

3. Measures for Resolving the Issue

3.1. Start-off slip control

Start-off slip control consecutively controls two clutch phases. The first one is called Phase A in which the lockup clutch piston strokes to engage the lockup clutch without causing any shock. The other one is Phase B which is defined as the stage where lockup clutch torque is generated so as to enable the engine to trace its target speed line at each accelerator pedal angle in order to secure a good balance of fuel economy, power and booming noise. The configuration of each phase is shown schematically in Fig. 2. A time chart of the commanded lockup pressure during start-off slip control is shown in Fig. 3.

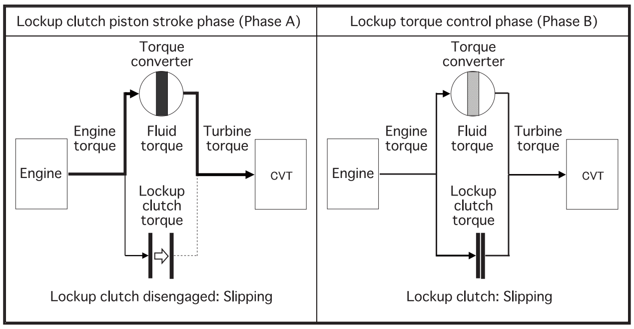

Fig. 2 Lockup clutch phases

In order to accomplish early engagement of the lockup clutch in Phase A, the lockup pressure command is issued simultaneously with the driver's depression of the accelerator pedal, immediately before the lockup piston begins to stroke. The actual lockup pressure may fluctuate at that time due to variation in the line pressure when the vehicle starts off. To avoid that influence, the control system holds the lockup pressure for a certain length of time, taking into account the fluctuation of the actual pressure, and that period is defined as Phase 1.

Subsequently, when the lockup clutch piston strokes to engage the clutch, a response delay occurs in the actual lockup pressure. The commanded lockup pressure is ramped up at the rate specified for each

フェーズ Aは，LU締結早期化のため，アクセル踏み込みと同時に，LUピストンがストロークを始める直前のLU指令圧を出力する．この時，発進時のライン圧変動によりLU実圧が変動してしまう現象が発生する．この影響を受けないように，実圧変動を考慮したLU指令圧を，所定時間保持する制御とし，これをフェーズ 1（以下「フェーズ 1」とする．）とする．

その後，LUクラッチ締結のために作動させるが，LUピストンがストロークすることで，LU実圧に応答遅れが発生する．遅れ後の締結でも，ショックが許容値に収まるよう，アクセル開度毎に所定ランプでLU指令圧を上昇させて，LUクラッチを緩やかに締結させる制御とし，油圧が上昇してもLUピストンがカバーコンバータにトルクを伝えていない，スリップロックアップ直前の段階をフェーズ 2（以下「フェーズ 2」とする．）とする．

フェーズ AではLU指令圧と実圧の精度が要求される．そこで停車中にLU指令圧を徐々に上昇させ，エンジン回転及びエンジントルク変動を検出し，LU指令圧との実圧の乖離を補正する学習機能を採用した．

スリップLU時のフェーズ Bでは，エンジン回転の吹け上がりや引け込みが発生する可能性がある．これは，エンジントルク信号のバラツキや車体振動など,外乱の影響を受け，必要LUトルクが変化するためである．なお，必要LUトルクとは，目標エンジン回転数に実回転数を追従させるために必要なLUトルクを示す．

必要LUトルクの変化に順じて実エンジン回転数を追従させるため，スリップロックアップコントロールしている間の，ある演算周期で任意に検出した時点t0の，エンジン回転数から目標エンジン回転数までを，1次遅れ系で追従させ，演算周期毎に必要LUトルクを算出し，LU指令圧を得ることとした．この必要LUトルク演算の際，急な指令圧変化とならないよう，目標エンジン回転数と現在エンジン回転数に応じた適合係数を持たせることとした．また，前回演算周期時点t-1と，t0時点のエンジン回転数変化に対する必要LUトルクの演算結果を比較し，次回演算周期時点t+1の必要LUトルクを演算することで，ロバスト性を向上させた．この段階をフェーズ 3（以下「フェーズ 3」とする．）とする．

その後，変速開始車速に達すると，変速制御とLU制御の干渉での意図しないエンジン回転変動が

accelerator pedal angle so as to keep any shock within the allowable level even when the clutch engages after the response delay. The lockup clutch is therefore controlled so that it engages gradually. The lockup clutch piston does not transfer any torque to the torque converter cover even if the pressure rises. This stage just before start-off slip lockup is defined as Phase 2.

Phase A requires that the commanded lockup pressure and the actual pressure be accurate. Therefore, an adaptive learning control function has been adopted for correcting any disparity between the commanded lockup pressure and the actual pressure. This is done by gradually raising the commanded lockup pressure even while a vehicle is stopped and detecting any fluctuation in the engine speed and engine torque.

Engine speed flares or dips may occur in Phase B during slip lockup control. These speed fluctuations occur because of changes in the required lockup torque, which are influenced by various disturbances such as variation in the engine torque signal or vehicle vibrations. The required lockup torque refers to the lockup torque that is needed to make the actual engine speed follow the target engine speed.

The following control procedure was adopted for making the actual engine speed follow the target value according to the change in the required lockup torque. During slip lockup control, the actual speed is made to follow the target according to a first-order delay system from the engine speed arbitrarily detected at time t0 in a certain calculation cycle to the target engine speed. The commanded lockup pressure value is obtained by calculating the required lockup torque in each calculation cycle. At the time the required lockup torque calculation is performed, a compatibility coefficient is applied to the target engine speed and the current engine speed so as to avoid any sudden change in the commanded lockup pressure. In addition, a comparison is made of the calculated required engine torque at the time of the previous calculation cycle t-1 and the value calculated in relation to the change in the engine speed at time t0. The required lockup torque at the time of the next calculation cycle t+1 is calculated. This procedure works to improve robustness, and this stage is defined as Phase 3.

懸念される．所定スリップ回転数差（=エンジン回転数ータービン回転数）に応じて，LU油圧傾きを変更させ，滑らかな締結を実現した．この段階をフェーズ 4（以下「フェーズ 4」とする．）とする．

本制御にて適合を行った実車での実験結果をFig. 4に示す．動力性能である加速度（以下「G」とする．）をほぼ従来同等とし，運転性を確保しつつ，エンジン回転吹き上がりの低減とLU締結早期化を実現することができた．

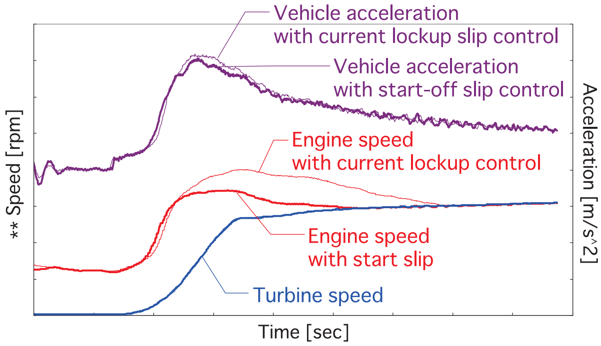

Fig. 4 Vehicle test results for start-off slip control

3.2. トルクコンバータ開発

先述した制御を使うトルクコンバーター（以下「TC」とする.）と，従来のTCの大きな変化点は，TCの摩擦材に与えられる発熱量の増加となる．従来，TCの流体部分だけで受け持っていたトルクを，摩擦材でも分担することになるため，シミュレーションでは，従来のTCに対し約3倍の発熱量が与えられる．

LUクラッチへの発熱量の増加に伴い，摩擦材の焼け防止及びジャダー耐久性の向上が必要となり，以下2つの方策を採用した．

1つは，摩擦材の焼け防止として，LUクラッチの局部当たりを改善することで，発熱量に対する温度上昇の低減を図った．

TCは一般的にアーク溶接にて，インペラーとカバーコンバータを接合する．その際，エンジン取り付けボスの有無による剛性差や，溶接の重なりの有無により溶接歪が発生し，カバーコンバータの摩擦材摺動部表面の平面度が悪化する．局部的面圧過大部が発生すると，摩擦材との接触面圧が上り，摩擦材の摺動面温度が上がることになる．Fig. 5にTC構成部品を示す．

CVT8用TCにおいては，接合工法の改善により，カバーコンバータの平面度を従来の6割以下まで小さくした．実測した結果はFig. 6の通りである．

There was concern that subsequently the engine speed might vary unintentionally when the vehicle speed reaches the onset of shifting owing to a conflict between shift control and slip lockup control. Smooth lockup clutch engagement was achieved by varying the slope of the lockup pressure according to the difference with the specified slip rotational speed (i.e., engine speed - turbine speed). This stage is defined as Phase 4.

Figure 4 presents the experimental results for the tuning of this control using a test vehicle. The results show that engine speed flare was reduced and that early lockup clutch engagement was accomplished while securing driveability and power performance in terms of acceleration (G) nearly equal to that obtained with the existing control system.

3.2. Development of a new torque converter

The increased amount of heat applied to the friction material of the lockup clutch is the biggest difference between the new torque converter incorporating the control system described above and the existing torque converter. A simulation revealed that the amount of heat generated in the new torque converter was roughly three times greater than the level in the existing converter. The reason for that is the friction material also partially shares the torque load, whereas in the existing torque converter the fluid alone bears all the torque.

The increased heat applied to the lockup clutch friction material made it necessary to prevent the burning of the material and to improve anti-shudder durability. The following two measures were adopted

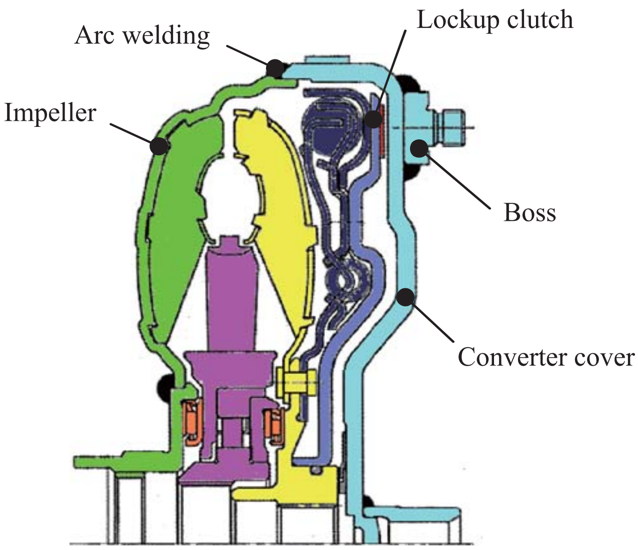

Fig. 5 Cross section of torque converter

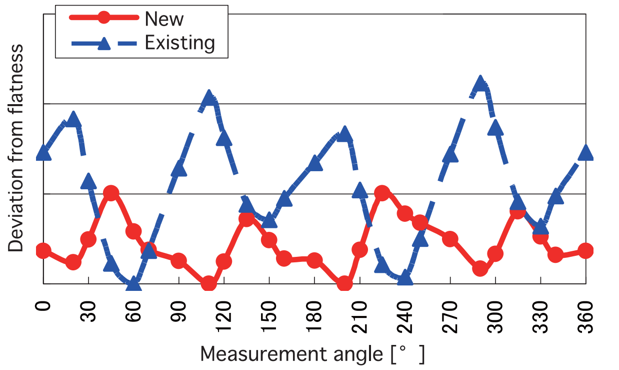

Fig. 6 Deviation from flatness of torque converter cover

2つ目の方策は，ジャダー耐久性向上策としての新規摩擦材開発である．ジャダー発生の主要因は，CVT油の劣化によるスラッジが，摩擦材表面の気孔に目詰まりすることでジャダーが発生する．スラッジの発生は，温度が高い方が顕著になるため，高い温度に晒されても，気孔が詰まらないよう，予め気孔率の高い摩擦材にするという方策を採用した．

従来の摩擦材とCVT8で使用した摩擦材の，温度と摩擦特性が負勾配になるまでの時間感度線をFig. 7に示す．摩擦材のジャダー耐力は，気孔率向上により，従来品に対して4倍強の耐力向上を実現した．

一般に気孔率を上げると，摩擦材密度がおろそかになり剥離寿命が低下するが，CVT8用TCにおいては使用材料，工法の変更により剥離寿命の低下を極力抑え，剥離強度を確保した．成立範囲をFig．8に示す．

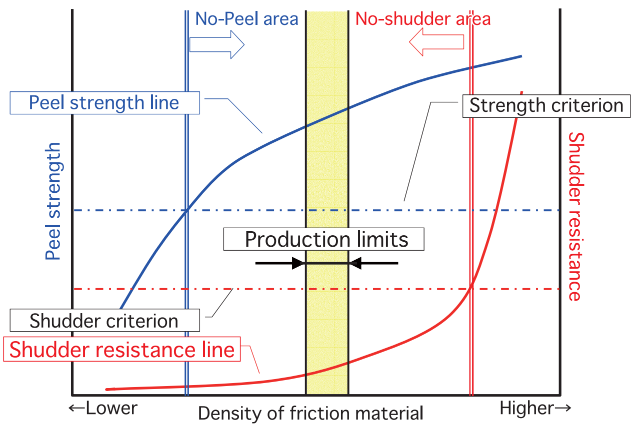

Fig. 8 Production limits

to meet these requirements.

The measure adopted to prevent burning of the friction material was to improve local contact with the lockup clutch. That was done to reduce the temperature rise relative to the amount of heat generated.

The impeller and cover of the torque converter are generally arc-welded together. In the welding process, a difference in stiffness may occur depending on the presence of bosses for connecting the cover to the engine or welding strain may develop due to the overlapping of welding. As a result, the flatness of the converter cover surface that slides against the friction material may be affected. If excessive surface contact pressure occurs locally, it increases the contact pressure with the friction material, causing the temperature of the sliding surface of the friction material to rise. Figure 5 shows a cross-sectional view of the components of a torque converter.

For the Jatco CVT8 series torque converter, the welding method was improved so as to reduce the deviation in the flatness of the converter cover surface by 60% compared with the previous level. The measured deviation in flatness is compared in Fig. 6.

The second measure for improving anti-shudder durability was to develop a new friction material. Shudder is mainly caused by clogging of the pores in the surface of the friction material by sludge resulting from deterioration of the CVT fluid. Sludge markedly occurs at higher temperatures. Therefore, the measure adopted was to give the friction material a higher percentage of pores in advance so that they would not become clogged even if the material was exposed to high temperatures.

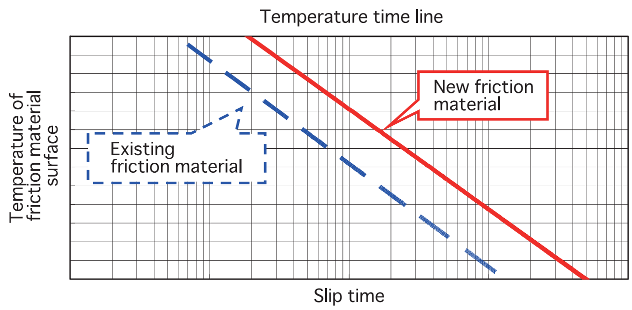

Fig. 7 Temperature time line

Figure 7 show temperature sensitivity time lines for the existing friction material and the new friction material used in the CVT8 series torque converter. The lines indicate the elapsed time until the

4. おわりに

TCは車両動力性能，燃費性能への寄与率が高い機能部品であり，特にLUに関しては，高機能化への要望が強い．制御とハードを組み合わせることで，今後もLUの領域拡大に向け，更なる技術開発を進めていきたい．

本開発にあたりご協力いただいたヴァレオユニシアトランスミッション株式会社の皆様，株式会社エクセディの皆様をはじめ，多大なる協力をいただいた関係者の方々に深く感謝の意を表します．

temperature and friction characteristics reach a negative slope. The anti-shudder durability of the new friction material was improved by approximately four times over that of the existing material as a result of increasing the material's porosity.

Increasing the porosity generally reduces the friction material density, causing its anti-peel life to decline. The reduction of the anti-peel life of the friction material used in the CVT8 series torque converter was suppressed as much as possible by changing the material used and the engineering method, thereby securing sufficient anti-peel strength. The production limits of the material with respect to these criteria are shown in Fig. 8.

4. Conclusion

The torque converter is a key functional part that contributes greatly to vehicle power performance and fuel economy. There are especially strong desires for higher functionality with respect to lockup performance. We intend to proceed with further technology development efforts to expand the region of lockup operation in the future through a combination of the control software and hardware.

The authors would like to thank everyone concerned for their invaluable cooperation with the development work described here, especially the people involved at Valeo Unisia Transmissions K.K. and Exedy Co., Ltd.

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スライディングモード制御を用いた変速機構制御の紹介

Overview of the Ratio Control System using Sliding Mode Control

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抄　録　本稿では，Jatco CVT8（以下「CVT8」とする．）に採用している変速機構のハードウエアと，この変更に伴う制御ソフトの変更（スライディングモード制御活用）について紹介する．

Summary　This article describes the shift mechanism hardware adopted for the Jatco CVT8 and the associated changes made to the control software, specifically effective use of sliding mode control.

1. はじめに

従来ユニットであるJF011Eに対して，今回開発したCVT8は，ユニットのコスト削減，小型化のために調圧方式を「ステッピングモータリンク方式」から，「直動油圧方式」に変更した．従来のロバスト制御は，ステッピングモータ（以下「SM」とする．）との組み合わせが前提となっているため，代替制御が必要となる．

今回，直動油圧方式にスライディングモード制御を組み合わせて採用した．

2. 制御対象となる変速機構

2.1. ステッピングモータリンク変速機構

従来ユニットであるJF011Eの変速機構は，Fig. 1に示すようにプライマリ（以下「PRI」とする．）プーリーの油圧をSMとメカニカルリンクを組み合わせたメカニカルサーボ機構を用いており，定常状態では，ステッピングモータの位置と変速比が対応する．本機構では，PRIプーリーの軸方向位置を検出するプーリー位置センサ部分と，SMとを可動リンクで連結し，その中央部に変速制御弁を連結することで，プーリー位置を目標値に合致させる油圧サーボ系を構成している．この変速制御弁は，PRIプーリーピストンに供給する油圧の給排を行い，これによってプーリーピストン位置，すなわち変速比を制御することになる．

1. Introduction

The newly developed CVT8 adopts a direct pulley pressure control system instead of the stepping motor-based system used in the existing JF011E unit. This change in the pressure control system was made to reduce the cost and size of the new CVT. The previous robust control system was premised on the combined use with a stepping motor, so it became necessary to adopt an alternative control method.

The new direct pulley pressure control system was adopted together with sliding mode control.

2. Shift Mechanism Representing the Plant

2.1. Shift mechanism with stepping motor and mechanical linkage

Figure 1 shows the shift mechanism of the existing JF011E on which the CVT8 is based. The primary pulley pressure is controlled by a mechanical servo system consisting of a stepping motor and a mechanical linkage. Under a steady-state condition, the position of the stepping motor coincides with the pulley ratio. In this system, a movable linkage connects the stepping motor and the primary pulley position sensor that detects the position of the pulley in its axial direction. The center of the servo linkage is connected to the ratio control valve. This arrangement forms a hydraulic servo system that moves the position of the primary pulley to coincide

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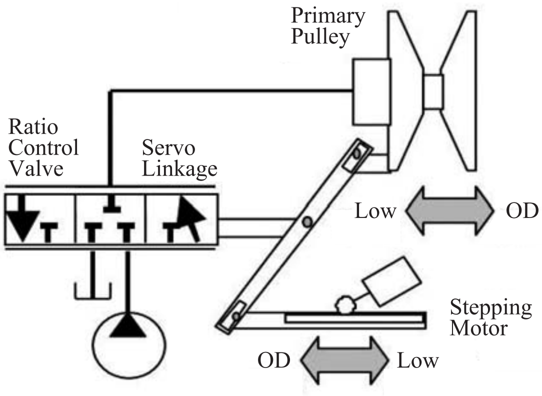

Fig. 1 Stepping Motor and Servo Linkage

2.2. 直動油圧変速機構

一方，本CVTで用いた直動油圧方式は，Fig. 2のようにPRIプーリーの油圧をソレノイドバルブで直接，調圧して変速比を制御するものである．

本機構は従来のSMリンク方式に比べて，少ない部品でシンプルに構成されており，ユニットの重量低減，サイズ縮小に大いに貢献している．

3. スライディングモード制御

3.1. スライディングモード制御の導入

ベルト式CVTの変速は両プーリーに与えるクランプ力によって決まるが，その応答はベルト巻付きの幾何学形状や変速速度の回転数依存性による非線形性を持つことが知られている1)．

従来のSMリンク方式では，上述のように強力な油圧サーボ系が構成されており，プーリー油圧系の元圧を十分に確保してその範囲で作動油の給排を調整することにより，線形制御でも十分な制御性を確保していた．

一方，メカニカルな油圧サーボ系を持たない直動油圧方式では，CVTの変速特性をありのままの非線形システムとして取り扱う必要があり，新たな非線形制御理論の導入が必要となった．

また，CVTの変速制御では，追従性良く加速感のある変速を行い，かつ燃費を向上させるため可能な限りプーリー圧を下げることが要求される．

そこで，高い追従性と良好なロバスト性を，非線形系に対して比較的単純な制御則を適用できる手法であるスライディングモード制御（以下「SMC」とする．）をCVT8へ導入した．

with the target ratio value. The ratio control valve supplies and evacuates the hydraulic pressure that is supplied to the primary pulley piston. Controlling the position of the primary pulley piston in this way accomplishes pulley ratio control.

2.2. Shift mechanism by direct pulley pressure control

The direct pulley pressure control system adopted for the CVT8 is shown in Fig. 2. The primary pulley pressure is regulated directly by a solenoid valve to control the pulley ratio.

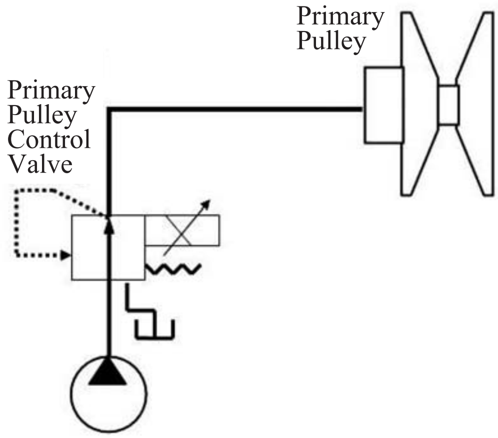

Fig. 2 Direct Pulley Pressure Control System

This shift mechanism has a simpler structure consisting of fewer parts compared with the previous stepping motor and mechanical linkage system, which contributed greatly to reducing the weight and size of the new CVT.

3. Sliding Mode Control

3.1. Adoption of sliding mode control

The shifting action of a steel-belt CVT is determined by the clamping forces applied to both pulleys. It is known that shift response has nonlinearity due to the geometrical shape of the belt wrapped around the pulleys and the rotational speed dependence of the shift speed.[(1)]

The previous system using a stepping motor and a mechanical linkage formed a powerful hydraulic servo system, as described above. Ample ratio control performance was assured even with linear control by regulating the supply and evacuation of the CVT fluid within the range where the source pressure of the primary pulley pressure system was fully secured.

3.2.SMCの概念

SMCは所望の応答を制御系の状態変数の関係式（切換面）として設定し，そこに応答を拘束させるような操作を加える制御手法である．CVTの変速制御へ適用するにあたり，この切換面を式（1）のように置き制御することにした．

$$\sigma = \ dip/dt + c(ip - ip^*) = 0 \tag{1}$$

ここで，ipは実変速比，ip*は目標変速比，cは定数，σは切換面からのずれを示す．SMCの適用により，Fig. 3に示すように変速の状態をまず，切換面（σ= 0）へ素早く到達，拘束させて，切換面に沿って狙いの変速速度で目標変速比に収束させることが可能となる．

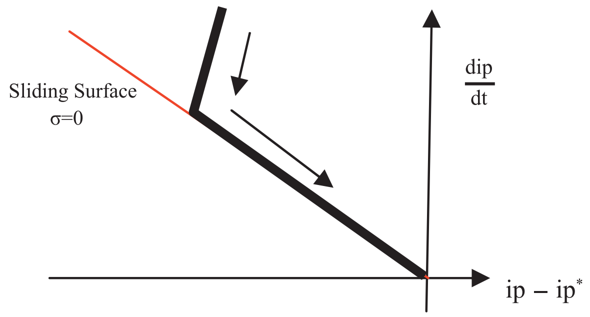

Fig. 3 Concept of SMC

3.3. チャタリングへの対応

SMCは一番単純には，切換面からのずれが正（σ >0）のときは負の補正を，負（σ<0）のときは正の補正を行うスイッチング（以下，SW）ゲイン入力のみの単純な制御則で構成できる．このSWゲイン入力は，応答性のずれの矯正を目的とし，ゲインを大きく設定すると高いロバスト性が得られる半面，チャタリングが発生し，結果として変速挙動がビジーになる．（Fig. 4）

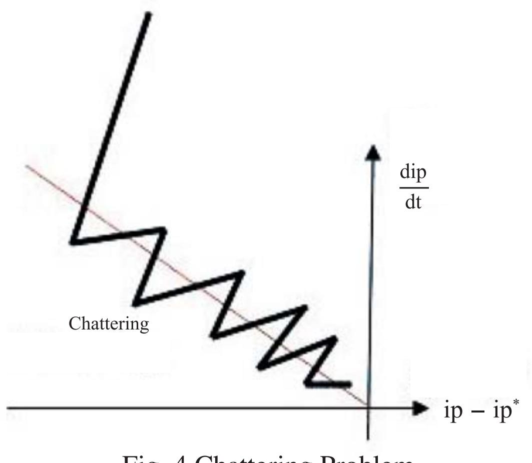

Fig. 4 Chattering Problem

In contrast, the direct pulley pressure control system does not have any mechanical hydraulic servo system. That makes is necessary to treat the CVT shift characteristics as they are in the form of a nonlinear system. To do that required the introduction of a new nonlinear control theory.

The shift control system must be able to shift the CVT so as to provide a feeling of acceleration that tracks the engine speed. Additionally, the pulley pressure must be reduced as much as possible in order to improve fuel economy.

Sliding mode control (SMC) was adopted for the CVT8 to satisfy those requirements. This control methodology allows the application of a relatively simple control law to a nonlinear system to ensure high tracking capability and excellent robustness.

3.2. Principle of SMC

With the SMC technique, the desired response is defined as a relational equation (sliding surface) in terms of the state variables of the control system, and a control operation is added so as to constrain the response (Fig. 3). In applying SMC to CVT ratio control, the sliding surface was assumed as expressed in Eq. (1) below for performing the control operation.

$$\sigma = \ dip/dt + c(ip - ip^*) = 0 \tag{1}$$

where ip is the actual ratio, ip* is the target ratio, c is a constant and σ is the deviation from the sliding surface. With the application of SMC, the shift state quickly reaches the sliding surface (σ = 0) and is confined there. It can then converge to the target ratio, moving along the sliding surface at the desired shift speed.

3.3. Measures against chattering

In its simplest form, the control law of SMC can be configured simply as only a switching gain input, whereby negative compensation is applied when the deviation from the sliding surface is positive (σ > 0) and positive compensation is applied when it is negative (σ < 0). The purpose of this switching gain input is to correct the response difference. Setting a large gain obtains high robustness, but it also causes chattering that results in busy shift control behavior as shown in Fig. 4.

このチャタリングの対策として，ノミナル応答の誘導を行う等価制御入力を追加し，さらに非連続であるSWゲイン入力が滑らかになるよう近似を行った．SWゲイン入力の近似により生じた定常偏差に対しては，PI補償器を併用することで対応した．

3.4. CVT8への適用

CVT8への適用にあたっては，変速過渡の追従性の高い領域では大きなゲインを設定し，追従性の低い領域ではゲインを下げることで高い応答性と安定性を両立させている．

また，等価制御入力については，実験結果より取得した指示圧を与えた際の実圧の応答性，および実圧からプーリーに推力が加わった際の変速応答性に応じて，設定した．

Fig. 5にCVT8のSMCのブロック図を示す．

As measures against chattering, an equivalent control input was added that induces a nominal response and an approximation of the noncontinuous switching gain input is performed to make it smooth. A proportional-integral (PI) compensator was also added to deal with the steady-state deviation produced by approximating the switching gain input.

3.4. Application to CVT8

In applying SMC to the CVT8, a large gain was set in the region where high tracking capability is needed for shift transients and the gain level was reduced in the region where low tracking capability suffices. This made it possible to obtain both high responsiveness and stability.

The equivalent control input was set according to the responsiveness of the actual pulley pressure when an indicated pressure value obtained experimentally was applied and the shift responsiveness when the thrust forces from the actual pressure were applied to the pulleys. A block diagram of the SMC system adopted for the CVT8 is shown in Fig. 5.

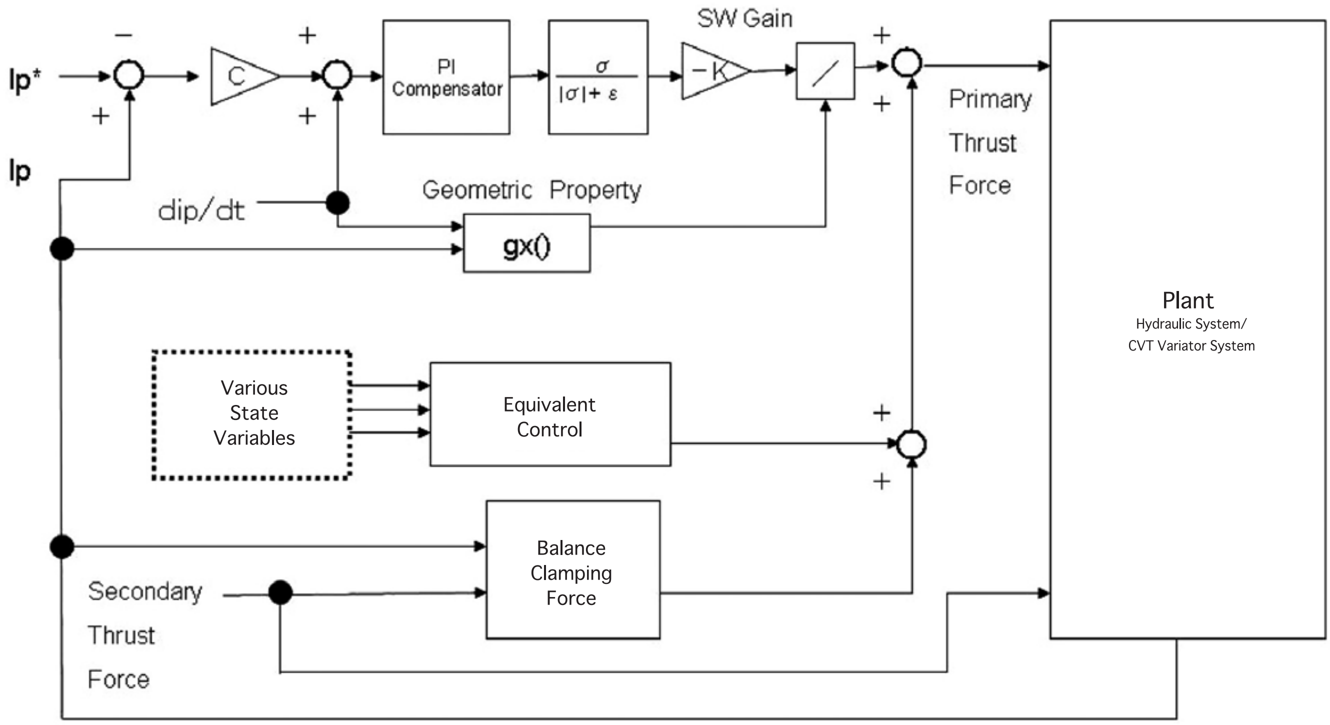

Fig. 5 Block Diagram of SMC for CVT8

4. 効果

CVT8搭載車両のオートアップ及び足離しアップシフトの実車波形をFig. 6，Fig. 7に示す．

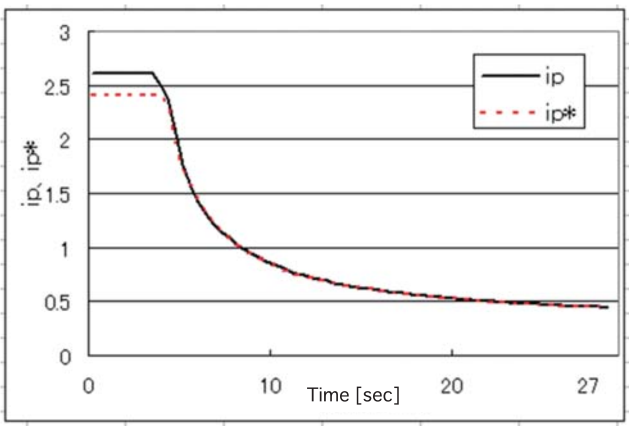

Fig. 6 Automatic Upshift Mode

目標変速比ip*（点線）に対して実変速比ip（実線）が非常に良く追従できており，従来と比べて変わらないレベルの変速性能を達成することができた．

5. まとめ

スライディングモード制御を採用し，制御内部にCVTの変速特性を組み込むことにより，ステッピングモーターレスで従来並みの変速性能を実現した．

6. 参考文献

1. Ide, T., Uchiyama, H. and Kataoka, R. *Experimental Investigation on Shift Speed Characteristics of a Metal V-Belt CVT*. 1996. JSAE paper 9636330.
2. Adachi, K. et al. *Robust Control System for Continuously Variable Belt Transmission*. 1999. JSAE Review, Volume 20, Issue 1.

4. Effects of SMC

The shift waveforms obtained with a test vehicle fitted with the CVT8 are shown in Fig. 6 for the automatic upshift mode and in Fig. 7 for the lift foot upshift mode.

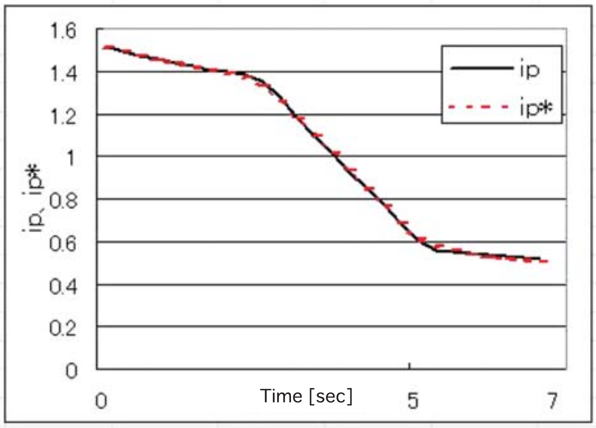

Fig. 7 Lift Foot Upshift Mode

The results show that the actual ratio ip (solid line) tracked the target pulley ratio ip* (dashed line) very well. This indicates that the SMC system achieves the same level of shift performance as that of the previous ratio control system.

5. Conclusion

The adoption of sliding mode control and the incorporation of CVT shift characteristics into the control software have achieved shift performance equal to the previous system without using a stepping motor.

6. References

1. Ide, T., Uchiyama, H. and Kataoka, R. *Experimental Investigation on Shift Speed Characteristics of a Metal V-Belt CVT*. 1996. JSAE paper 9636330.
2. Adachi, K. et al. *Robust Control System for Continuously Variable Belt Transmission*. 1999. JSAE Review, Volume 20, Issue 1.

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熱性能向上について

Improvement of Heat Performance

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抄　録　Jatco CVT8（以下「CVT8」とする.）の熱性能開発にあたり，世界中に拡大する市場や搭載される車両のカテゴリーを意識し，充分なポテンシャルを備えるための検討を行った．本稿ではCVT8における熱性能開発の内容を紹介する．

Summary　In developing the heat performance of the new Jatco CVT8 series, studies were conducted to ensure that it would have sufficient performance potential. This took into account the vehicle categories the new series would be used on and the ongoing expansion of vehicle markets throughout the world. This article describes the details of the heat performance developed for the CVT8 series.

1. はじめに

ジヤトコはトランスミッション（以下「TM」とする.）をグローバルに展開している．世界中の様々な使われ方や環境下でも，TMの性能や耐久性を確保するために，TM内の油温を許容温度以下にしている．しかしグローバル市場は日々拡大しており，TMの更なる発熱･放熱性能の開発が求められている．

本稿ではこれらの要求を満足させたCVT8における熱性能向上技術について紹介する．

2. CVT8の熱性能開発コンセプト

CVT8の熱性能コンセプトは，コストや搭載性の面で他のTMとの競争力を確保しつつ，拡大するグローバル市場に対応できるポテンシャルを備えている事，即ち，更に厳しくなる市場環境においても発熱を抑え放熱を確保する事とした．

Fig. 1は各国の車速と路面勾配を表したものである．近年は特に新興国で高速道路網が整備され，要求車速も高速化している．（Fig. 1中A）またトレーラ牽引や山岳地域等の高負荷運転での走行も増えている．（Fig. 1中B）

車速と路面勾配には負の相関が見られ，高車速

1. Introduction

JATCO supplies transmissions to vehicle manufacturers around the world. Our transmissions must ensure performance and durability for use in diverse environments and under various driving styles in markets worldwide. To accomplish that, the fluid temperature in the transmission has to be kept below a certain allowable level. However, vehicle markets are constantly expanding, making it necessary to develop further the heat generation and radiation performance of transmissions.

This article describes the technologies developed for improving the heat performance of the JCVT8 series in order to satisfy the foregoing requirements.

2. Development Concept for Heat Performance of CVT8 Series

The heat performance concept defined for the CVT8 series was to suppress heat generation and ensure sufficient heat radiation in increasingly harsher usage environments. In short, the new series needed to have the performance potential to cope with use in ever-expanding global markets, while being competitive with other transmissions in terms of cost and vehicle mountability.

Figure 1 shows typical vehicle speeds and road

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条件と高勾配条件では発放熱の要因が異なる．そこで，それぞれの条件で熱性能を向上させるための方策を検討した．

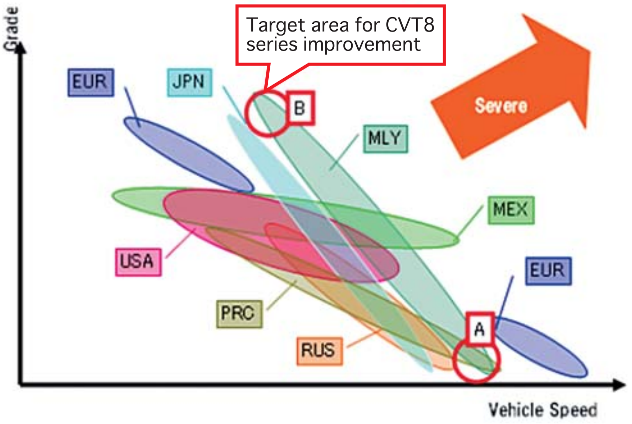

Fig. 1 Vehicle usage conditions around the world

2.1. 高車速条件

高車速条件では走行風により放熱量が確保されているため，発熱量の低減を主に取組んだ．TMの発熱量はTMでの損失エネルギであり，回転数と損失トルクの積である．したがって発熱量低減のためには損失トルクを低減する必要がある．CVT8では高回転時に発熱への影響が大きいTM内油の攪拌抵抗の低減に取組んだ．

2.2. 高勾配条件

高勾配条件では，Fig. 1に示した傾向にあるように，高車速条件に比べ車速が低く，走行風による放熱量が減少するため，放熱量の増加に着目した．具体的な方策としてはオイルクーラーの大型化が考えられるが，コストアップや搭載性が悪化するため最良の方法ではない．したがってTM内部の改善であるオイルクーラー（以下「OC」とする．）に流す油の流量増加に取組んだ．

3. コンセプト実現の方策

3.1. 攪拌抵抗の低減

TM内の回転体が油面と接触すると損失トルク（攪拌抵抗）を生じる．特に高油温時は油の体積膨張により油面が上昇するため，油面と回転体の接触が増加し，発熱量が増加する．そのため油面を低下させつつ，車両が傾斜した際や，極低温下でも確実にストレーナーが油没している技術開発が必要となった．

grades found in various countries. One notable characteristic is that the required vehicle speed has been increasing in emerging economies in recent years accompanying the construction of expressway networks (A in Fig. 1). Additionally, the incidence of driving under high loads is also increasing, such as for pulling a trailer or driving in mountainous regions (B in Fig. 1).

The negative correlation seen between the vehicle speed and road grade indicates that the factors involved in heat generation/radiation differ between high vehicle speeds and steep road grades. Therefore, a study was made of measures for improving performance under both sets of conditions.

2.1. High vehicle speeds

Wind generated by vehicle motion secures ample heat radiation in high-speed driving. Accordingly, the main focus under this condition was to reduce the amount of heat generation. The heat generated by a transmission represents the unit's energy loss. Heat generation is a product of the rotational speed and torque loss. Therefore, in order to reduce the amount of heat generated, it is necessary to reduce torque loss. For the CVT8 series, efforts were made to reduce fluid churning resistance inside the unit, which has a large effect on heat generation during operation at high rotational speeds.

2.2. Steep road grades

As the tendency shown in Fig. 1 indicates, the vehicle speed is lower on steep road grades than it is during high-speed driving. Because the heat radiation promoted by the wind produced by vehicle motion decreases at lower vehicle speeds, priority was put on increasing the amount of heat radiation under this condition.

One specific way of accomplishing that would be to increase the size of the oil pan. However, that is not the best approach because it would increase the cost and worsen vehicle mountability. Therefore, efforts were made to increase the fluid flow rate to the oil cooler, representing an internal transmission improvement.

CVT8ではオイルパンの形状を上記トレードオフ性能を満足させた形状とする事で，この課題を解決した．Fig. 2にオイルパンの形状を示す．オイルパンのストレーナー吸い口の部分を一部深底化にする事で，ストレーナーの油没を確保しつつ，油面を従来CVTより17mm低下させた．

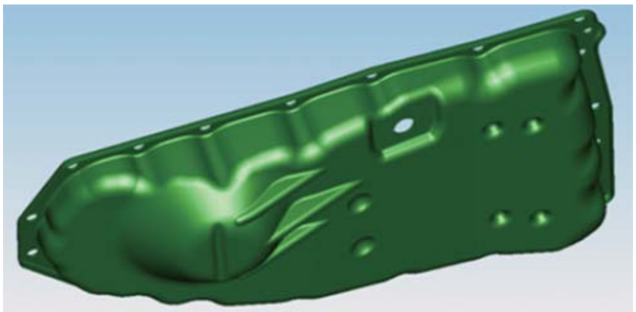

Fig. 2 Oil pan geomtry

ただ油面を低下させてもファイナルギアの一部は油没する位置にあり，攪拌抵抗が生じる．そこでCVT8ではファイナルギアの攪拌抵抗の低減のため，回転体を覆う部品，すなわちバッフルプレートを開発した．Fig. 3に形状を示す．回転により内部の油を排出し，油没量を低減させ攪拌抵抗を低減する．

Fig. 4にCVT8と従来CVTの損失トルクの比較を示す．CVT8は従来CVTより損失トルクが低減しており，その効果は油温が高くなっても維持されている．これはCVT8は油温が上昇し難いというロバスト性も備えている事を示している．

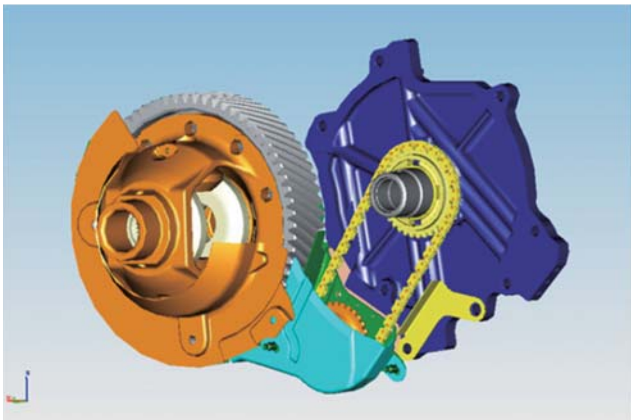

Fig. 3 Baffle plate

3. Measures for Attaining Development Concept

3.1. Reduction of churning resistance

Contact between the rotating elements of the transmission and the fluid surface results in torque loss, i.e., churning resistance. Such contact increases especially at high fluid temperatures when the fluid surface level rises due to the fluid's thermal expansion, which results in greater heat generation. Therefore, it was necessary to develop some technical measure for lowering the fluid surface level, while at the same time ensuring reliable submersion of the strainer even under extremely low temperature conditions and when the vehicle is tilting.

For the CVT8 series, this issue was resolved by designing the oil pan geometry as shown in Fig. 2 so as to satisfy the above-mentioned performance trade-off. One part of the suction port of the strainer was made deeper, which ensures that the strainer remains submerged in the fluid while also lowering the fluid surface level by 17 mm compared with that of an Existing CVT.

However, even though this geometry lowered the fluid surface level, a part of the final gear was still submerged in the fluid, which would cause churning resistance. Therefore, a baffle plate was developed for the CVT8 series to cover the rotating final gear and thereby reduce the churning resistance it causes. The geometry of the baffle plate is shown in Fig. 3. Rotation of the plate discharges the fluid on the inside, thereby reducing the extent to which the final gear is submerged, which has the effect of lessening churning resistance.

Figure 4 compares the torque loss of the CVT8 series and an Existing CVT. The results show that the CVT8 series experiences less torque loss than the

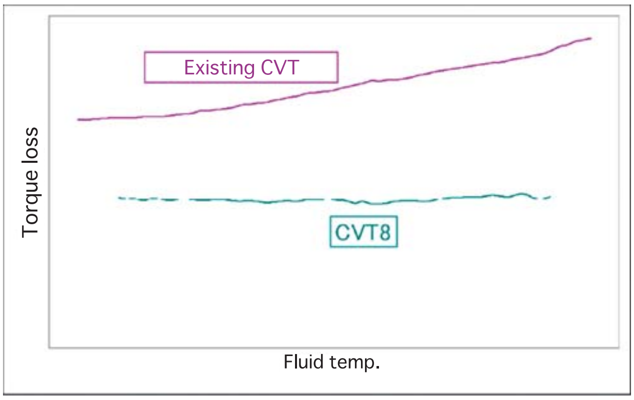

Fig. 4 Comparison of torque loss

3.2. クーラー流量の増加

OCに流す油の量を増やす手段として下記がある.

- オイルポンプの吐出量増加
- リークの低減

オイルポンプ(以下「OP」とする.)の吐出量を増加させるとOPの駆動負荷が増加し, TMの効率が悪化する. そこで以下の施策によって大幅なリーク低減をした. CVT8では特に影響が大きいコントロールバルブ(以下「CV」とする.)部とプーリー部のリーク低減を重点的に改良した.

CVは各種スプールをソレノイドによって作動させ, 最適な油圧を生成している. スプールは常時作動するため, 摺動部には隙間がある. この隙間からリークするため, CVT8では隙間を最小にする開発をし, リークを低減させた.

プーリーはスライドプーリーとフィックスプーリーによって構成され, 油圧によりベルトを押付けている. ベルトの押付け力が高い状態では, ベルトからの反力によってプーリーが変形し, スライドプーリーとフィックスプーリーの隙間が増加する. (Fig. 5)そこで隙間の増加を防ぐために, スライドプーリーとフィックスプーリーの勘合長増加, スライドプーリーの剛性を大きくしてリークを低減させた.

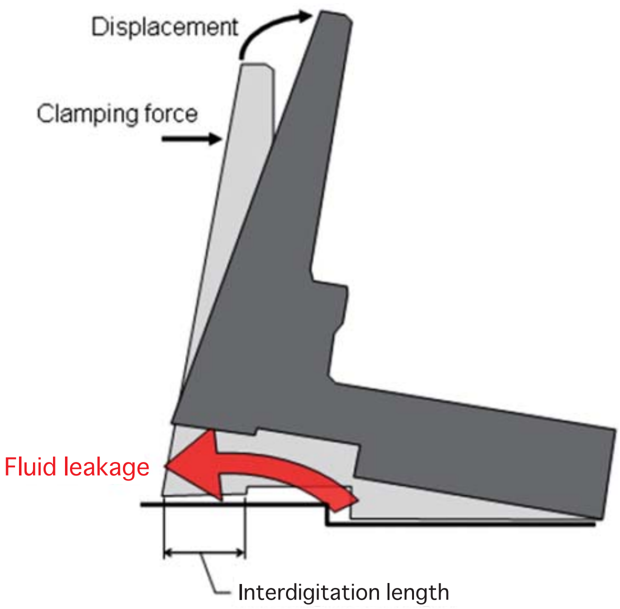

Fig. 5 Leakage from pulley

Fig. 6にCVT8と従来CVTのOCに流れる油の流量の比較を示す. CVT8は従来CVTより流量が増加し, 放熱量が確保されている.

Existing CVT and that this reduction is maintained even at high fluid temperatures. This indicates that the CVT8 series also has more robustness in that the fluid temperature is less likely to rise.

3.2. Increased flow rate to oil cooler

The amount of fluid flowing to the oil cooler can be increased by the following measures:

- increasing the discharge rate of the oil pump, and
- reducing fluid leakage.

Increasing the discharge rate of the oil pump would require greater torque to drive the pump, which would lower the efficiency of the transmission. To avoid that, the following measures were taken to reduce fluid leakage substantially. For the CVT8 series, priority was put on reducing leakage between the control valve and the pulleys, which accounts for an especially large proportion of the total leakage.

The control valve serves to generate the optimum pressure by using solenoids to actuate the spools. Because the spools are always moving, gaps occur between the sliding parts and fluid leaks through the gaps. The control valve of the CVT8 series was developed so as to minimize such gaps and thereby reduce fluid leakage.

The pulleys consist of sliding and fixed pulley halves and clamp the belt by means of hydraulic pressure. Under a high clamping force condition, the pulleys are displaced by the reaction force from the belt, thus increasing the gap between the sliding and fixed pulley halves (Fig. 5). As measures for preventing this gap increase, the interdigitation length of the sliding and fixed pulley halves was increased and the sliding pulley half stiffness was increased.

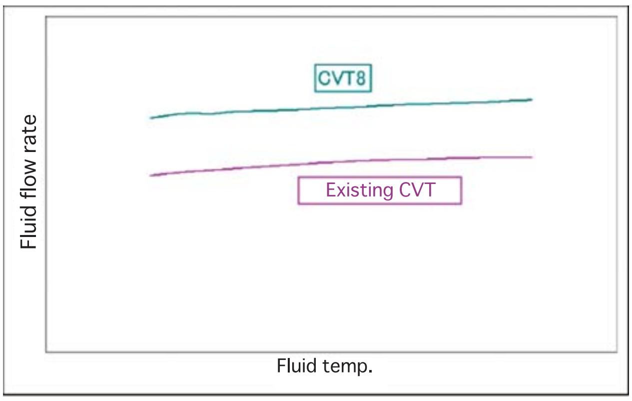

Fig. 6 Comparison of flow rate

4. まとめ

以上のように，CVT8では拡大するグローバル市場を見据え，厳しくなる市場環境においても発熱を抑え放熱を確保することで，ロバスト性が向上されたユニットの開発に成功した．

今後も市場の変化に対応しながら，他のTMとの競争力を確保し，更なる熱性能向上の開発を推進していく．

These measures proved effective in reducing fluid leakage.

Figure 6 compares the fluid flow rate to the oil cooler for the CVT8 series and an Existing CVT. The results show that the flow rate in the CVT8 series has been increased over that of the Existing CVT, thereby securing the desired amount of heat radiation.

4. Conclusion

This article has described the measures taken to suppress heat generation and to secure ample heat radiation in the newly developed CVT8 series. These measures successfully improved the robustness of the series for use under even harsher driving environments, keeping in mind vehicle applications in ever-expanding global markets.

We intend to continue development work for improving heat performance further, while coping with future market changes and ensuring competitiveness with other transmissions.

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低粘度CVTオイルの開発

Development of a Fuel-efficient CVT Fluid

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抄　録　燃費向上への材料からの取り組みとして，油の攪拌抵抗の低減によるユニットフリクション低減を目的とした低粘度無段変速機油（以下「CVTF」とする．）を開発し，新開発Jatco CVT8に採用した．開発油は，低粘度でありながら基油，粘度指数向上剤を工夫することにより従来CVTFと互換性を持たせることにより，既存のCVTにも採用し，これらの燃費向上にも貢献している．本稿では，低粘度CVTFの開発の狙い，性能について報告する．

Summary　The low viscosity CVT fluid was developed and adopted for the new Jatco CVT8 series. The purpose was to lower the CVT friction level by reducing fluid churning resistance as one measure for improving vehicle fuel economy from a material perspective. While possessing low viscosity, the newly developed fluid is interchangeable with existing CVT fluids as a result of formulation changes made to the base oil and the viscosity index improver. Therefore, it can also be used in existing CVTs to contribute to fuel economy gains. This article describes the development aims and performance of the low viscosity CVT fluid.

1. はじめに

省資源，地球温暖化防止等の地球環境問題への対応の重要度が年々増してきている．これに対し，当社では，CVTの適用トルク拡大による適用車種拡大，およびオイルポンプの小型化や新型の金属ベルト等の技術開発による変速機のフリクション低減により車両の燃費向上に貢献してきた．

変速機油におけるフリクション低減への取り組みとしては，低粘度化による攪拌抵抗やクラッチの引きずり抵抗の低減が行われており，ステップATでは2005年以降低粘度ATFの採用が進んできている．[1]これに対し，CVTはステップATに比べて高い油圧が必要であること，高面圧で摺動されるベルトープーリー間の摩耗防止等の理由により，CVTFの低粘度化は行われてこなかった．当社ではCVTの燃費向上を目的に，上記課題に対応した低粘度CVTFを開発し，Jatco CVT8に採用した．なお，本油は2011年5月以降，既存CVTへの採用が始まり．現在海外生産工場を含む当社の全CVTに採用されている．

本稿では，上記の低粘度CVTFについて報告する．

1. Introduction

The importance of measures for addressing global environmental issues, such as conservation of resources and prevention of global warming, has been increasing every year. In this regard, JATCO has been working to improve vehicle fuel economy by reducing transmission friction through the development of new technologies. This has included expanding the torque capacity range of CVTs to make them applicable to a wider variety of vehicle models, the downsizing of the oil pump, and the development of a new steel belt, among other measures.

As one measure for reducing friction in connection with the transmission fluid, the viscosity was lowered to reduce churning resistance and clutch drag resistance. Low-viscosity automatic transmission fluids (ATFs) have been adopted for our stepped ATs since 2005.[(1)] In contrast, the viscosity of CVTFs was not reduced for several reasons, including the fact that CVTs require higher hydraulic pressure than stepped ATs and for preventing wear between the belt and pulleys that are in sliding contact under high surface pressure.

With the aim of improving the fuel economy

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2. 開発の狙い

油の粘性は，撹拌抵抗などによりユニットフリクションに影響する要因の一つである．Fig. 1に油の粘度とユニットフリクションの関係を示す．このため，フリクション低減を目標に粘度を低減させた．また，既存のCVTへの採用を可能とするため，せん断後粘度および摩耗防止性能，疲労防止性能は従来油と同等以上の性能を有することを目標とした．

CVT搭載車両の販売地域のグローバル化に伴い，弊社CVTも海外生産工場での生産比率が年々高くなってきている．これに対応して，開発油はグローバルに生産可能であることを目標とした．

以下に開発油の目標をまとめる．

（1）低粘度化
（2）せん断後粘度の確保
（3）潤滑性能の確保
（4）グローバル生産による入手性の向上

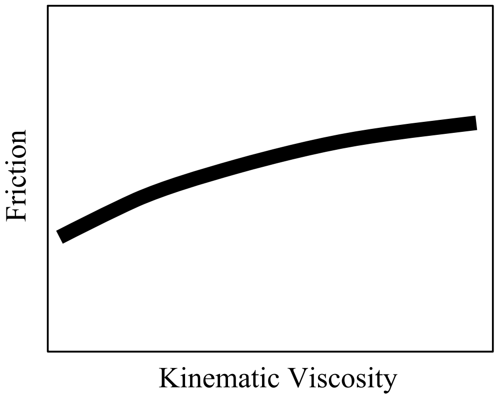

Fig. 1 CVT friction as a function of fluid kinematic viscosity

3. 方策

低粘度・せん断後粘度の確保・潤滑性能の確保を目的として，従来油に対して以下Table 1のような処方変更を行った．また，同一処方の油をグローバルに生産可能とするため，グローバルに入手可能な原材料を用いた．

Table 1 Formulation changes from existing fluid to new fluid

	Base Oil	VII
Low viscosity	・Using high VI	・Using low molecular mass ・Reduced the percentage of VII
Permanently sheared viscosity at high temperature	・Keeping viscosity of base oil at high temperature	・Using low molecular mass ・Reduced the percentage of VII
Lubrication	・Keeping viscosity of base oil at high temperature	・Using low molecular mass

※VI: viscosity index ， VI（High ⇔ Low）= viscosity change（little ⇔ large）

obtained with CVTs, we recently developed a low viscosity CVTF that overcomes these issues and adopted it for the Jatco CVT8 series. This new fluid began to be adopted in existing CVTs in May 2011 and is currently used in all our CVTs included those manufactured at our overseas production plants.

This article describes the new low viscosity CVTF.

2. Development Aims

Fluid viscosity is one factor influencing the friction level of a CVT due to churning resistance, among other things. Figure 1 shows CVT friction as a function of the fluid's kinematic viscosity. Accordingly, the viscosity of the new fluid was lowered with the aim of reducing friction. In addition, another aim was to give the new CVTF the same or better post-shear viscosity, anti-wear performance and fatigue resistance as existing CVTFs in order to make it applicable to CVTs already in use.

Along with the global expansion of the regions where CVT-equipped vehicles are sold, the proportion of our CVTs produced at overseas plants has been increasing every year. In line with this trend, a further target set for the new CVTF was to make it producible worldwide.

The development aims set for the new CVTF are summarized below.

(1) To lower the viscosity
(2) To ensure post-shear viscosity
(3) To ensure lubrication performance
(4) To improve fluid availability through global production

3. Measures

Table 1 outlines the formulation changes that were made to the new fluid in comparison with an existing CVTF for the purpose of achieving low viscosity and ensuring post-shear viscosity and lubrication performance. In addition, globally procurable materials were adopted to facilitate worldwide production of the new CVTF having an identical formulation.

4. 開発油の性能

4.1. 粘度特性

Fig. 2に開発油と従来油の温度－粘度特性を示す．開発油は，従来油に対し全温度域において約7℃分低粘度化している．

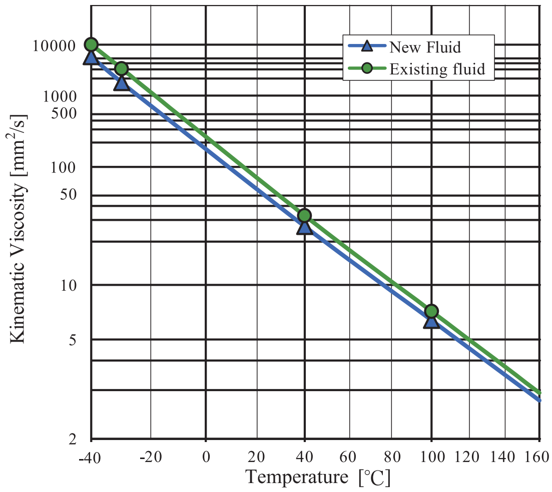

Fig. 2 Viscosity properties of new fluid

4.2. せん断安定性

開発油のせん断安定性はJASO M347 1995 [2]に規定されている超音波せん断安定性試験機を用い，超音波による油のせん断時間をふって試験を行うことにより，粘度の経時変化を評価した．

また，せん断後粘度は上記試験結果を用い，式(1)[3]で示す式から算出した．Fig. 3に超音波せん断安定性試験の結果，Fig. 4にせん断後粘度を示す．これらの結果から，開発油は良好なせん断安定性を有し，従来油同等以上のせん断後粘度を有することが確認された．

$$KV = KV_{lim} + (KV_{in} - KV_{lim}) / (1 + K \times t) \quad (1)$$

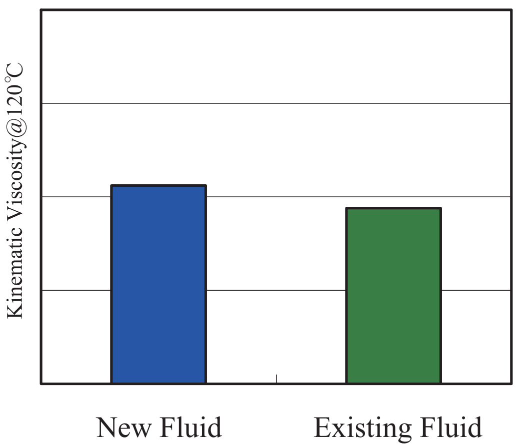

Fig. 4 Calculated values of fully sheared viscosity

4. Performance of New CVTF

4.1. Viscosity properties

Figure 2 compares the temperature-viscosity properties of the new CVTF and an existing CVTF. The kinematic viscosity of the new CVTF has been reduced by an amount equal to 7℃ over the entire temperature range compared with that of the existing CVTF.

4.2. Shear stability

The shear stability of the new CVTF was evaluated by conducting a test in which the shear time of the fluid was varied by applying ultrasonic radiation. The test was conducted using a sonic shear stability tester as specified in JASO standard M347 1995.[2]

The post-shear viscosity was calculated from the test results using the formula shown in Eq. (1)[3] below. Figure 3 presents the sonic shear stability test results for the existing and new CVTFs, and Fig. 4 compares their post-shear viscosity. These results confirm that the newly developed fluid possesses excellent shear stability and also has post-shear viscosity equal to or better than that of the existing fluid.

$$KV = KV_{lim} + (KV_{in} - KV_{lim}) / (1 + K \times t) \quad (1)$$

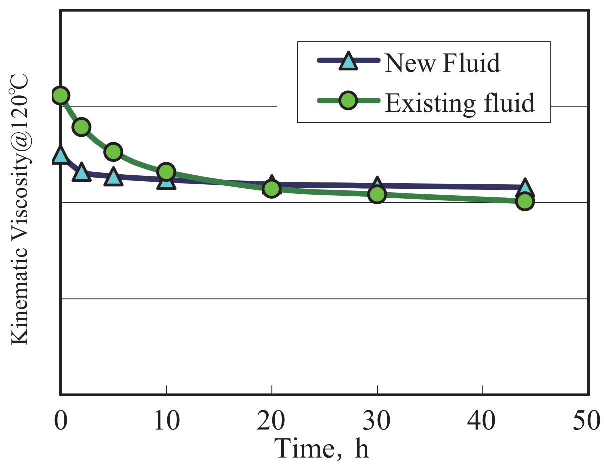

Fig. 3 Results of sonic shear stability test

4.3. Lubrication performance

The thickness of the fluid film that forms generally decreases as the viscosity is reduced. However, the film thickness of the new fluid was secured by the measures explained in section 3. Figure 5 compares the fluid film thickness measured with an

4.3. 潤滑性能

一般に粘度が低くなると形成される油膜厚さも薄くなるが，本開発油は3に述べた方策をとることにより油膜厚さを確保した．Fig. 5にEHL試験機により測定した油膜厚さを示す．開発油は従来油と同等の油膜厚さを形成することが確認された．開発油の焼付き防止性能と摩耗防止性能はシェル式4球試験にて評価した．Fig. 6にシェル式4球極圧試験（ASTM D2763-88[4)]）の結果，Fig. 7にシェル式4球摩耗試験（JPI-5S-32-90[5)]）の結果を示す．疲労防止性能はスラストニードルベアリングによる寿命評価を実施した．Fig. 8に上記ベアリング疲労寿命試験の結果を示す．開発油は従来油と同等の潤滑性能を有することが確認された．

elastohydrodynamic lubrication (EHL) test rig. The results confirm that the film thickness formed by new fluid is equal to that of the existing fluid. The anti-seizure performance and anti-wear performance of the new fluid were evaluated by conducting shell four-ball tests. Figure 6 shows the results obtained in a shell four-ball test for measuring extreme-pressure properties (ASTM D2763-88)[(4)] and Fig. 7 shows the results obtained in a shell four-ball wear test (JPI-5S-32-90).[(5)] Fatigue resistance was evaluated in a life test conducted with thrust needle bearings and the fatigue life results are compared in Fig. 8. The results indicate that the new fluid provides the same level of lubrication performance as the existing fluid.

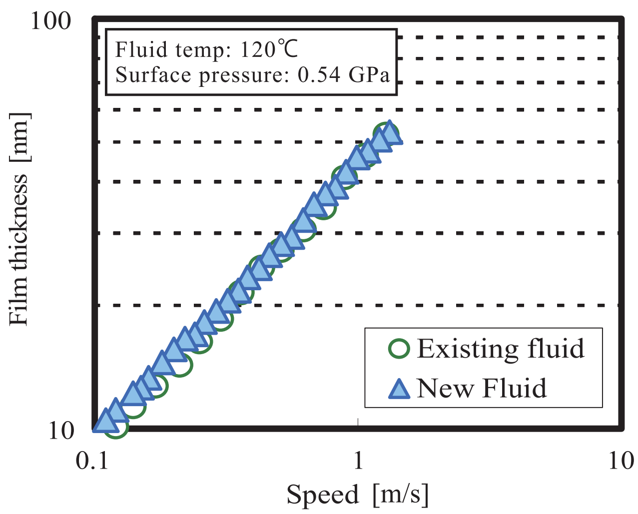

Fig. 5 Results of EHL film thickness measurement

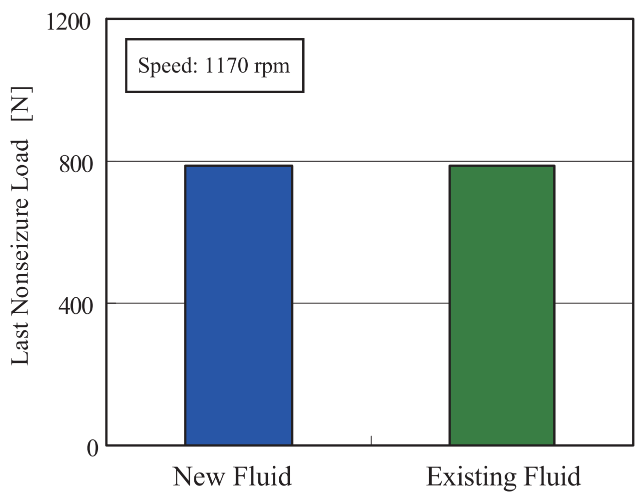

Fig. 6 Results of shell four-ball extreme pressure test

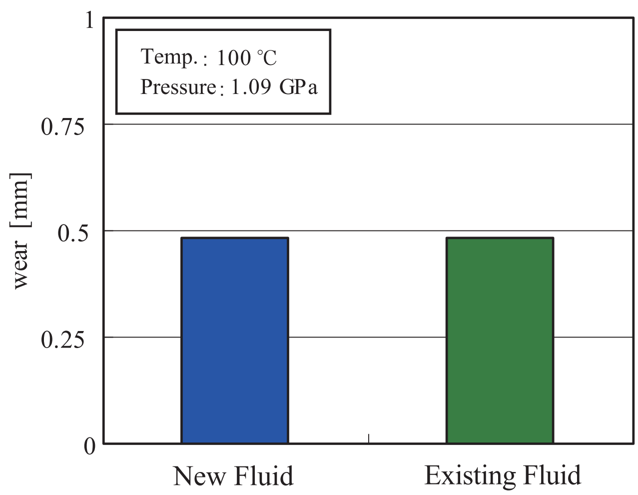

Fig. 7 Results of shell four-ball wear test

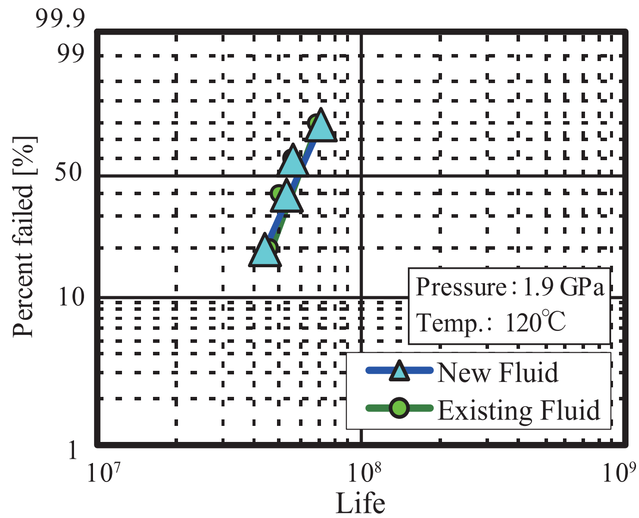

Fig. 8 Results of bearing fatigue test

4.4. 実機評価

実車によるフリート試験を実施し，終了後の油に含まれる金属分を測定した結果をFig. 9に示す．本結果からも，開発油は従来油と同等の潤滑性能を有することが確認された．

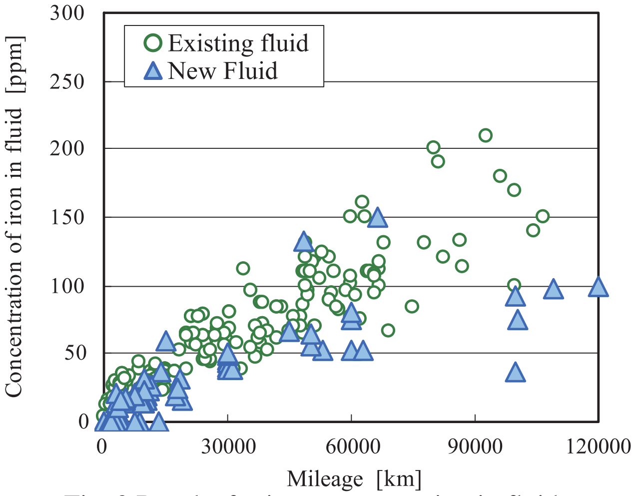

Fig. 9 Results for iron concentration in fluid after vehicle test

4.5. フリクション低減効果

従来CVTの同一個体にて開発油と従来油のフリクション測定を行い，開発油のフリクション低減効果を確認した．Fig. 10に25℃および80℃における開発油の従来油に対するフリクション低減率を示す．開発油は従来油に対して，両温度にてフリクション低減効果を有することが確認された．また，実車によるUS コンバイン．およびJC08モードでの燃費測定試験にて，約0.5%の燃費向上効果があることを確認した．

5. グローバル生産と供給

現在，当社は日本，中国，メキシコに生産工場を持ちCVTを生産しており，2013年には新たにタイでの生産も開始される．また，当社CVTを搭載する車両の車両工場も多岐にわたっており，CVT搭載車は全世界に販売されている．

生産工場および車両の販売地域の拡大に対応し，油剤もグローバル生産と供給が求められている．

開発油はグローバルに入手可能な原材料を用いることにより，油の採用当初から現地生産を行い採用した．

4.4. Evaluation in vehicle tests

A fleet test was conducted with test vehicles and the iron concentration in the fluid was measured following the test. The results are shown in Fig. 9. These results also confirm that the new fluid provides the same level of lubrication performance as the existing fluid.

4.5. Friction reduction effect

Friction measurements were made for the new and existing fluids using the same Existing CVT in order to confirm the friction reduction effect of the newly developed fluid. Figure 10 shows the rate of friction reduction achieved by the new fluid in comparison with the existing fluid at 25℃ and 80℃. The results confirm that the new fluid effectively reduces CVT friction at both fluid temperature levels compared with the existing fluid. It was also confirmed in vehicle tests that the new fluid is effective in improving fuel economy by approximately 0.5% in fuel economy tests conducted under both the U.S. combined driving cycle and Japan's JC08 test mode.

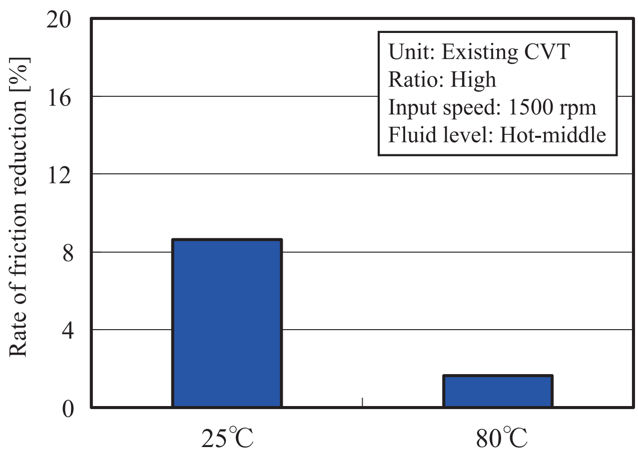

Fig. 10 Results of CVT friction test

5. Global Production and Supply

JATCO is currently producing CVTs at our production plants in Japan, China and Mexico and will also launch CVT production in Thailand in 2013. Vehicles fitted with our CVTs are produced at a wide range of assembly plants and the CVT-equipped vehicles are sold throughout the world.

In order to accommodate the ongoing expansion of vehicle assembly plants that produce CVT-equipped vehicles and the regions where they are marketed, it is necessary for us to have a global network for

6. まとめ

油膜形成とせん断安定性を考慮した基油と粘度指数向上剤を処方することにより，従来油と同等のせん断後粘度および潤滑性能を有する低粘度無段変速機油を開発した．また，実機を用いたフリクション測定を行い，8%（@25℃）のフリクション低減効果を有することが確認した．本油は，2011年5月以降既存のCVTユニットへの採用が開始され，新開発Jatco CVT8のフリクション低減にも貢献している．

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5）JPI-5S-32-90：Standard Test Method for Measurement of Wear Properties of Lubricating Fluids（Four-Ball Method）

producing and supplying CVTFs.

The use of globally procurable materials for the new fluid made possible its global production from the time it was initially adopted.

6. Conclusion

This article has described a newly developed low viscosity CVT fluid that possesses the same post-shear viscosity and lubrication performance as an existing fluid. That performance was achieved by taking into account fluid film formation and shear stability in the formulation of the base oil and viscosity index improver. Friction measurements made with an actual CVT showed that the new fluid is effective in reducing friction by 8% compared with an existing fluid at a fluid temperature of 25℃. This new fluid began to be adopted in our existing CVTs in May 2011, and it contributes to a significant friction reduction in the newly developed CVT8 series.

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大容量CVTチェーンの開発

Development of a High Torque Capacity Chain for CVT

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抄　録　新開発の大容量（エンジン）FF車用CVTであるJatco CVT8 High Torqueにおいて，その開発目標である優れた燃費性能と小型軽量化，および静粛性を達成するために，新たにLuK GmbH & Co. KGと共同開発した大容量CVTチェーンを採用した．本稿では，その開発におけるプーリーなどの周辺部品を含めた大容量化や高効率化，および音振性能確保などの取り組みについて述べる．

Summary　The new Jatco CVT8 High Torque model was developed for use on front-wheel-drive vehicles fitted with a large displacement engine. The development objectives set for this new CVT with a high torque capacity were outstanding fuel economy, size and weight reductions and quiet operation. To achieve those targets, a high torque capacity CVT chain was newly developed in cooperation with LuK GmbH & Co. KG. This article describes the efforts undertaken to develop this new chain, including the pulleys and other associated parts, with respect to increasing torque capacity, boosting efficiency, and ensuring good noise and vibration performance, among other attributes.

1. はじめに

当社は2012年に新型Jatco CVT8，およびJatco CVT8 High Torque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

特にJatco CVT8 High Torqueでは，Table 1に示すように，従来の3.5LクラスのCVTに対してプーリーの軸間距離を5mm短縮しながら，許容トルクを380Nm，レシオカバレッジを6.3にまで拡大した．

1. Introduction

JATCO launched production of the new Jatco CVT8 and the Jatco CVT8 High Torque (CVT8HT) model in 2012. This new CVT series, designed for use on front-wheel-drive vehicles, was developed around the three concepts noted below. Two Existing CVT models were unified into one series for use on 2.0L to 3.5L-class vehicles, making it possible to cover a wide range of applications. At the same time, the constituent parts were thoroughly improved to achieve a substantial fuel economy gain.

(1) To achieve both higher fuel economy and better power performance by expanding the ratio coverage
(2) To improve fuel economy by reducing friction
(3) To develop a common CVT for use on 2.0L-3.5L-class front-wheel-drive vehicles by downsizing the unit

As shown in Table 1, it is especially notable that the Jatco CVT8HT provides a torque capacity of 380 Nm and expands the ratio coverage to 6.3, while the distance between the pulley shafts was reduced by 5

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Table 1 Major Specifications

Item	Existing CVT	CVT8 HT
Torque capacity [Nm]	350	380
Ratio coverage	5.4	6.3
Pulley ratio	2.37~0.44	2.43~0.38
Distance between pulley shafts [mm]	178	173
Drive mechanism	CVT belt	LuK chain

これらを実現するための鍵となる技術として，LuK GmbH & Co. KGと共同で，大容量のCVTチェーン（以下「LuKチェーン」とする．）を開発した．本稿では，その開発にあたり，前述のユニット開発コンセプトを達成するために取り組んだ技術開発の内容について述べる．

2. LuKチェーンの特徴

今回開発したLuKチェーンは，Fig. 1に示すように，積層された長さの異なる2種類のリンクプレート間を2本のロッカーピンで構成されるロッカージョイントで連結した構造となっており，当社が従来のベルトCVTに採用してきた金属製プッシュベルト（以下「CVTベルト」とする．）とは全く異なる構造となっている．

このLuKチェーンの特徴としては，特にJatco CVT8 High Torqueのような大容量CVTへの搭載に際しては，従来のCVTベルトに比較して高トルク容量化に有利な構造であり，小型軽量化と広いレシオカバレッジを両立できること，さらにフリクションロスの少ないことなどが挙げられる．

3. 推力設定の最適化

ベルト，或いはチェーンを変速要素として用いたCVTはFig. 2に示すように，ベルト，或いはチェーンとその相手部品であるプーリーのシーブ面との間で，両者の摩擦力を利用してトルクを伝達している．よって，油圧でベルト，或いはチェーンを挟み込む推力の設定が低すぎると，両者の間にスリップロスが発生する．一方，推力設定が高すぎる場合には，油

mm compared with that of the existing CVT for use on 3.5L-class vehicles. One key technology for achieving this performance is the high torque capacity CVT chain (LuK chain) that was newly developed in collaboration with LuK GmbH & Co. KG. This paper describes in detail the technical features of this new chain that was developed to accomplish the development concepts mentioned above.

2. Features of LuK Chain

The structure of the newly developed LuK chain is shown in Fig. 1. It consists of two types of layered link plates of different lengths which are connected by means of a rocker joint comprising two rocker pins. This chain has a completely different structure from that of the metal push belt (CVT belt) adopted previously for our steel-belt CVTs.

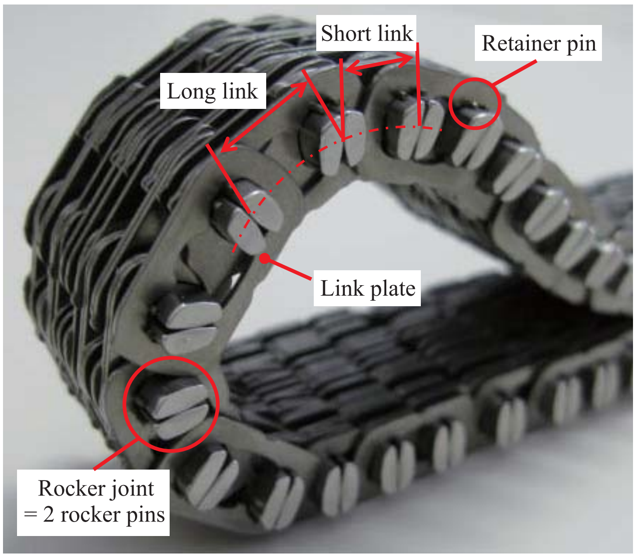

Fig. 1 Structure of LuK chain

The distinctive features of this LuK chain include its structure that reconciles a smaller, lighter design with wider ratio coverage and a low level of friction loss. The structure is better suited to supporting higher torque capacity than the existing CVT belt, making it especially suitable to a high torque capacity CVT like the Jatco CVT8HT.

3. Optimization of Clamping Force

Figure 2 shows a model of the torque transmission mechanism of a CVT that uses a belt or chain as its shifting element. Drive torque is transmitted by

圧を発生させるオイルポンプの負担が高くなり，フリクションロスが増加するなど，いずれの場合も燃費の悪化につながる．よって，LuKチェーンの適用にあたっては，推力設定の最適化が重要となる．

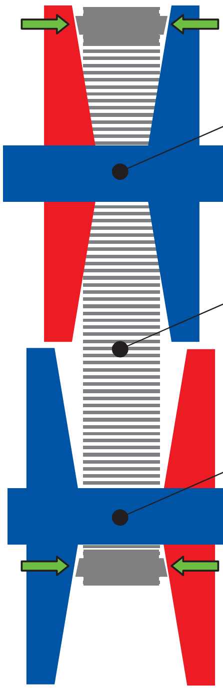

Fig. 2 CVT torque transmission model

スリップロスを発生させないために必要となる最低推力は，走行条件や周辺部品のスペックといった，さまざまな要素を考慮して決めなければならない．一例として，入力トルクや回転数，変速レシオ，潤滑油種や油温，シーブ面の表面性状やプーリーの剛性などが挙げられる．

筆者らはLuK チェーンを採用するにあたり，以下に述べるZETA max法[1]を用いて必要推力を決定した．本手法は，非破壊で必要推力を求められることから，従来よりも効率的な試験評価が可能となる．ここで，ZETAとはプライマリー推力とセカンダリー推力の比である．

測定方法はFig. 3に示すように，変速レシオ，入力回転数，および，セカンダリー推力を一定に保持した上で，プライマリー推力を逐次コントロールしながら，入力トルクを徐々に増加させることにより，ZETAが最大値となるZETA maxトルクを求め，必要推力を決めていくものである．

実際のZETAの測定にあたっては，Fig. 4に示すように，従来からCVTベルトの試験に使用していたCVTベルト用ボックス試験機に，プログラマブルコン

means of the friction force of both the belt or chain and the pulley sheave face that serves as the mating part. Accordingly, if the force (pulley thrust) produced by the applied hydraulic pressure to clamp the belt or chain is set too low, slip occurs between the mating parts. Conversely, if the clamping force is set too high, it puts a higher load on the oil pump that generates the hydraulic pressure, thereby increasing friction loss. In either case, fuel economy deteriorates. Therefore, in adopting the LuK chain it was essential to optimize the clamping force.

Many different factors must be considered in determining the minimum necessary clamping force so as not to cause any slip loss, including the driving conditions and specifications of associated parts, among other things. As one example, it is necessary to consider the input torque and speed, ratio coverage, type of fluid used for lubrication and its temperature, the surface properties of the sheave face, pulley stiffness and other aspects.

In connection with the adoption of the LuK chain, we used the zeta maximum method(1) explained here to determine the necessary clamping force. With this method, the necessary clamping force can be found in a nondestructive manner, making it possible to conduct test evaluations more efficiently than before. The term zeta refers to the ratio of the clamping force of the primary pulley to that of the secondary pulley.

As shown in Fig. 3, the shift ratio, input speed and the clamping force of the secondary pulley are all kept at a certain given level with this measurement method. While constantly controlling the primary pulley clamping force, the input torque is gradually increased to determine the zeta maximum torque level at which zeta reaches its maximum value. In this way, the necessary clamping force is determined.

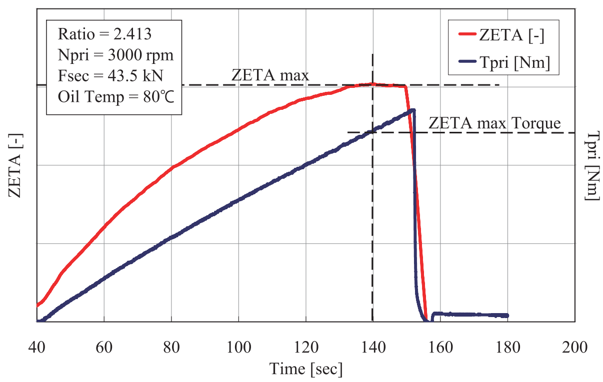

Fig. 3 Clamping force measurement with ZETA max method

トローラーとサーボバルブを接続し，変速レシオをフィードバックしてプライマリー推力を可変できるように改造した．また，推力設定において，CVTチェーンに対する支持剛性の影響を排除するため，実機のプーリーをそのまま使用可能な構造とした．

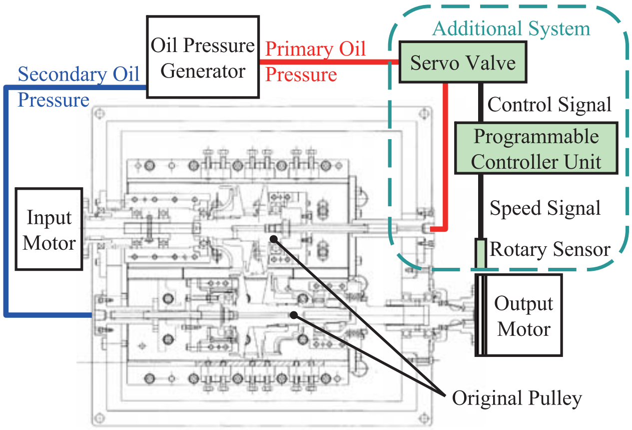

Fig. 4 CVT chain box test rig

Fig. 5にCVTチェーン用ボックス試験機，および実機を用いた場合の各ZETA測定結果の比較を示す．本結果より，両者のZETA maxトルクは良好な一致を示すことが確認できたため，CVTチェーン用ボックス試験機を用いて推力設定の最適化を実施した．

4.シーブの表面テクスチャ最適化による トルク容量確保

今回のJatco CVT8 High TorqueへのLuKチェーン採用にあたり，CVTベルトを用いるJatco CVT8との製造設備の共用化も考慮し，プーリーはストレートシーブを採用した．そして，トルク容量確保を目的として以下に述べるシーブ面の表面テクスチャーに関する開発を行った．

4.1. シーブ面の表面テクスチャの検討

380Nmの高トルクを効率よく伝達するためには，LuKチェーンとプーリー間のスリップロスを防止する必要がある．LuKチェーンのロッカーピンと，その相手側であるシーブ面はFig. 6に模式的に示すように，混合潤滑状態にある．すなわち，潤滑のため供給されたCVTフルードの油膜厚さに対して，ロッカーピンとシーブ面接触部の表面粗さ（表面の突起高さ）が過小となると，摩擦係数の低下によるスリップロス

In measuring the actual zeta value, a CVT chain box test rig like that shown in Fig. 4 is used. This box test rig has been used previously to conduct tests on the CVT belt. The box test rig is connected to a programmable controller and a servo valve. The test rig has been modified so that the shift ratio can be fed back to vary the primary pulley clamping force. The test rig is built such that actual CVT pulleys can be used as they are in measuring the clamping force, which eliminates any effect of the load-bearing stiffness on the CVT chain.

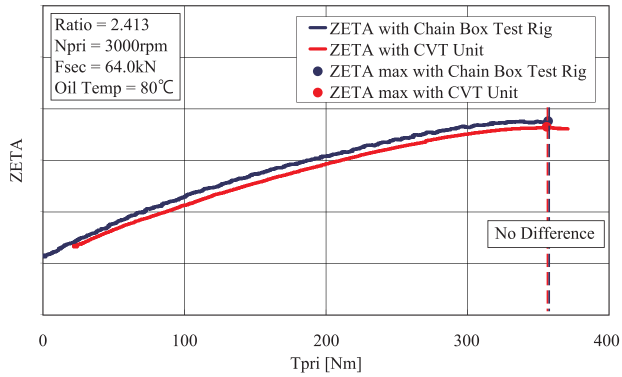

Fig. 5 Comparison of zeta maximum torque values between chain box test rig and actual CVT

Figure 5 compares the zeta maximum torque values measured with the CVT chain box test rig and with an actual CVT. The results show good agreement between the measured zeta maximum torque levels. Therefore, the CVT chain box test rig was used in optimizing the clamping force.

4. Optimization of Sheave Surface Texture to Secure Desired Torque Capacity

In connection with the adoption of the LuK chain for the new Jatco CVT8HT, straight sheave faces were selected for the pulleys to facilitate shared use of the manufacturing facilities with the Jatco CVT8 that is fitted with a steel belt. The sheave surface texture described below was developed for the purpose of securing the desired torque capacity.

4.1. Investigation of sheave surface texture

In order to transmit high torque of 380 Nm efficiently, it was necessary to prevent slip loss between the LuK chain and the pulleys. As shown schematically in Fig. 6, a condition of mixed lubrication exists at the contact surface between the

が発生する．逆に油膜厚さに対して表面粗さが過大となった場合には，金属間接触が顕著となり，過酷な条件下では凝着摩耗を生じる場合がある．

それらを防止するため，Fig. 6に示すように，シーブ表面の突起高さを抑えると共に，微細な溝を円周方向に設けることにより，過度な油膜厚さの形成を防止することを主眼とした表面の微細粗さ形状（以下「表面テクスチャー」とする．）の最適化を行った．

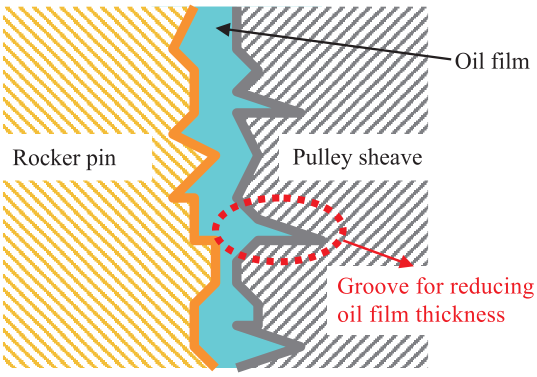

Fig. 6 Schematic diagram of contact surface

このシーブ面の表面テクスチャーを定義するにあたり，適切な油膜厚さを保持するためのパラメータAと，金属間接触を抑制するためのパラメータBの2種類の指標を用いることにより，Fig. 7に示すように，トルク容量と耐摩耗性の両立が可能な領域を設定した．

4.2. シーブ面硬さの向上

運転中のロッカーピンとシーブ面の間には高荷重が繰り返し作用するため，シーブ面の硬さが不十分であると，表面テクスチャーが摩耗により徐々に平滑化し，Fig. 7のトルク容量限界を外れる可能性がある．

Fig. 8にSCR420H鋼に浸炭焼入れ焼戻しを施したプーリーにおける，耐久前後のシーブ面の粗さ曲線を示す．耐久後には表面粗さが顕著に平滑化していることがわかる．また，Fig. 9に示すように，耐久後のシーブ面の表面硬さも顕著な低下が認められた．

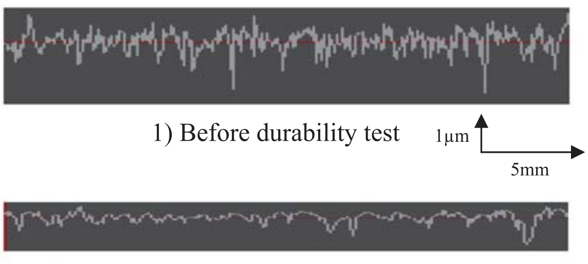

Fig. 8 Surface roughness profiles of sheave before and after durability test

rocker pins of the LuK chain and the mating sheave face. In other words, if the surface roughness (height of surface asperities) in the area of contact between the rocker pins and the sheave face is too small relative to the film thickness of the CVT fluid supplied for lubrication, the resultant decline in the friction coefficient will cause slip loss. Conversely, if the surface roughness is too large relative to the fluid film thickness, pronounced metal-to-metal contact will occur and this harsh condition will cause adhesive wear.

To avoid those problems, the texture (i.e., tiny roughness geometry) of the sheave surface was optimized as shown in Fig. 6. The height of the surface asperities was suppressed and tiny grooves were also provided in the circumferential direction principally to prevent the formation of an excessively thick fluid film.

Two types of indexes were used to define the sheave surface texture. One was parameter A for maintaining a suitable fluid film thickness and the other was parameter B for inhibiting metal-to-metal contact. As shown in Fig. 7, these two parameters were used to define a region where both the desired torque capacity and anti-wear property can be obtained.

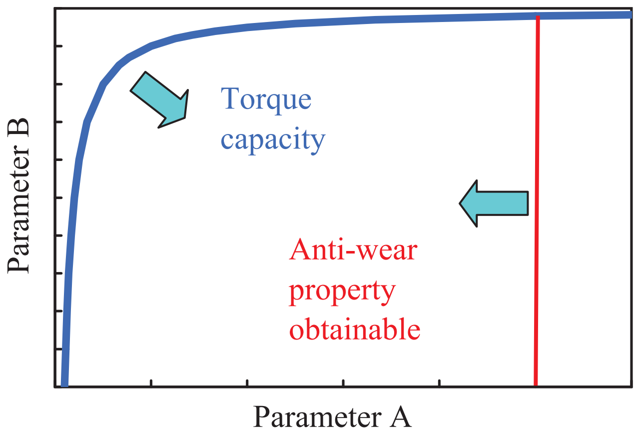

Fig. 7 Optimized sheave surface texture

4.2. Improvement of sheave surface hardness

High loads repeatedly act between the rocker pins and the sheave face during vehicle operation. For that reason, if the sheave face is not sufficiently hard, the surface texture will gradually be flattened and smoothed by wear, with the result that performance might deviate from the desired torque capacity limit in Fig. 7.

Figure 8 shows surface roughness profiles of the sheave face before and after a durability test conducted on a pulley made of carburized, quenched

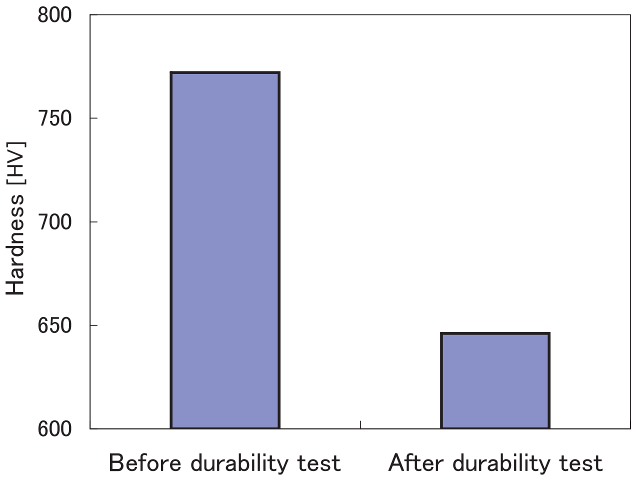

Fig. 9 Decline in sheave surface hardness after durability test

そこで，このようなシーブ面の平滑化を防止し，適切な表面テクスチャーを維持することを目的に，シーブ面の硬さ向上策について検討した．その際には過酷条件下における温度上昇の影響も考慮した．

Fig. 10に，ベースであるSCR420H浸炭焼入れ焼戻し仕様と，Cr-Mo鋼の浸炭窒化焼入れ焼戻しを実施した仕様，およびベース仕様に対してマイクロショット2)を追加した各プーリーを，さらに推定接触温度で焼戻した後の表面硬さの測定結果を示す．

Fig. 10より，マイクロショット仕様は他の仕様に対して，推定接触温度に焼戻した後も高い表面硬さを有することがわかった．さらに既存熱処理炉の流用も可能であるため，シーブ面の硬さ向上策としてマイクロショットを採用することとした．実際のプーリーの製造にあたっては，表面テクスチャーの形成と硬さの両立をはかるため，マイクロショットはシーブ面の最終仕上げ加工前に実施している．

4.3. 表面テクスチャー管理範囲の決定

過酷な運転条件下での経時変化を想定し，Fig. 11に示すシーブ面の表面テクスチャー管理範囲を設定した．すなわち，初期の表面テクスチャーをFig. 11の管理範囲内とすれば，マイクロショットの摩耗抑制効果により，たとえ微小な経時変化が生じても，Fig. 7に示したトルク容量限界，および凝着摩耗限界内の表面テクスチャーを維持可能となる．

and tempered SCR420H steel. The results after the durability test show that the surface roughness was markedly flattened and smoothed. The results in Fig. 9 also show a pronounced decline in sheave surface hardness following the durability test.

Therefore, a technique was investigated for improving sheave surface hardness with the aim of maintaining a suitable surface texture by preventing it from being flattened and smoothed by wear. The investigation also took into account the temperature rise that occurs at the contact surface under harsh operating conditions.

Test pulleys were made of three different specifications: the baseline carburized, quenched and tempered SCR420H steel, a Cr-Mo steel that was carbonitrided, quenched and tempered, and the baseline SCR420H steel that was subjected to an additional micro-shot peening process.(2) Figure 10 presents the measured surface hardness of the pulleys before and after tempering at the estimated contact temperature.

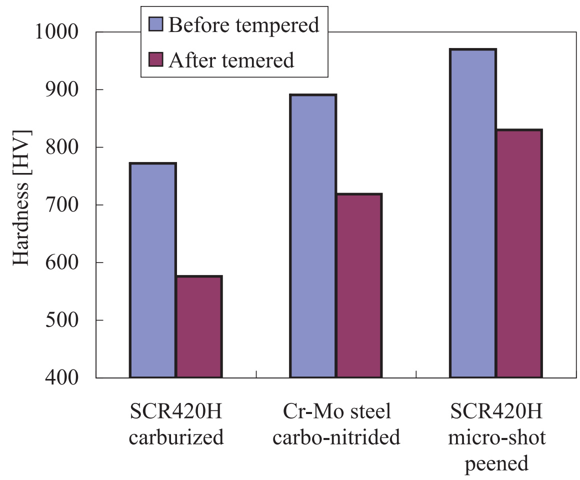

Fig. 10 Change in sheave surface hardness before and after tempering at the estimated contact temperature

The results in Fig. 10 show that the micro-shot peened pulley possessed higher surface hardness than the other two pulley specifications following tempering at the estimated contact temperature. Moreover, because this specification would also facilitate shared use of the existing heat treatment furnace, micro-shot peening was selected as the technique for improving sheave surface hardness. In the actual pulley manufacturing process, micro-shot peening is performed before the sheave face is finished machined so as to achieve both surface hardness and the formation of the surface texture.

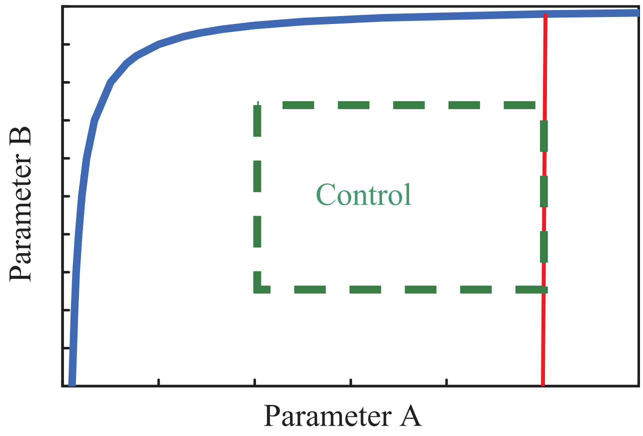

Fig. 11 Control window for optimized sheave surface texture

5. 音振性能

LuKチェーンの採用にあたり，以下に述べる加振力低減，振動伝達感度改善による対策を採用し，静粛性を確保した．

5.1. 加振力低減

加振力低減策としてチェーンピッチパターンのランダム化を採用すると共に，Fig. 12に示すように，ロッカーピンとプーリー間の接触角度の最適化により，加振力の低減を図った．

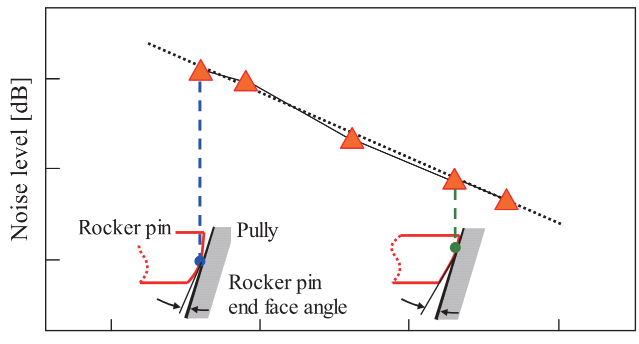

Fig. 12 Effect of rocker pin end face angle on noise level

5.2. 振動伝達感度低減

LuKチェーンのみならず，CVTチェーンの特徴は弦共振を持つことである．このため，CVTチェーンを採用するユニットはこの弦共振周波数において加振力のピークを持つため，この点に着目して振動伝達感度の低減を図った．

(1) ガイドレール形状の最適化

Fig. 13に示すように，弦共振による振動振幅低

4.3. Determination of the surface texture control window

Figure 11 shows the control window defined for the sheave surface texture based on the estimated change in the sheave face over time under harsh operating conditions. Assuming that the initial surface texture is within the control window shown in the figure, the anti-wear effect of micro-shot peening can keep the surface texture within the torque capacity limit and the adhesive wear limit shown in Fig. 7, even if tiny changes occur in the sheave face with the passage of time.

5. Noise and Vibration Performance

In connection with the adoption of the LuK chain, the measures described below were taken to secure quiet operation by reducing excitation forces and the sensitivity to vibration transmission.

5.1. Reduction of excitation forces

One measure for reducing excitation forces was to adopt a random chain pitch pattern. Another measure was to optimize the contact angle between the rocker pins and the pulley as shown in Fig. 12, which was effective in reducing excitation forces.

5.2. Reduction of sensitivity to vibration transmission

One characteristic of CVT chains, not only the LuK chain, is their sinusoidal resonance. Accordingly, CVTs that adopt a chain display a peak excitation force at the sinusoidal resonance frequency. An effort was made to reduce the sensitivity to vibration transmission by focusing on this characteristic.

(1) Optimization of guide rail shape

As shown in Fig. 13, a stiffer guide rail with an optimized shape was adopted for the purpose of reducing the vibration amplitude due to sinusoidal resonance.

(2) Separation of sinusoidal resonance frequency and CVT's natural frequencies

The case stiffness was optimized and the vibration amplitude of the vibration transmission mechanism was minimized in order to separate the sinusoidal resonance frequency of the LuK chain from the adjacent natural frequencies of the CVT.

減のため，形状を最適化した高剛性ガイドレールを採用した．

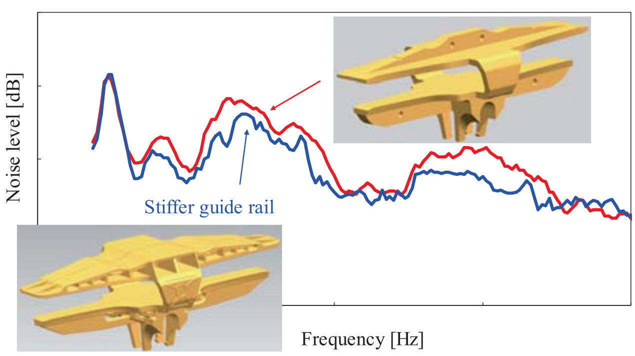

Fig. 13 Effect of guide rail stiffness on noise level

（2）弦共振周波数とユニット固有値との分散

LuKチェーン弦共振周波数とユニットの近接固有値とを分散させるため，ケース剛性の最適化を図り，伝達系での振動増幅を最小化した．

6. まとめ

新開発の大容量（エンジン）FF車用CVTであるJatco CVT8 High Torqueに対して，当社としては初めてLuKチェーンを採用し，開発目標である優れた燃費性能，小型軽量化の達成に大きく貢献することができた．

LuKチェーンの開発にあたり，相手部品であるプーリーの基本仕様はCVTベルトを使用するJatco CVT8と共用化しながら，トルク容量や音振性能の確保など，数多くの課題に対して，新たな実験手法開発も含めて意欲的に取り組むことにより，高い目標性能を得ることができた．

6. Conclusion

JATCO adopted its first-ever LuK chain for the CVT8 High Torque model, a newly developed CVT with high torque capacity for use on front-wheel-drive vehicles equipped with a large displacement engine. This LuK chain contributed substantially to the attainment of outstanding fuel economy and size and weight reductions, which were defined as the development objectives of the new CVT series.

In developing this LuK chain, vigorous efforts were made to address many different issues, including assuring the desired torque capacity and noise/vibration performance, while sharing the same basic pulley (i.e., mating parts) specifications with the CVT8 that is fitted with a steel belt. Those efforts also included the development of new experimental methods, and they made it possible to accomplish the high performance targets set for this new CVT series.

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パワートレインGPECによる課題クローズ早期化

Early Issue Resolution Through Powertrain GPEC Activities

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抄　録　「Jatco CVT8」(以下「CVT8」とする．)については，開発試作段階での量産課題の潰し込みと製造品質の確保を目的としてトランスミッションにおける量産等質化活動(Powertrain Global Production Engineering Center)(以下「パワートレインGPEC」とする.)を行い，課題の早期摘出およびその解決を行った．本稿ではその概要と適用事例を紹介する．

Summary　For the Jatco CVT8 series, JATCO established a Powertrain Global Production Engineering Center (GPEC) to ensure uniform mass production quality for this transmission by detecting and resolving mass production issues early. That was accomplished by eradicating mass production issues in the production trial carried out in the development phase and ensuring manufacturing quality. This article outlines the Powertrain GPEC and presents examples of the activities carried out.

1. はじめに

自動車業界を取り巻く環境は，国内需要の大幅な減少や急激な円高などによって，生産のグローバル化が加速度的に進んでいる．また近年では新機種の企画から量産立ち上げまでの大幅な期間短縮と高い製造品質の両立が求められている．当社においては従来国内工場で立ち上げた後，海外工場へ生産拡大するという形態を取っていたが，CVT8では最初から海外工場で直接量産を開始することとなった．そのためには開発試作段階で量産品質と同等の製造品質の造り込みをすることが必要不可欠となる．この考えは日産自動車では既に座間の「グローバル車両技術センター(Global Production Engineering Center)」(以下「GPEC」とする．)で採用されているが，当社ではCVT8の開発に合わせて，開発段階で最適な設計図面，生産工程･作業を生産と開発が一緒につくりこむ場所，および環境でもあることを前提にパワートレインGPECの活動を本格的に開始した(Fig. 1)．

1. Introduction

The environment surrounding the Japanese automotive industry is accelerating moves to globalize production owing to the marked decline in domestic vehicle demand and the sharp appreciation of the yen, among other factors. In recent years, it has also been necessary to shorten development lead time substantially from the planning of a new transmission model to the launch of mass production, while at the same time ensuring high manufacturing quality. Previously, JATCO first launched a new product at a plant in Japan and then expanded production to overseas plants later. However, mass production of the CVT8 series was initiated directly at overseas plants from the beginning. For that reason, it was necessary

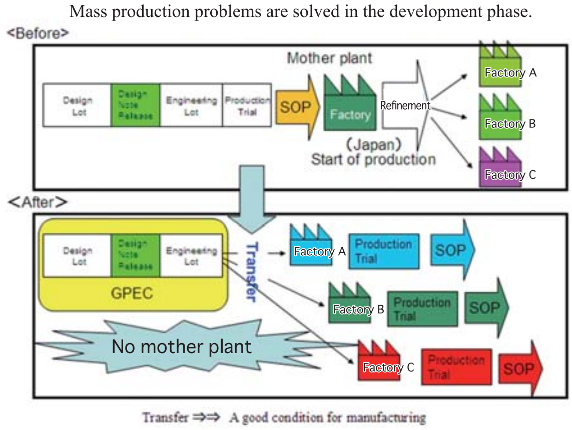

Fig. 1 Concept of Powertrain GPEC

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Prototype Manufacturing Dept.

2. パワートレインGPECの特徴

車両GPECは，生産工場のマスターマシンを配置した環境下で，デジタルプロセスで造り込んだ工程条件やデータを実際の設備，治工具，部品を使ってエンジニアリング試作のタイミングで量産性の評価の検証を行っている．

一方これと比較して，パワートレインGPECの特徴は三点ある．

一点目は実施時期で，車両ではエンジニアリング試作のプロセスの中で量産性の検証～対策立案（不具合発生の場合）～最終品質確認を行っているが，パワートレインGPECではエンジニアリング試作以前の開発試作段階から開始している点が異なる．これはユニットの場合，仕様確定するのに長期間のリードタイムが必要であり，正規手配までに製品仕様を確定させ，主たる生産課題解決を行なう必要があるからである．

二点目としては，従来は机上検討を中心に量産シミュレーションを行っていたが，例えばギヤホーニング加工条件の最適化量産シミュレーションを開発試作のモノづくりの中で実施したことが車両と異なっている点である．

それは，ユニットは部品形状だけでなく，油圧性能やギアノイズなど機能の造り込みも多いため，早期に量産図面や生産工程･作業を確定させるために，パワートレインGPECでの活動と位置づけて実施する必要があったからである．そこで，CVT8では新工法･新技術を採用したプーリーの最適な仕上げ加工条件や治工具形状決定において，量産シミュレーションを実施した．

三点目はパワートレインGPECのインフラと取り巻く環境にある．車両はNissan Integrated Manufacturing Systems（NIMS）により各工場の生産プロセス標準化を実施しているため，前述のように車両GPECに同等の設備を構えることが可能だが，ユニットは多機種生産に対応すべく設備仕様が多岐に渡り，同等のインフラ準備には多くの期間と資金が必要になる．そこで，検証すべき工程の重要因子（治工具形状･クーラント量･圧入速度等）を選定し，同等な環境を整えて検証を実施している．また必要であれば社外にその環境を求めてパワートレインGPECを実施して

to build in manufacturing quality at stage of the development phase production trial equal to that attained in mass production. This way of thinking is already being practiced at Nissan Motor Company's Global Production Engineering Center (GPEC) located at the Zama Operations Center. In conjunction with the development of the CVT8 series, we established a full-scale Powertrain GPEC that was intended to provide a workplace and an environment in which the development and manufacturing divisions could work together in creating the optimum design drawings, production processes and work procedures starting from the development stage (Fig. 1).

2. Features of Powertrain GPEC

At Nissan's Vehicle GPEC, tests are conducted at the time of the engineering phase production trial to evaluate mass producibility using actual production facilities, jigs, tools and parts. These tests are done in an environment equipped with the master machines of the vehicle production plant, which have been digitally programmed with the process conditions and related data. In contrast to this situation, our Powertrain GPEC has the following three features.

The first feature concerns the timing of the activity. At the Vehicle GPEC, mass producibility is examined in the course of carrying out the engineering phase production trial. Corrective measures are devised for any problems that occur, and the final product quality is confirmed. Our Powertrain GPEC differs in that the activity begins from the design lot phase prior to the engineering lot. One reason for that is a longer lead time is required for determining the specifications of a transmission. The product specifications must be finalized and any major production issues must be settled before the production design release.

A second feature that differs from the vehicle program is that theoretical studies for transmissions have traditionally been conducted mainly in the form of mass production simulations. For example, a mass production simulation to optimize the machining conditions of the gear honing process has been conducted in the course of building a development phase prototype. That has been done because there are many performance attributes that must be built in early, including the hydraulic pressure performance

いる点が大きな特徴である（Fig. 2）.

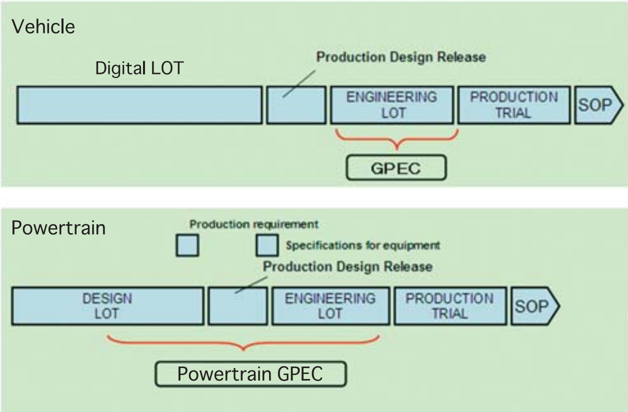

Fig. 2 Comparison of Vehicle GPEC and Powertrain GPEC

3. CVT8での取り組み

ここでは実際のCVT8で実施したパワートレインGPECの活動について記述する.

3.1. 加工検証

CVTを構成する主要部品のFixプーリーの加工において，量産同等ツールを使用したバリ残りの確認の事例を以下に示す.

Fixプーリーについては，量産ラインでの加工時の油穴回りに発生するバリ残りが，故障モードの影響解析で重大な懸念項目としてあがった．そこでバリを除去するために，実際想定されている量産工具・加工条件を徹底的に分析し，その結果，品質的に重要であると予想されたポイントを等質化マップとしてまとめた上で関連部署と合意を行いながら，等質な条件で加工ができる準備を整えて検証を行った．結果はFig. 3に示すように油穴回りの形状変形も無

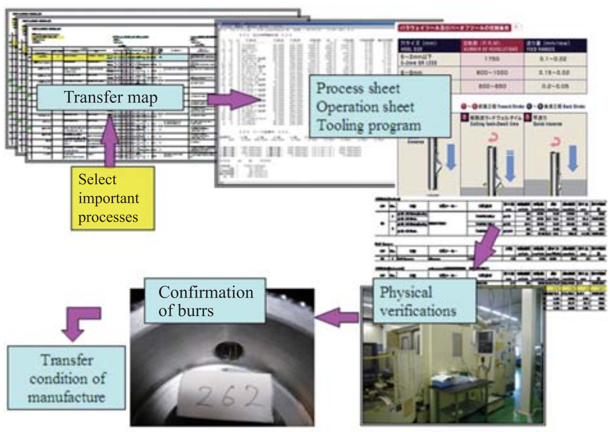

Fig. 3 Verification of machining process by reproducing actual working conditions

and gear noise performance, in addition to the shapes of the transmission parts. It was necessary to conduct those simulations as part of the activities of the Powertrain GPEC in order to finalize the mass production drawings, production processes and work procedures at the earliest possible stage. Accordingly, a mass production simulation was performed to determine the optimum finish machining conditions and jig/tool geometries for the CVT8 pulleys for which new engineering methods and technologies were adopted.

The third feature concerns the infrastructure and surrounding environment of the Powertrain GPEC. At the Vehicle GPEC, the production process in each shop is standardized according to the Nissan Integrated Manufacturing System (NIMS), making it possible to equip the center with facilities equivalent to the mass production setup as mentioned above. However, because the facility specifications needed to support production of various transmission models extend over such a wide range, it would take enormous amounts of time and capital investment to prepare the equivalent production infrastructure. Therefore, at the Powertrain GPEC we select the critical process factors that need to be examined, such as the jig/tool shapes, coolant volume, press fitting speed and so on. Those factors are then examined under an equivalent environment, and, if necessary, the Powertrain GPEC program is carried out in an environment sought outside the company. That is another major feature of the Powertrain GPEC (Fig. 2).

3. Activities Undertaken for CVT8 Series

This section describes some of the Powertrain GPEC activities actually undertaken for the CVT8 series.

3.1. Machining process verification

The example presented here concerns checking for burrs remaining on fixed pulley halves in the machining process for these principal components of a CVT. This operation is done using tools identical to those used in mass production.

Burrs sometimes remain around the fluid holes when they are machined in the fixed pulley halves on the mass production line. A simulation of the failure

く，また，バリの除去も良好な状態であった．なお，量産工場加工立ち上がり時においても，バリに起因する不具合は起きていない．

3.2. 組立検証

プーリーアセンブリーをケースに組み付ける際に使用する治具の等質化事例を以下に示す．

CVT8では，プーリーアセンブリー の専用化と他機種との共用を前提としたプーリー移載治具が必要になった．その移載治具の構造や使い易さが作業速度や安全性に大きく影響するため，開発試作の段階から実際の作業者･部品･治具･方法を等質にして，パワートレインGPECの場でそれぞれが最適なものになるように検証と改善を行った．この治具は量産工場に転写され，量産試作から採用されている．（Fig. 4）

Fig. 4 Transfer of the jig for carrying and loading pulley assemblies

3.3. 購入部品品質保証方法の等質化

購入部品においては，図面の要求値が明確になっているものの，その測定方法が不明確であったため，実際には図面スペックを満足しておらず，後工程に悪影響を及ぼした．その対応として量産サプライヤーと購入部品の品質保証等質化活動を行ったので，事例を以下に示す．

3.3.1. 寸法測定方法の等質化

サプライヤーと当社間で，測定方法の違いが原因で量産時の品質トラブルになるケースがあった（Fig. 5:寸法測定方法の違いによる面粗度の誤測定事例）．この対応策として，パワートレインGPECでは当社品質保証部門とサプライヤーが寸法特性に対して，測定方法を明確にした上で検査規格書への落としこみを実施した．

mode impact showed that burrs are a critical item of concern. Therefore, in order to eliminate burrs, a thoroughgoing analysis was made of the mass production tools and machining conditions that presumably would be used for the CVT8 series. As a result, a uniform quality map was created to show the points assumed to be critical in terms of quality. An environment was put in place for machining under identical conditions, and a verification exercise was conducted with the agreement of other related departments. The results shown in Fig. 3 revealed that no shape deformation occurred around the fluid holes and that burrs were cleanly removed. It is noteworthy that burrs did not cause any problems when machining operations were subsequently launched at the mass production plants.

3.2. Assembly process verification

This section presents an example of the uniform quality achieved for the jig used when the pulley assembly is installed in the transmission case. A jig capable of carrying multiple pulley assemblies at one time was needed based on the assumption of dedicated pulley assemblies for the CVT8 that would be shared with another CVT model. It was assumed that the structure of the jig and its ease of use would greatly influence the work speed and safety. Therefore, verification exercises were conducted at the Powertrain GPEC beginning from the development phase production trial. This involved participation by actual line workers using parts, jigs, tools and methods identical to those employed in mass production operations. Improvements were repeatedly made until each element was optimized. The same jig was then transferred to the mass production plants and put in use from the mass production trial (Fig. 4).

3.3. Implementing uniform quality assurance methods for purchased parts

Although the values required of purchased parts were clearly indicated on the design drawings, the methods to be used in measuring the values were not specified. Consequently, there were parts that did not actually meet the specifications and adversely affected downstream operations. To address this situation, an activity was undertaken with the

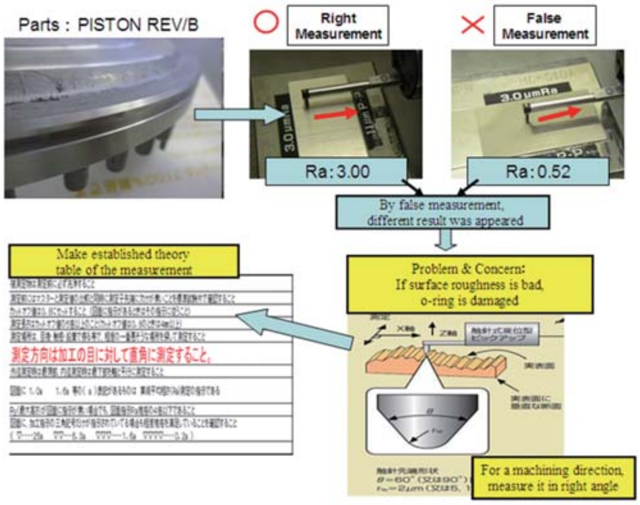

Fig. 5 Example of incorrect measurement for purchased parts and establishment of a table of standard measurement methods

3.3.2. 夾雑物測定方法の等質化

夾雑物測定は夾雑物の量を測定する検査であるが，やり方や使用する機材で結果が左右される．事前調査の結果，CVT8のサプライヤー数社は独自の方法で夾雑物測定を実施しており，双方が違うやり方で測定していることが明確になった．

このため，夾雑物管理の重要性説明を含むサプライヤー夾雑物測定指導会を実施し，同じやり方・機材で測定を行うことを双方合意し，夾雑物測定の等質化を図った．

この結果，量産試作では検査方法の違いによる不具合の発生を抑制することができた（Fig. 6）．

Fig. 6 Instructing workers in contamination measurement

suppliers of mass-produced parts to implement uniform quality assurance methods. Examples of this activity are explained below.

3.3.1. Uniform methods of measuring dimensions

There were cases of quality troubles during mass production that were caused because the measurement methods being used differed between some of our suppliers and JATCO. For instance, Fig. 5 shows an example of incorrect measurement of surface roughness due to the use of different methods to measure part dimensions. As a measure for resolving this problem, suppliers and JATCO's quality assurance division clearly defined the methods to be used for measuring dimensions and characteristics at the Powertrain GPEC, and those methods were then incorporated into the inspection standard documents.

3.3.2. Uniform method of measuring contamination

The inspection for contamination involves measuring the quantity of foreign matter present, but the measured results are greatly influenced by the measurement method and equipment used. The results of a preliminary survey revealed that several suppliers were applying their own methods to measure contamination, which made it clear that those suppliers and JATCO were using different procedures.

A workshop was therefore held to instruct suppliers in contamination measurement procedures, including explanations of the critical importance of controlling contamination (Fig. 6). A mutual agreement was reached to measure contamination using the same method and equipment, resulting in the adoption of a uniform method of measuring contamination.

As a result, no problems due to differences in inspection methods occurred in the mass production trial.

3.4. Early creation of a standard operations manual

Previously, we began creating a standard operations manual during the mass production trial after the production line had been completed. Consequently, problems in work procedures were not identified until later because of the delay in finalizing the details of how operations should be performed. In order to solve that problem, it was essential to advance the timing for creating a standard operations manual.

3.4. 標準作業書作成の早期化

従来，標準作業書は生産ラインが完成する量産試作から作成を開始していた．このため，作業手順詳細の確定が遅くなる事により作業上の問題点抽出が後手に回っていた．この問題を解消するためには標準作業書の作成時期の早期化が不可欠である．そのため，CVT8では開発試作の早い段階で標準作業書を完成させ，その標準作業書を使いながら実際の作業者が手順通りの作業を行って，カン･コツ作業になると思われる事項を洗い出すようにした．これにより，品質を維持するための作業上の重点ポイント（急所）を早い段階で標準作業書へ落とし込め，量産開始当初から拠点作業者教育に活かすことができた（Fig. 7）．

Fig. 7 Checking the standard operations manual

3.5. 人材育成

当社には人材育成の仕組みとして技能塾やグローバルトレーニングセンター（以下「GTC」とする．）がある．そこで，より効果的に海外拠点製造部署のトレーナーを育成するために，CVT8ではパワートレインGPECとGTCの融合を行った．具体的にはパワートレインGPECの検証インフラ（組立ラインなど）を活用して作業に必要な技能把握，作業指導のトレーニングを行い，現地に生産ラインが完成する前に要員育成技量のスキルアップが図れて，量産開始段階から高い品質レベルを維持することに繋げることができた．現在，組立工程に関しては，パワートレインGPECと同等のミニラインを各拠点に設置し，新規要員の作業習熟に活用することを計画している．

Therefore, a standard operations manual for the CVT8 series was completed at an early point in the development phase production trial. Actual line workers used the standard operations manual in carrying out their jobs according to the specified procedures, and work details were identified that presumably would require intuition or a special knack. As a result, the critical points of work operations for maintaining quality were incorporated into the standard operations manual early on. That information was then used effectively in training the assembly plant workers from the outset of mass production (Fig. 7).

3.5. Employee training

JATCO's employee training programs are conducted at the Ginou Juku (Technical Skills School) and the Global Training Center (GTC). For the CVT8 series, the activities of the Powertrain GPEC and the GTC were merged in order to develop the trainers of the manufacturing departments at the overseas plants more effectively. Specifically, the verification infrastructure (assembly line, etc.) at the Powertrain GPEC was used to identify the skills needed for the assembly jobs and to conduct training courses for the trainers of assembly operations. That was done to improve the teaching skills of the trainers prior to the completion of the production line at the overseas plants. It was effective in enabling the overseas plants to maintain high quality levels from the launch of mass production. Currently, it is planned to build a mini-production line equal to that of the Powertrain GPEC at each overseas plant and to use it in thoroughly training new employees in the standard work procedures of the assembly processes.

4. Activity Results

The objective of the Powerplant GPEC's activities is to detect issues at the time mass production is launched and to resolve them quickly. In Fig. 8, the achievement index of the vertical axis for results is the issue resolution rate, which indicates the percentage of detected issues that are settled successfully. The index of the horizontal axis for causes is the uniform quality rate, which is the condition supporting issue resolution and early

4. 活動の成果

パワートレインGPECの活動目的は『量産立ち上がり時における課題の早期摘出，早期解決』であり，結果系の成果指標としては，摘出された課題に対しての“課題クローズ率”（Fig. 8）としている．また，要因系の指標としては，課題の解決，および早期解決を支える条件である“等質化率”とし，CVT8では98％の等質化率とすることができた．

これらにより，当初の狙い通り課題登録（数）の前倒しができた（Fig. 9）．全てがパワートレインGPEC諸活動の成果とは言えないものの，その寄与度は大きく，実に約80％以上の課題が正規手配前に摘出された．

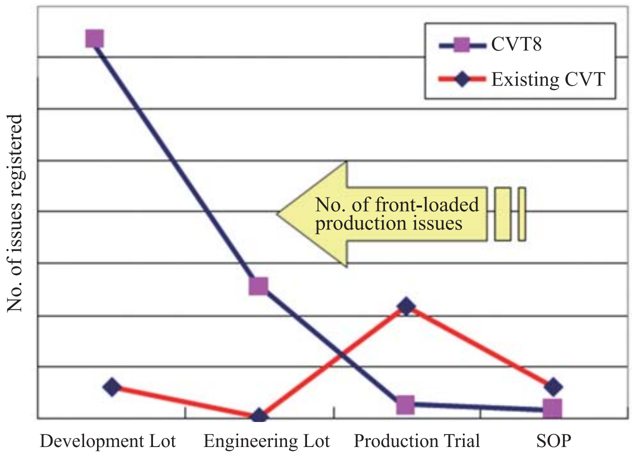

Fig. 9 Number of production issues registered for CVT8

5. まとめ

今回，CVT8の開発，生産準備においてパワートレインGPECを適用した成果として，各製造工程の重点ポイントの等質化率を98％まで高め，その結果として課題の早期摘出を行い，課題クローズ率を量産試作時には100％とすることができた．この結果はパワートレインGPECを始めとするサイマル活動の総合的な成果であり，当社の生産技術力の結集でもある．

今後も多数の海外立ち上げのプロジェクトが計画されており，パワートレインGPECとその諸活動との相乗効果を更に大きくするため，検証の質向上をすでに進めている．具体的には人間工学に基づいた作業性の確認や，新興国をにらんだ素人的な作業視点での確認などである．

problem solving. A uniform quality rate of 98% was achieved for the CVT8 series.

As a result of these activities, many registered issues were solved in advance as was originally intended (Fig. 9). While that was not due entirely to the various activities of the Powertrain GPEC, its contribution was significant. Indeed, approximately 80% of the issues were detected before the production design release.

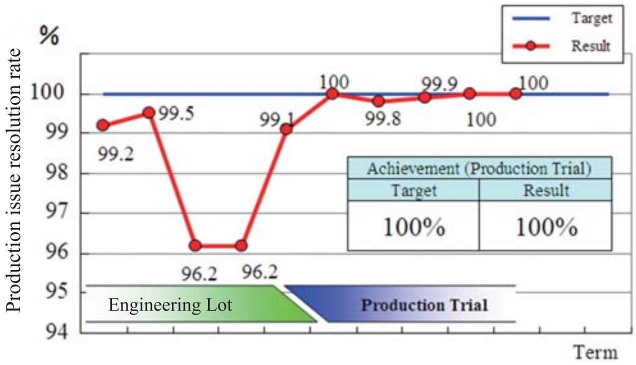

Fig. 8 Improvement of production issue resolution rate for CVT8

5. Conclusion

This article has described the role of the Powertrain GPEC in the development of the new CVT8 series and the production launch preparations. The uniform quality rate with regard to the critical points in each manufacturing process was raised to a high level of 98%. As a result, issues were identified early and an issue resolution rate of 100% was attained at the time of the mass production trial. That result stemmed from the comprehensive simultaneous engineering activities that were carried out, including the activities of the Powertrain GPEC.

Many production launch projects are scheduled to be carried out at the overseas plants in the coming years. In order to further expand the synergies obtained through the various activities of the Powertrain GPEC, efforts are already under way to improve the quality of the verification process. Specifically, the ease of work procedures is being verified on the basis of ergonomic principles, and work operations are being confirmed from the perspective of inexperienced workers particularly in emerging markets.

We intend to continue to improve the Powertrain GPEC program by enhancing the quality of the

これからも検証の質向上や検証領域の拡大を行い，様々な生産環境の変化に追従できる活動となるように，本活動を充実させていく．

verification process and expanding the range of verification work so that the program can be adapted to diverse changes in the manufacturing environment.

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暗騒音下での放射音測定手法

A Method for Measuring Sound Below the Background Noise Level

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抄　録　従来放射音測定が困難であった暗騒音の影響の大きな生産ラインにおいて，測定室，遮音壁等の設備対応なしにCVTから発生する微小なノイズを測定する手法を開発したので，その手法とJatco CVT8（以下「CVT8」とする．）への適用事例について紹介する．

Summary　This article describes the development of a method for measuring tiny noises radiated from a CVT without requiring any measurement room, sound insulation wall or other special facilities. This method can be used on the production line where the large effect of background noise has traditionally made it difficult to measure radiation noise. The application of this method to the chain noise produced by the Jatco CVT8 High Torque (CVT8HT) model is also described.

1. はじめに

燃費・コスト・強度の更なる向上を目的に，新機種であるCVT8には，Luk製チェーンベルトを採用する事となった．開発が進む中で，チェーンベルトとプーリーの噛み合い時に発生するノイズ（以下「チェーンノイズ」とする．）が技術課題として挙げられた．

そこで，CVT8のチェーンノイズを保証するため，生産ラインにおける放射音の測定が必要と判断し，本手法の開発に取り組んだ．

2. 放射音測定手法の課題

CVTから発生する放射音を正確に測定するには，周囲から発生する音（以下「暗騒音」とする．）に対し，検出する音のレベルが6dB以上大きい事が必要である．今回検出対象となるチェーンノイズ（周波数1200Hz以上の領域）において，生産ラインの暗騒音とチェーンノイズのレベルを比較したところ，生産ラインの暗騒音の方が3dB高い結果となった．（Fig. 1）

この環境下でチェーンノイズを正確に測定するには，約9dB以上の暗騒音の低減，あるいは，放射音計測結果から暗騒音の除去が必要となる．

従来は，前者の暗騒音低減を対策手段として，工場内に外部から隔離した部屋を設置し，この中

1. Introduction

A LuK chain was adopted for the new CVT8HT model for the purpose of improving fuel economy, reducing costs and increasing the strength of the transmission. As the development work proceeded, the noise produced when the chain was squeezed by the pulleys, referred to here as chain noise, was identified as a technical issue that had to be addressed.

In order to ensure that the chain noise of the CVT8HT was at an acceptable level, it was deemed necessary to measure this radiation noise on the production line. To accomplish that, we set out to develop the noise measurement method described here.

2. Issues in Radiation Noise Measurement Method

In order to measure the noise radiated from a CVT accurately, the noise level to be detected must be at least 6 dB larger than the background noise. The chain noise to be detected in the frequency region of 1200 Hz or higher was compared with the background noise from the production line. It was found that the background noise of the production line was 3 dB higher than the chain noise (Fig. 1).

In order to measure the chain noise accurately in this environment, it would be necessary to reduce the

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で放射音測定を行うのが常套手段であった．しかしながら，この対策には，新たな防音室を設置するためのスペースや設備投資が発生する事より，後者の放射音計測結果から暗騒音の排除を可能とする測定手法の開発を最優先課題として取り組んだ．

3. 計測手法の考え方

基本的な考え方は，ガウスの定理（ガウスの発散定理）に基づいており，この考えに基づくと音響インテンシティー・マイクロホンが配置された仮想球体内部より，発音する音響パワーのみを算出する事ができ，仮想球体外部にて発生し，仮想球体を通過する音響パワーは計算上相殺する事が出来る．（Fig. 2）

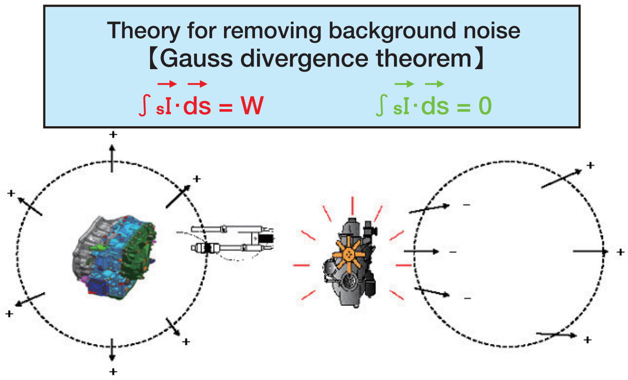
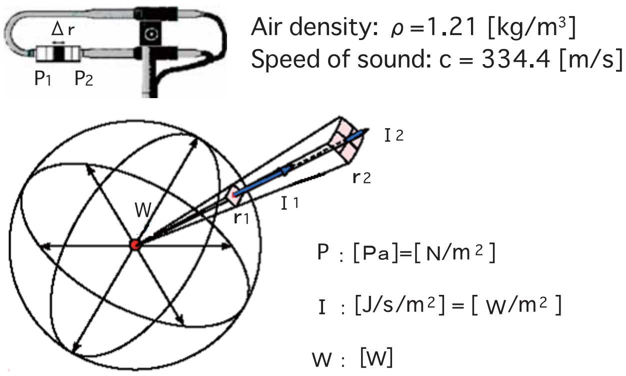


Fig. 2 Concept of measurement method

音響パワーの計算式を以下に示す．



Sound pressure average: $P = \dfrac{P1+P2}{2}$

Particle velocity: $\nu = \dfrac{1}{\rho}\displaystyle\int \dfrac{P1-P2}{2}\,dt$

Sound intensity: $I = \overline{\dfrac{P1+P2}{2\rho\,\Delta r}\displaystyle\int (P1-P2)\,dt}$

Sound power level: $W = I \cdot 4\pi r^2 = \dfrac{P^2}{\rho c}$

background noise by about 9 dB or to remove the background noise from the measured radiation noise results.

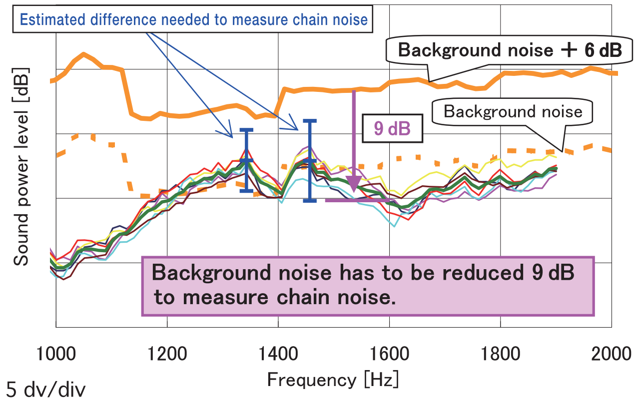


Fig. 1 Comparison of measured chain noise and background noise levels

Previously, the usual approach to reducing the influence of background noise was to build a special room isolated from the surrounding environment at a plant. Radiation noise measurements were generally made in such a room. However, that approach requires capital investment in equipment and space for newly constructing such a soundproof room. Therefore, the first priority was put on developing a measurement method capable of removing background noise from the measured radiation noise results, and a project was undertaken to develop the necessary technology.

3. Concept of Measurement Method

The fundamental concept of the method is based on the Gauss divergence theorem. Applying this concept makes it possible to calculate only the sound power output from a virtual sphere on which sound intensity microphones are positioned. Sound power that is produced outside the virtual sphere and passes through it can be cancelled out in the calculation (Fig. 2).

The equation for calculating sound power is shown below.

4. Application to Production Line

4.1. Configuration of measurement system

Using a larger number of microphones is advantageous for removing background noise, but it was decided that four microphones were the

4. 生産ラインへの適用

4.1. 計測システム構成

マイクロホンの数は，多い方がより暗騒音の除去に有利であるが，ラインレイアウトと音響パワー計測時の検討結果より，必要最低本数として4本を選択し，対角上に配置する事とした．（Fig. 3）

4.2. 事前トライアル

4.2.1. 測定機器の妥当性確認

今回，ジヤトコ初のB&K製の音響インテンシティー・マイクロホンと分析ソフトを使用するため，機器の妥当性確認を実施した．測定機器以外の影響を排除するため，暗騒音の影響のない当社のマスターベンチとなる無響ベンチにて，その測定機器と生産ライン測定機器による同時データ測定を実施し，各々の結果を各々の分析ソフトで測定し，そのデータを比較した．その結果，両者のデータは非常に良く一致し，生産ライン測定機材の妥当性を確認する事が出来た．（Fig. 4）

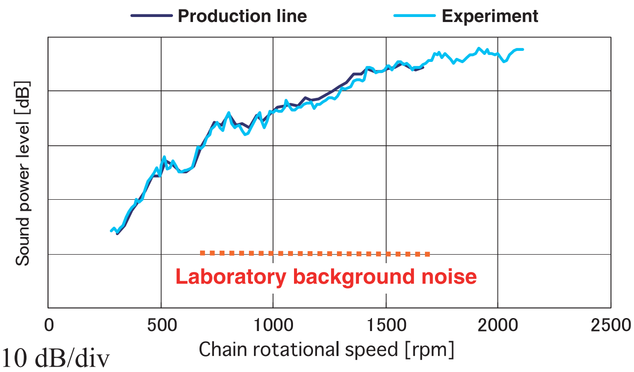


Fig. 4 Comparison of background noise levels

4.2.1. 暗騒音低減効果の確認

測定機材を生産ラインに取り付け，周りの設備の稼動／非稼動時の暗騒音を測定し比較したところ，推定していた通り音響インテンシティーの4点測定結果から計算された音響パワーレベルは，周りの設備稼働状況≒暗騒音の影響を受けない事が確認出来た．（Fig. 5）

一方，CVT直上に配置した1本マイクの同時測定結果（音圧レベル）を見ると，周りの設備の稼動によって大幅にレベルが上昇している事が解る．

minimum necessary number in this study. That decision was based on the results of a study that examined the line layout and measured sound power. The four microphones are arranged diagonally as shown in Fig. 3.

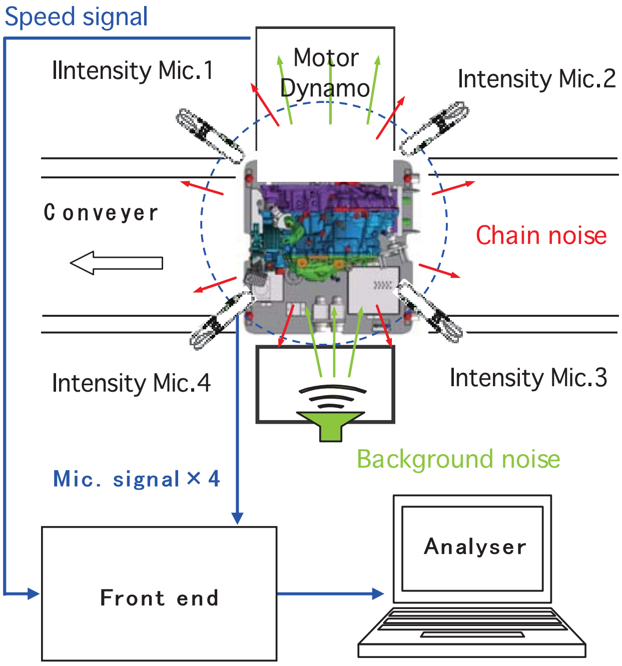


Fig. 3 Configuration of measurement system

4.2. Preliminary trial

4.2.1. Confirmation of suitability of measurement equipment

As this was the first time for JATCO to use sound intensity microphones and analysis software made by Bruel & Kjaer (B&K), a preliminary trial was conducted to confirm the suitability of the equipment. JATCO's master anechoic test bench, which is not affected by background noise, was used to eliminate any influence other than the measurement equipment. Simultaneous measurements were made using B&K's measurement equipment and the measurement devices incorporated in the production line. The data measured with each measurement system were analyzed using a separate analyzer and the results were compared. It was found that both sets of measured data agreed very well, which confirmed the validity of the measurement equipment incorporated in the production line (Fig. 4).

4.2.1. Confirmation of the background noise reduction effect

The measurement equipment was installed on the

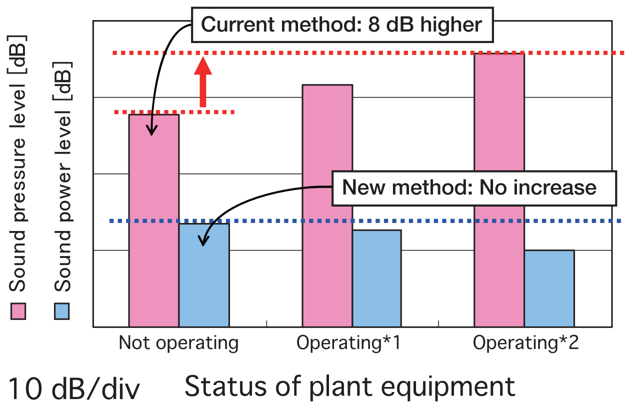


Fig. 5 Sound power level with/without equipment operation

4.3. 生産ラインへの適用結果

生産ラインのファイナルテスターに今回開発した放射音測手法を適用し，同じユニットのチェーンノイズの放射音をマスターベンチである無響ベンチ（暗騒音なし）と生産ライン稼動中のファイナルテスター（暗騒音大）にて測定した結果，放射音が問題となる高周波領域で，両者のデータが非常に良く一致する事を確認出来た．（Fig. 6）

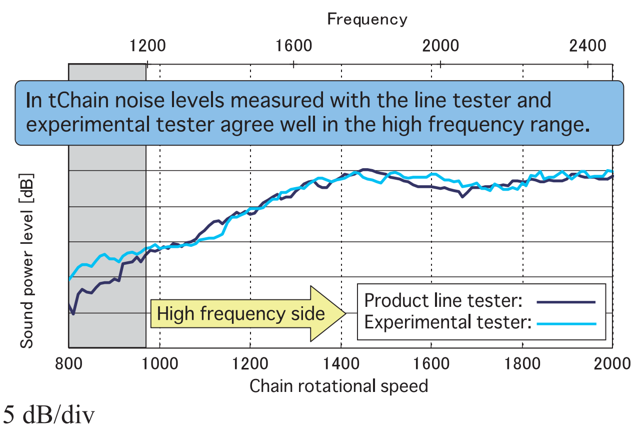


Fig. 6 Comparison of measured chain noise levels

5. まとめ

本放射音測定手法の開発により，暗騒音の大きな環境化での放射音の評価を可能とする事が出来た．

その適用例として，暗騒音の大きな生産ラインのファイナルテスターにおいてCVT8の技術課題として取り上げられたチェーンノイズの評価を可能とする事が出来た．

今後，生産ラインで放射音管理が必要なノイズ課

production line, and the background noise was measured and compared when the surrounding facilities were operating and when they were shut down. The sound power level was calculated from the results measured at four points with the sound intensity microphones. As expected, it was confirmed that the calculated sound power level was not affected by the background noise, which was approximately equivalent to the condition when the surrounding facilities were operating (Fig. 5).

The sound pressure level was simultaneously measured with one microphone positioned directly above the CVT. An examination of the results indicated that the sound pressure rose markedly owing to the operation of the surrounding production facilities.

4.3. Results of application to production line

The radiation noise measurement method developed in this project was implemented in the final tester of the production line. The chain noise radiated from the same CVT was measured using the master anechoic test bench (no background noise) and at the final tester (large background noise) while the line was operating. The results confirmed that both sets of data agreed very well in the frequency region where background noise is a problem (Fig. 6).

5. Conclusion

The development of the radiation noise measurement method described here makes it possible to evaluate radiation noise in an environment with large background noise. As an example of its application, this article described the evaluation of the chain noise of the CVT8HT, which this method made possible. Chain noise was a technical issue of this unit, and the newly developed method was used in the final tester stage on the production line where there is large background noise.

In future work, we intend to further develop and apply this method to noise issues involving orders, frequencies and other characteristics that differ from those of chain noise. This will anticipate situations that arise on the production line concerning noise issues requiring the control of radiation noise.

In preparation for full-scale use on the production

題が発生した場合を想定し，チェーンノイズと異なる現象（次数／周波数／等違い）についても適用開発を進めて行きたい．

また，生産ラインの本格運用に備え，ライン適用時の課題の抽出とその改善方法についても合わせて検討を進めていく．

line, it is also planned to identify issues that might arise when applying this method to the line and to investigate related improvement measures.

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CVTケース粗材への薄肉化技術の適用

Application of Wall Thickness Reduction Technology to CVT Case Casting

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Masashi OKUDA

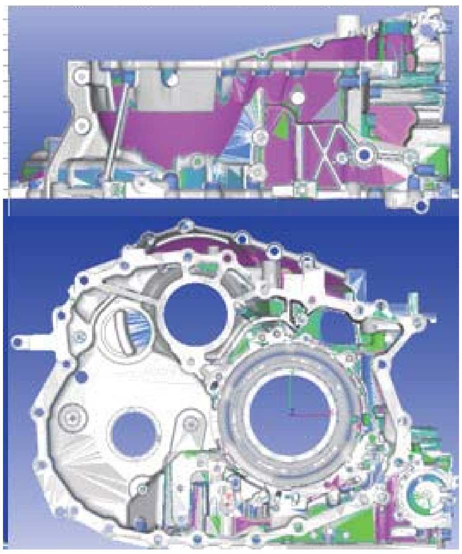
抄　録　自動車業界において省燃費化は，最も重要な課題のひとつとして様々な技術開発が進められ，新技術が投入されている．粗形材分野の視点で，省燃費に貢献すべく，肉厚の薄肉化による軽量化技術を最新のJatco CVT8（以下「CVT8」とする．）に適用したので，その事例を紹介する．

Summary　Various new technologies are being developed and implemented for improving vehicle fuel economy, which is one of the most critical issues in the automotive industry. In this regard, reducing the wall thickness of the thick sections of casting/forgings can contribute to substantial fuel economy gains. This article describes the application of a weight-saving technology for reducing the wall thickness of the case of the Jatco CVT8, the company's latest CVT series.

1. はじめに

今回薄肉化に取り組んだCVT8のケース粗材は，ユニットとして必要な剛性を確保するリブ形状や厚肉形状を除いた一般肉厚部と呼ばれる部位を，従来の3.0mmから2.3mmに薄くする事で，ユニットの軽量化，および材料費低減によるコスト削減を図ることを狙った．Fig. 1に薄肉部の詳細部位を示す．

CVT8では剛性，音振性能といった機能上必要な部位を除き，その肉厚を2.3mmとした．



▪▪▪ Area targeted for wall thickness reduction

Fig. 1 Area of reduced wall thickness of the CVT8 case

1. Introduction

This project was undertaken to reduce the wall thickness of the CVT8 case casting. The aims were to lighten the unit weight and to lower the material cost by reducing the wall thickness of general thick sections from the previous dimension of 3.0 mm to 2.3 mm. This would exclude the rib shapes and thick sections needed to secure the stiffness of the unit.

Figure 1 shows the details of the sections where the wall thickness was reduced. For the CVT8, the wall thickness of the case was set at 2.3 mm, excluding the sections where thicker walls were needed to secure the desired stiffness and noise and vibration performance.

2. Preliminary Study

The most effective way to reduce the wall thickness of the case casting is to shorten the die fill time of the molten aluminum material. A study was undertaken aimed at minimizing the fill time for case, as this was identified as one of the top priority issues for the CVT8.

The relationship between the wall thickness of the casting and the time needed for the molten aluminum to solidify is shown in Eq. (1) below.

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2. 事前検討

ケース粗材に薄肉化を適応するために最も効果的なのは，金型への材料，すなわち溶解したアルミの充填時間を短縮することである．

CVT8でも充填時間を最小にすることを，最重要項目に掲げ検討に着手した．

鋳造粗材の肉厚とアルミが凝固するのにかかる時間と肉厚との関係は，式(1)で示される．

凝固時間[msec] =0.017×肉厚[mm^2] ×70%　(1)

上記式(1)による計算の結果，今回適応する肉厚2.3mmでは，金型に充填させたアルミは62.9 msec後には凝固してしまうことになる．鋳造は溶けた材料(今回はアルミ)が凝固してしまう前に金型内に充填を完了させる必要があるため，

充填時間≦凝固時間　(2)

であることが前提となる．したがって，今回の場合は62.9msec以下の時間でアルミを金型内に充填完了させる必要がある．ちなみに従来の肉厚3.0mmの場合は100msecであり，今回の薄肉化により凝固時間を，37%以上短縮させる必要がある．

その対応として金型に鋳込む速度(射出速度)を高速化する事を検討した．充填時間と金型に充填するアルミの体積から必要な高速速度を算出した結果，射出速度は5m/sとなった．Fig. 2に既量産部品と今回薄肉を採用しているCVT8の高速条件を比較した結果を示す．

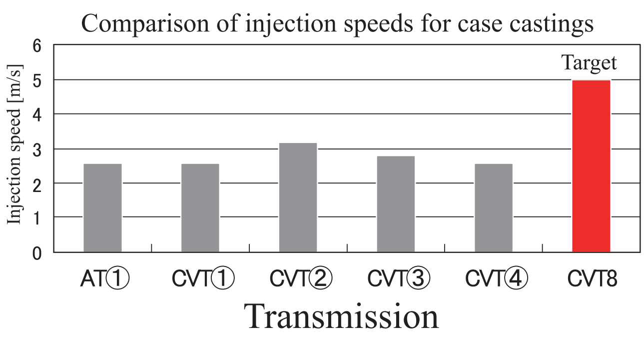

Fig. 2 Comparison of injection speeds

Solidification time [msec] = 0.17 × wall thickness [mm^2] × 70%　(1)

According to the time calculated with Eq. (1), with a wall thickness of 2.3 mm for the CVT8 case, the molten aluminum would solidify in 62.9 msec after being poured into the die. In the casting process, the operation of filling the die with molten aluminum must be completed before the material solidifies. The necessary condition for that is:

Fill time ≦solidification time　(2)

For the CVT8 case, this meant that the molten aluminum had to fill the die in less than 62.9 msec. By comparison, the time for the previous case with a wall thickness of 0.3 mm was 100 msec. In other words, the solidification time had to be shortened by at least 37% to facilitate the reduction of the wall thickness.

To accomplish that, the possibility of increasing the injection speed of the material into the die was investigated. The required increase in the injection speed was calculated from the fill time and the volume of molten aluminum to be filled in the die. The results showed a higher injection speed of 5 m/s was needed. Figure 2 compares the higher injection speed required for the CVT8 case due to the reduced wall thickness with the speed for existing cases already in mass production. A high injection speed of 5 m/s represents an extremely fast condition for which we had no previous experience in the mass production of transmission cases. Accordingly, it was necessary to confirm the following issues:

- Is an injection speed of 5 m/s actually possible in mass production?
- Impact on the die, such as an increase in die damage

3. Confirmation of Feasibility

First, this section describes the performance results confirmed for the die casting machine. Production of the CVT8 case was scheduled to be launched simultaneously in Japan and at Jatco Mexico (JMEX). Because cases would be cast at both locations, it was necessary to confirm the material injection

高速5m/sという値は，今まで生産した事の無い非常に高速な条件になるため，

・射出速度5m/sという値は量産可能な値なのか？
・金型へ影響（型故障の増加）

のそれぞれの課題として確認する事とした．

3. 成立性の確認

まずは鋳造機の性能を確認した結果を以下に示す．CVT8ケースは日本とJatco Mexico S.A.de C.V（以下「JMEX」とする．）の同時立ち上げとなる部品であり，それぞれの拠点で鋳造するため，両方の鋳造機の射出性能を確認する必要がある．そこで，それぞれの鋳造機のP-Q2線図による机上検討を実施した．Fig. 3が確認した結果である．

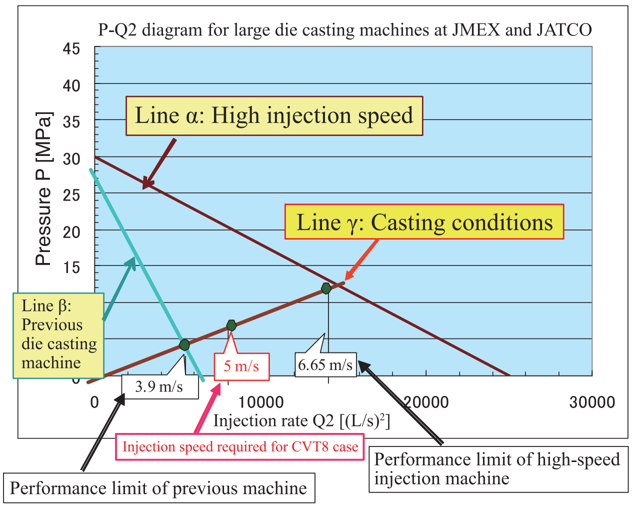

Fig. 3 P-Q2 diagram

ラインαがJMEXにて生産予定の鋳造機の性能線である．ラインβが日本の鋳造機である．ラインγが鋳造条件により決まる線であり（射出チップ径と金型のゲート断面積により決定される），ラインαとラインγまたはラインβとラインγが交差するポイントがそれぞれの鋳造機の実現可能な高速性能の限界値となる．これらを確認した結果，ラインαでは最高速6.65m/sまで実現可能であるが，ラインβでは3.9m/sとなっており日本の設備では5.0m/sという速度は実現不可能という結果となった．今回選定した設備は30年以上前に導入した設備であり射出の性能が薄肉化には対応できないことがわかった．

そこで日本の設備は新型射出への入替えを実施することで対応した．射出交換によりJMEXに設置

performance of each plant's die casting machine. Therefore, the performance of each die casting machine was examined on the basis of its P-Q2 diagram. The results confirmed are shown in Fig. 3.

Line α indicates the performance of the die casting machine scheduled to be used in producing cases at JMEX and Line β is for the die casting machine used in Japan. Line γ is determined by the casting conditions, i.e., the diameter of the injection nozzle and the cross-sectional area of the die gates. The points where Line α and Line γ intersect and Line β and Line γ intersect indicate the limit of the injection speed that is actually possible with each die casting machine. The results confirmed that the fastest injection speed achievable with JMEX's die casting machine was 6.65 m/s, while that of the die casting machine in Japan was 3.9 m/s. This indicated that an injection speed of 5.0 m/s was impossible with JATCO's die casting machine in Japan. The die casting machine in Japan that was examined in this study was installed more than 30 years ago. The results revealed that the desired reduction in wall thickness could not be achieved with this die casting machine.

Therefore, a new die casting machine was installed in Japan to support the wall thickness reduction. The old machine was replaced with one having the same specifications as JMEX's die casting machine. The peak injection speed was thus improved to the same level as that of the machine installed at JMEX. Moreover, the newly installed die casting machine allows multi-level control of the injection speed, instead of just two-level control between low and high injection speeds.

Next, we will explain the results of a study that examined potential damage to the die due to the higher injection speed. When the injection speed is increased, the gates that force the molten aluminum inside the die are the parts that are most susceptible to damage. In the die casting process, the cross-sectional area of the gates is reduced at high speed to inject the molten aluminum into the die so as to fill the far recesses of the cavity.

For that reason, the flow speed of the molten aluminum increases the most near the gates, which is why the most severe die wear is said to occur in that vicinity. The flow rate of the molten aluminum through the gates is generally referred to as the gate

されている設備と同一仕様となり，高速のピーク性能がJMEX同等までに向上する．また射出制御も低速･高速の2速切替であったものから多段速制御対応な設備を導入した．

次に金型へのダメージの検証を実施した結果を説明する．射出速度を上げた場合，最も金型へのダメージを受けるのはゲートと呼ばれるアルミを金型内部に充填させる入り口となる部位である．ダイカストでは溶けたアルミを金型に充填する際にゲート部分で断面積を急速に減少させアルミを噴射させることで，より遠方までアルミを充填させる．

そのためゲート付近が最もアルミの流入速度が上がることになり，それゆえ金型の損耗が最も激しいのがゲート付近ということになる．

このゲートでのアルミの通過速度を一般に『ゲート通過速度』といい，湯周りとゲート前の金型の耐久性を両立する値に設定する必要がある．

このゲート通過速度は，射出速度とゲート断面積，射出チップ断面積とからなる以下の関係式で表される．

ゲート通過速度［m/s］＝射出速度［m/s］/ゲート断面積［m^2］×射出チップ断面積［m^2］　　(3)

式(3)により算出された既量産部品のゲート通過速度を比較した結果をFig. 4に示す．

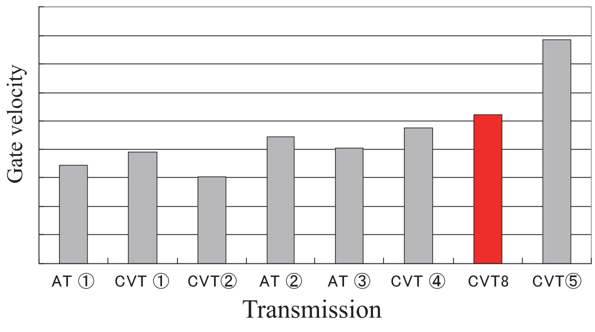

Fig. 4 Comparison of gate velocities

今回のCVT8ではゲート断面積を極力大きく設定する事で量産実績値と同じレベルにすることができた．

なお，最もゲート通過速度の高いCVT⑤に関しては実際もゲート前の金型の損耗が激しく，金型のメンテナンスに多くの時間を費やしている．

velocity. It is necessary to design the gate velocity so as to avoid misrun defects while at the same time ensuring die durability ahead of the gates. The gate velocity can be expressed by the following relational equation consisting of the injection speed, gate cross-sectional area and the injection nozzle diameter.

gate velocity [m/s] = injection speed [m/s]/gate cross-sectional area [m^2] × injection nozzle diameter [m^2] (3)

The gate velocity calculated with Eq. (3) for the CVT8 case is shown in Fig. 4 in comparison with the velocities for other transmission cases already in mass production.

For the CVT8 case, the gate cross-sectional area was designed as large as possible so as to obtain a gate velocity comparable to that of other mass-produced cases.

It should be noted that severe die wear actually occurs ahead of the gates in the dies used for the CVT5 case that has the highest gate velocity, and considerable time is spent on die maintenance.

4. Results of Confirmation Trial of New Casting Machine

A mass production trial was conducted using the newly installed die casting machine. The results showed that an injection speed of 5 m/s was achieved as was expected from the theoretical study. However, a defect called a cold shut that is caused by improper filling of the molten aluminum was found in a reduced wall thickness section near the top surface of the case (Fig. 5).

The cold shut that occurred in the reduced wall thickness section near the top surface was located near the gate through which molten aluminum flows into the die. It was found that molten aluminum filled the areas farthest from the gate without any problem at all. Those locations are at the greatest disadvantage for filling with aluminum and are generally places of concern for that reason. Therefore, it was decided to reexamine the flow simulation results in order to confirm the flow of molten aluminum into those areas.

Injection generally takes place at a slow speed until

4. 実機確認結果

新に導入した鋳造機により量産トライアルを実施した結果，射出速度は机上検討結果の通り5m/sを実現できた．しかし，トップ面の薄肉部位に湯境というアルミの充填不足に起因する欠陥が確認された．（Fig. 5）

湯境が発生したトップ面の薄肉部位はアルミを金型に入れるゲート部近傍であり，一般的に懸念されるゲートから最も遠い部位，すなわちアルミを充填させるために最も不利な部位には全く問題無く充填していることが確認された．

そこで，該当部への湯流れを確認するため湯流れ解析結果を再検証することとした．

一般的には射出の動作はゲート直前までは低速で動作させ，ゲート付近で高速に切りかえる．これにより，アルミが金型に入る前に空気を巻き込んで巣穴不良となることを最小限にしている．

今回確認した結果，射出が高速に切り替わる前にアルミがゲート近傍の薄肉部位に充填を始めることがわかった．（Fig. 6）

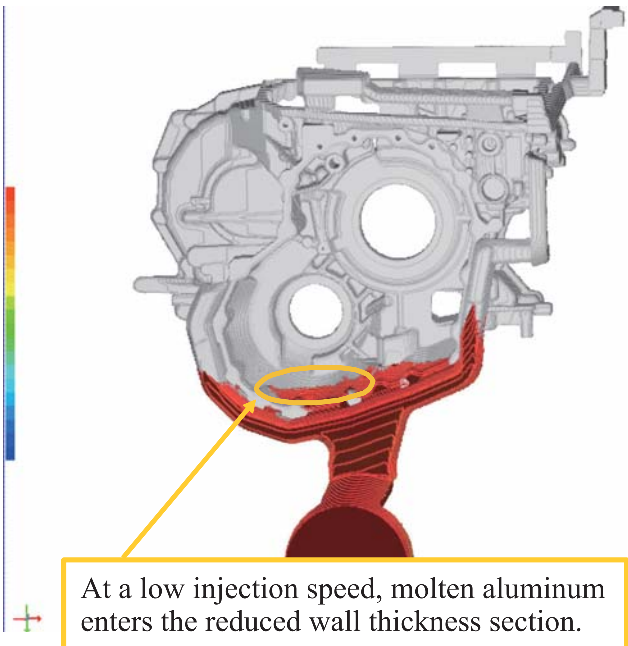

Fig. 6 Melt flow analysis

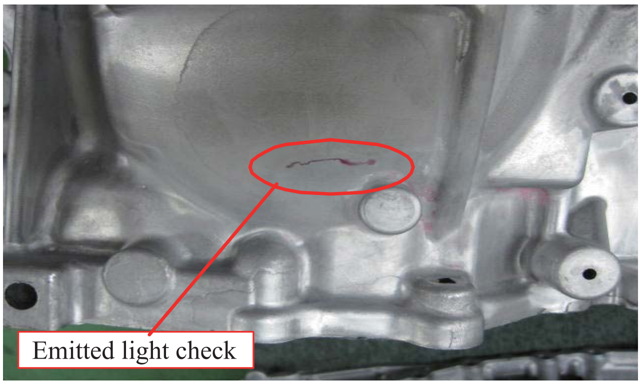

Fig. 5 Cold shut defect in reduced wall thickness section

just before the gate, where it is switched to a higher speed. That is done to minimize pocket defects caused by the entrainment of air before the molten aluminum enters the die.

The trial production results confirmed that molten aluminum began to fill the reduced wall thickness section near the gate before the switch to high-speed injection. (Fig. 6).

5. Corrective Measure

It was inferred from the simulation results that the cold shut occurred when molten aluminum entered the reduced wall thickness section at low speed and solidified. The basic measured devised for dealing with this issue was not to fill the reduced wall thickness section with molten aluminum at low speed.

First, an attempt was made to quicken the timing for switching to high speed injection. Casting was performed under a condition for preventing molten aluminum from filling the reduced wall thickness section. The result showed that this measure was effective against the cold shut in the reduced wall thickness region, but a pocket defect was discovered after the case was machined. An investigation into the nature of the defect revealed that it was a gas pocket. It was assumed that air was entrained into the molten aluminum because the timing for switching to high speed injection was advanced and that caused the gas pocket to occur.

The multi-level injection speed control function that was added to the new casting machine when it was installed was used to solve this issue by revising the injection speed pattern. Injection was performed at a slow speed until just before the molten aluminum reached the reduced wall thickness section ahead of

5. 対策

以上の分析より，薄肉部に低速でアルミが進入するとアルミが凝固してしまい湯境が発生すると推測された．そこで対策の基本方針は，

『低速で薄肉部へアルミが充填しないこと』

とした．

そこでまずは射出速度が高速に切り替わるタイミングを早くすることで，低速でアルミが薄肉部に充填しない条件で鋳造した．その結果，薄肉部の湯境に対して効果はあったが，加工後の巣不良が発生した．巣の性状を調査するとガス巣であり，高速に切り替えるタイミングを早くしたため，アルミ中に空気を巻き込んで巣が発生したと推測される．

そこで，今回射出を交換した際に追加した多段速制御機能を活用することとした．

ゲート前の薄肉部にアルミが到達する直前までは低速で射出させて，薄肉部にアルミが到達する直前で速度を上げ（中速追加），その後に所定の高速5m/sとなる様に設定を変更した．

従来の低速･高速という2速制御から低速･中速･高速という3速制御に変更することで，空気を巻き込むこともなく薄肉部を通過する速度を上げるという2つの要求を満たすことを狙った．射出変更イメージを（Fig. 7）に示す．

これらの対応によりゲート前の薄肉部の湯周りと内部品質の両立することができ，現在も薄肉化未採用のJF011Eと同等の品質を維持している．

6. まとめ

1）薄肉2.3mmの量産適応の手法を確立できた．

2）低速充填されることが多い，ゲート前を薄肉部にすると湯回り不良等の外観不良が発生しやすくなる．

3）上記の対策として，薄肉部をアルミが通過する際の充填速度を制御すること．具体的方策として，射出の多段制御を活用することが効果的である．

the gate. The speed was then increased by adding a medium speed interval just before the molten aluminum reached the reduced wall thickness section. Subsequently, it was then increased to the specified injection speed of 5 m/s.

Switching from the previous two-speed control of low and high injection speeds to three-speed control with low, medium and high injection speeds was intended to satisfy two conditions. One was to prevent air entrainment and the other was to raise the injection speed sufficiently for the molten aluminum to pass the reduced wall thickness section. The injection speed control procedure is diagrammed in Fig. 7.

This measure eliminated the cold shut in the reduced wall thickness section ahead of the gate while at the same time ensuring satisfactory casting quality in that section. Currently, the same level of casting quality is obtained as for the JF011E case for which the wall thickness has not been reduced.

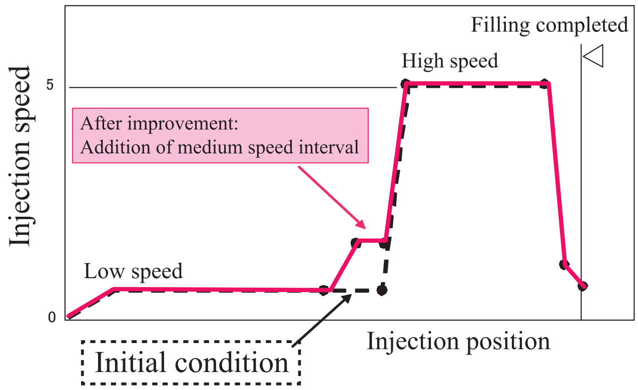

Fig. 7 Diagram of injection speed control

6. Conclusions

(1) A method of casting thinner CVT case walls of 2.3 mm in thickness was developed that is suitable to mass production.

(2) Material is often injected at slow speed ahead of a gate, but when a reduced wall thickness section is located nearby, it is apt to result in appearance defects such as a misrun.

(3) As a means of preventing such defects, the fill speed is controlled at the time the molten aluminum passes such a reduced wall thickness section. Specifically, it is effective to use multi-level injection speed control for that purpose.

7. 今後の課題

今回の手法は薄肉化により短縮されるアルミの凝固時間に対し，アルミの充填時間を短縮させる方案を採用することで，量産への薄肉化適応を実現することができたが，そのために性能が不足している鋳造機への設備投資が必要となった．また，現在の射出性能では現状よりもさらに高速化を行うことは，技術的なハードルが高くこれ以上の薄肉化に対しては今回の手法の延長では対応できない可能性が高い．また，その際に再度鋳造機に対し改造投資を行うようでは薄肉化による材料費低減効果が相殺されてしまう可能性がある．

したがって，更なる薄肉化が必要な新部品に対応しつつ，設備投資の抑制を両立していくためには，今後も継続的に，安価にアルミの凝固時間を延ばす技術を創出し開発していきたい．

7. Future Tasks

The method developed in this study is designed to facilitate a shorter solidification time of molten aluminum in connection with the reduction of the case wall thickness. Adopting a method for shortening the molten aluminum fill time made it possible to reduce the wall thickness of mass-produced CVT cases. To do that, it was necessary to invest in a new die casting machine, as the performance of the previous machine was insufficient. The current performance level of the die casting machine poses a formidable technical hurdle for increasing the injection speed further above the present speed. There is a good possibility that a simple extension of the method described here will not enable a further reduction of the case wall thickness. In that event, the capital investment needed to improve the die casting machine again may cancel out any material cost saving obtained by reducing the case wall thickness.

Therefore, we intend to devise and develop an inexpensive technology for extending the molten aluminum solidification time. Such technology will be needed to hold down the capital investment in die casting facilities while enabling the production of new cases for which the wall thickness must be reduced further.

■ Author ■

Masashi OKUDA

J−SSF 工法開発の取組み

Development of the New J-SSF Method

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抄 録 J−SSFとは，Jatco Special Surface Finishの略称であるが，Jatco CVT8（以下「CVT8」とする．）の動力伝達機構にチェーンを採用するため開発された工法である．本稿では，CVT8に欠かすことのできない，この工法について紹介する．

Summary The Jatco Special Surface Finish (J-SSF) method was developed to facilitate the adoption of a chain as the drive torque transmission mechanism of the Jatco CVT8 High Torque (CVT8HT) model. This article describes the J-SSF method, which is indispensable to the CVT8HT.

1. はじめに

CVT8のコンセプトは，更なる低燃費化と3.5Lクラスの高トルク車までの対応を両立できるということである．この，低燃費と高トルクを実現するために欠かせない技術として，動力伝達機構にチェーンの採用が決定された．

チェーン採用にあたり，課題を克服するために新たに開発した工法が，J−SSF（Jatco Special Surface Finish）である．本稿では，この，J−SSF工法開発の過程とその技術概要について紹介する．

2. J−SSF工法開発の背景

従来のCVTに使用されているベルトには，シーブ面（Fig. 1）との接触面（フランク面）に，溝が存在するが，CVT8に採用するチェーンには，溝が存在しない．そのため，図（Fig. 2）の様な溝が，シーブ面に必要となった．

シーブ面に要求される特性は，以下の2つである．

- 摩擦係数
- 耐摩耗性

今回のチェーン採用にあたり，トルク容量と耐久信頼性から，それぞれ，以下のような管理項目の要求があった．

1. Introduction

The development concept defined for the CVT8HT was to improve fuel economy further and to be applicable even to 3.5L-class high-torque vehicles. It was decided to adopt a chain as the drive torque transmission mechanism, representing the essential technology for achieving both improved fuel economy and high-torque capacity.

In connection with the adoption of a chain, we newly developed the Jatco Special Surface Finish (J-SSF) method to overcome various related issues. This article explains the development process of the J-SSF method and outlines the major features of this technology.

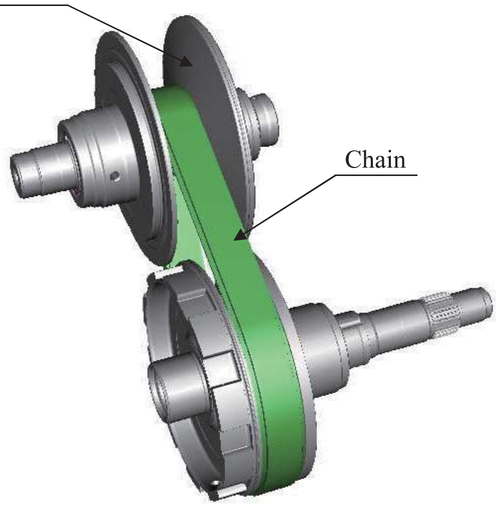

Fig. 1 Pulley and chain assembly

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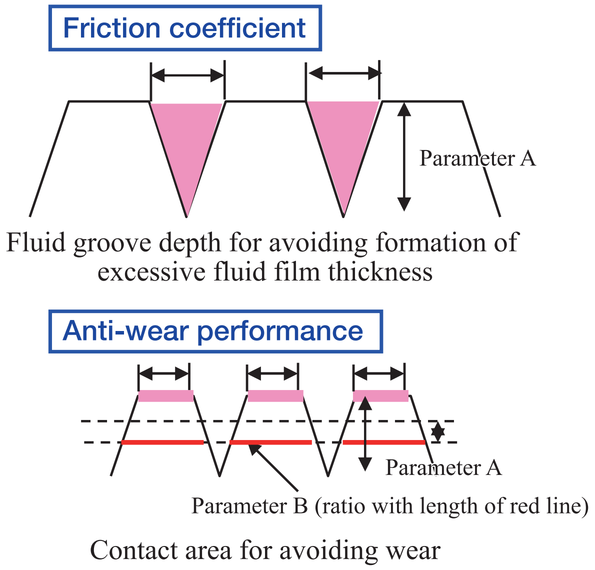


Fig. 2 Geometry of sheave face grooves

＜摩擦係数＞：“油膜形成を妨げるための油膜深さ”
として表面粗さパラメーターAで管理．
＜耐摩耗性＞：“摩滅を防止するための接触領域”
として表面粗さパラメーターBで管理．

摩擦特性と摩耗特性を両立させるため，パラメーターAとBの要求値を満足させる工法として，Jatco Special Surface Finish（以下「J-SSF」とする．）の開発に至った．

3. J-SSFの面粗度管理幅

シーブ面に要求される，パラメーターAとBは，Fig. 3の通りである．これは，開発部門での実験結果等を踏まえて，CVT8の要求性能を満足するための領域を示している．

生産技術部門に課された課題は，この範囲内のシーブ面性状を安定して量産する技術を確立することである．

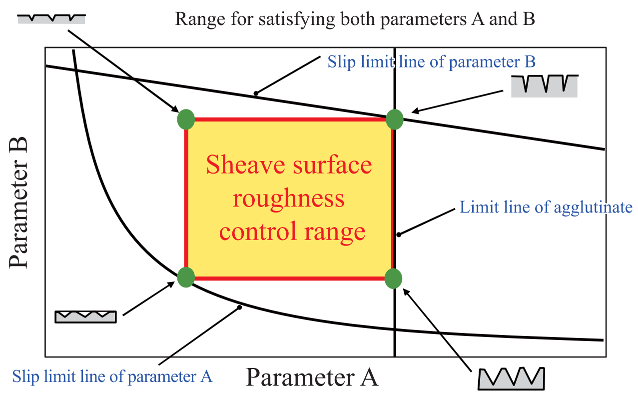


Fig. 3 Control range for sheave surface roughness

2. Motivation for Developing J-SSF Method

With the steel belt used for our existing CVTs, there are grooves at the contact surface (flank face) with the pulley sheave face (Fig. 1). Such grooves do not exist in the case of the chain adopted for the CVT8HT. For that reason, it was necessary to provide grooves in the sheave face as shown in Fig. 2.

The sheave face requires the following two properties.

- Friction coefficient
- Anti-wear performance

In conjunction with the adoption of a chain, the following parameters had to be controlled to ensure the desired torque capacity, durability and reliability.

Friction coefficient: Control of the sheave surface roughness (parameter A) to secure the desired fluid film thickness and prevent the formation of an excessively thick fluid film.

Anti-wear performance: Control of the sheave surface roughness (parameter B) in the contact area to prevent excessive wear.

The J-SSF method was developed as a surface finishing technique for satisfying the required values of parameters A and B in order to ensure both the friction and anti-wear properties needed.

3. J-SSF Control Range for Surface Roughness

The range of parameters A and B required for the sheave face is diagrammed in Fig. 3. The figure shows the region in which surface roughness must be controlled to satisfy the performance required of the CVT8HT, based on the results of tests conducted by the R&D division and other data.

The production engineering division was charged with the task of developing the technology to facilitate mass production of pulley sheaves having surface properties within the indicated control range.

4. Overview of J-SSF Process

A film lapping process was applied to develop a technique for forming tiny grooves in the sheave face in order to satisfy the surface roughness specification mentioned in the preceding section. Figure 4 outlines the newly developed J-SSF process.

4.J−SSF 工程概要

前述のシーブ面粗さ規格を満足させるため，フィルムラッピングを応用して，シーブ面に微細な溝を形成する技術を開発した．

Fig. 4は，今回開発した，J-SSFの工程概要を示す．

5. 最適加工条件とその結果

加工実験の結果から，最適加工条件を決定した．

その結果から，各モーションでのシーブ面の粗さデータが，目的通りに推移することを確認した．(Fig. 5)

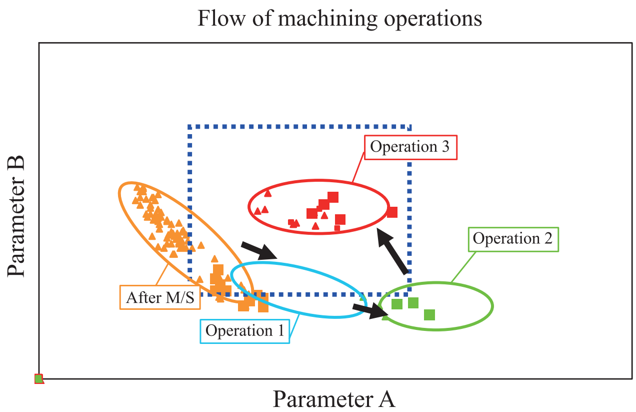


Fig. 5 Change in surface roughness data in each operation

仕上げ時間が表面粗さの結果に最も寄与するパラメーターであることがわかった．

また，オシレーションは，表面粗さの安定化に寄与することも判明した．

6. CVT8での加工結果

前項にて導き出した，最適加工条件にて実際にCVT8プーリーの加工を行った．(Fig. 6)

表面粗さの工程能力は，残念ながら確保することはできなかったが，全数検査することを前提に量産可能なレベルに達したことを確認できた．

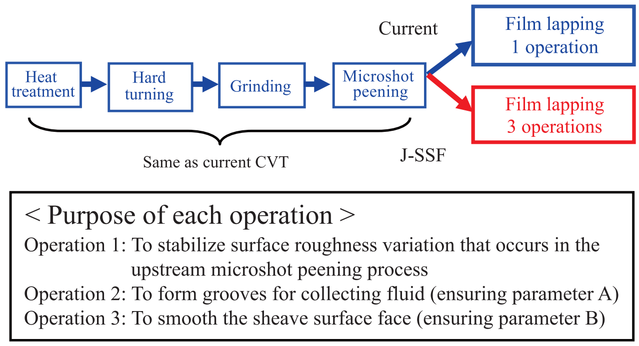


Fig. 4 Overview of J-SSF process

5. Optimal Machining Conditions and Results Obtained

The optimal machining conditions were determined from the results of machining tests. The sheave surface roughness data obtained in each machining operation confirmed that the process advanced to the target as intended (Fig. 5).

It was found that the finish machining time was the parameter that had the greatest effect on the resultant surface roughness. It was also found that an oscillating motion contributed to stabilizing the sheave surface roughness.

6. Machining Results for CVT8HT Pulleys

CVT8HT pulleys were then actually machined according to the optimal machining conditions derived in the preceding section (Fig. 6).

Unfortunately, it was found that the process did not have sufficient capacity to achieve the desired surface roughness. However, it was verified that the level obtained would facilitate mass production on the assumption that all pulleys would be inspected.

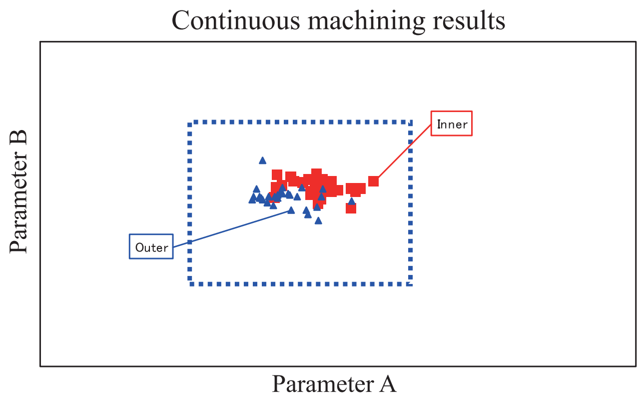


Fig. 6 Machining results for surface roughness of CVT8 pulley sheave face

7. まとめ

燃費と走りにこだわりを持って開発されたCVT8であるが，この開発部門のこだわりを量産できるレベルで実現させるのが，生産技術力である．今回のJ-SSF工法開発を通して，ジヤトコの生産技術力が発揮され，より高いレベルで完成されたCVT8を世の中に送り出すことに貢献できたのではないかと思う．

7. Conclusion

The CVT8 series was developed with specific emphasis put on fuel economy and driving performance. Our production engineering capabilities made it possible to achieve the rigorous demands of the R&D division at a level suitable for mass production. JATCO's production engineering strengths were fully utilized in the development of the J-SSF method and contributed substantially to the completion of the CVT8 series at a higher level of perfection for release in the marketplace.

■ Authors ■

Hiroshi TOYOMORI

Hajime KOUNO

CVT8 Launching in overseas

Carcia Luis Ricardo* Serafio Jose Luis*

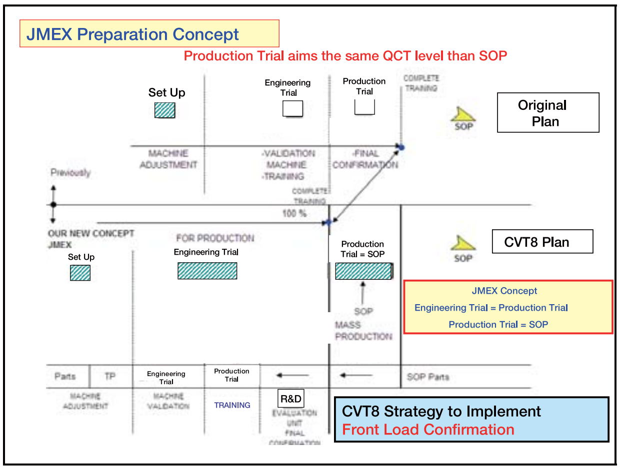
Summary In Jatco, there used to be: "All new projects launched in Japan first"··· But not anymore, lately this has changed. Globalization and market demands, have lead its mind and try new challenges. In JATCO Mexico, S.A. de C.V. (JMEX), we just had one of our biggest challenges so far, the launching of Jatco CVT8 for 2.5L class vehicles, the first time a project is launched outside Japan. This article refers to the problems JMEX manufacturing group had to overcome and the strategy that followed to achieve the launching of the CVT8.

1. Preparation of Modification

Given that until that time this was one of the biggest challenges JMEX had to deal with, a group of young engineers were dispatched to Japan to work during all the stages of the manufacturing preparation process: J-GPEC (Jatco Global Production Engineering Center) confirmation, modification estimations, machine's specifications making, R&D discussions, machines Tachiai, and machinery shipping. They participated in the project development for over a year, until all machines were in transit to Mexico.

This group consisted of Mexican engineers with high motivation and high skills from Casting, Gear Machining, Pulley Machining, Case Machining, Heat Treatment, and Assembly divisions.

This activity helped JMEX to understand in depth the line concept, as well as to prepare more proactively the line modifications, by taking the front load and discussing the issues directly with the R&D group and machine manufacturers.



* JATCO Mexico, S.A. de C. V.

2. Production Simul Training, J-GPEC, and Maintenance Collaboration

Engineering group was not the only one working on the modification; also Production members were dispatched to Japan, having several purposes:

- Understand the new features of the CVT8 model.
- Impact the machine specifications with their point of view.
- Feedback to R&D with their experience to find out difficult assembly points.
- Training in the first Vehicle confirmation assembly to become a trainer in JMEX.

Furthermore, Maintenance members also went to JTC to collaborate in the machines preparation, providing their assistance in the Tachiai confirmations and overhaul of several equipments; mainly for Control Valve machining, which was a completely new area for JMEX.

3. 5 Weeks Modification Challenge and Resume Operation

Besides the challenge of launching the first product overseas, JMEX had an additional challenge: to reduce the modification time from a period of 3 months to a period of 5 weeks, in order to assure the production volume was delivered in the customer's facilities on time.

To reach this period, it was required to increase working time to 24 hours shifts during most of the modification weeks, and increase supplier's manpower. A lot of issues came out among engineering divisions, but all of them had a proper countermeasure. Additional to the new models installations, several chronic problems were solved applying countermeasures, taking advantage of the supplier's manpower and from maintenance's support.

Quality confirmations were made in the second shift, and machine modifications and adjustments were done during the 24 hours. A high enthusiasm was felt among all group, because of the excitement of the new model, CVT8 and the 5 weeks challenge.

Additional to this, a special front-loading concept was established in JMEX, from the Executive Committee to the workers in the line, the concept of Engineering Trial = Production Trial, and Production Trial = SOP was strongly laid. This helped JMEX to reach its goals faster and with a more proactive attitude.

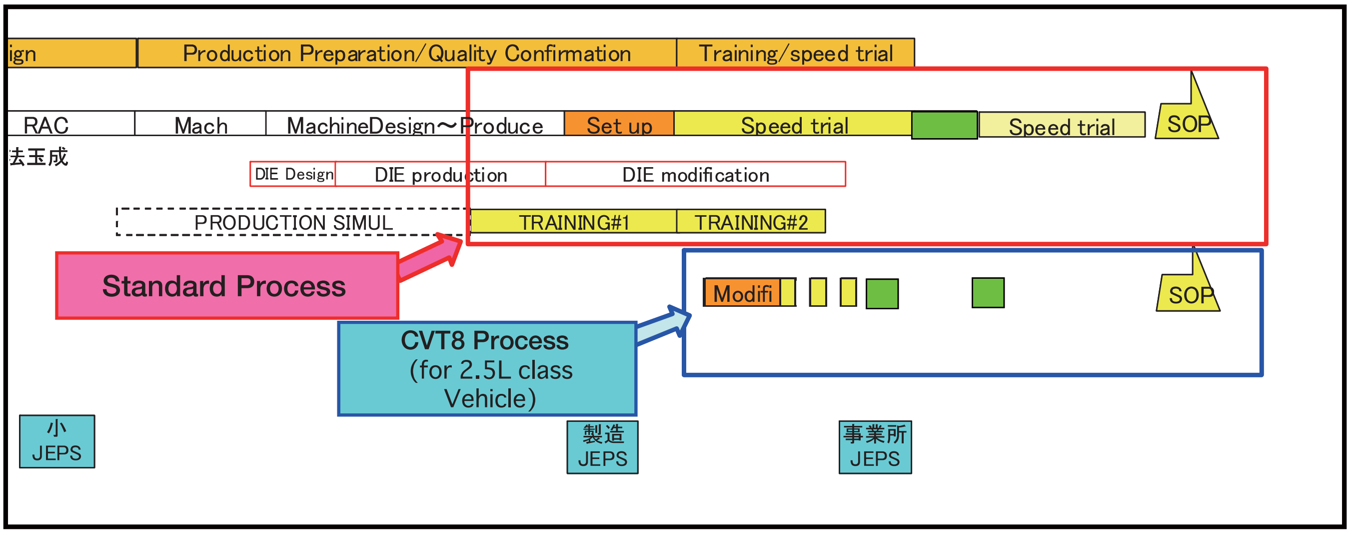
All these activities, training, front loading, and tackling challenges, allowed JMEX to reach a very important time reduction in the project standard timeline. In previous experiences and from basic concepts, 13 months were needed from the training and preparation of modification to the SOP. In JMEX, with the CVT8 model, we took only 9 months to complete the whole process.

5's was given a special focus during the modification term, through special daily patrols to confirm the working conditions and ensure safety of all Jatco members and supplier's.

Finally, the KPI's were considered very carefully, with daily follow up by manufacturing managers, helping to all members to look each detail thoroughly.

As the base of JMEX modification and resume operation, 6 pillars were taken into account:

- CPCM
- Cross Check
- 5's
- Quality Maintenance
- Cp, Cpk
- Layout inspection



4. Production Training

More over, Production also had a big challenge, train all workers in the new models; because of the importance this project represented a new concept was established in JMEX: "Mini-line".

Within this new concept of Mini-Line, an area was arranged as a simulation of the actual process in the assembly line, and it was used to train old and new operators on the new CVT8 for 2.5L, CVT8 for 3.5L, and CVT7 models.

5. Big Quality & Productivity Issues after SOP

Nevertheless, no modification is perfect, and several quality issues were found after the SOP.

For instance, Heat Treatment jigs caused low hardness in the pulley slides sheave, several dimensions were found out of specification in Control Valve machining and Pulley machining, and design notes were not applied properly in Pulley Machining. While in Assembly division, 2 big issues were detected: Snap Ring of Reverse Brake was found with burr and in an opposite direction, due to a validation mistake for the installation. And with the modification of one Revolution Sensor tightening, some interlocks were not validated properly, triggering the issue of having to send some units with missing torque to the customer.

Regarding productivity, in Assembly line, we had a huge lesson learned during Engineering Trials and Production Trials, the Cycle Time of all operations were not properly validated, affecting directly the JPH, for that reason it was necessary a big additional effort from all manufacturing department to achieve the targets in the shortest term possible.

Despite all, these problems were not seen as a failure, but as a huge learning experience for JMEX. And all these knowledge will be transferred and applied to every new project that JMEX will face from now on.

6. General Summary

Of course we found many problems during the modification and after it, several critical delays appeared caused by several variables, but the gained experience during the CVT8 project will help JMEX to push forward in the future projects, always with the "challenge" and "front loading" attitude.

The show is not over for JMEX, from now on we have huge projects that will represent high income for Jatco and a big challenge to JMEX's future. And, let me tell you something… bring them on!

■ Authors ■

Carcia Luis Ricardo

Serafio Jose Luis

FF車用4速AT Avto VAZ社向け JF414Eの紹介

Introducing the JF414E 4-Speed AT for Front-drive Cars

2010年8月に日産自動車（株）の中国向けマーチに搭載されたFF4速AT，JF414Eは，その後新興国，及び北米向けに拡大採用されています．

2012年9月には，ロシアの自動車メーカーであるAvto VAZ社のラーダ･グランタに搭載され，発売が開始されました．

コストの最適化，軽量コンパクト，機能･耐久信頼性を実現したJF414Eで，お客さまの要求する性能を満足することができ，好評を得ております．

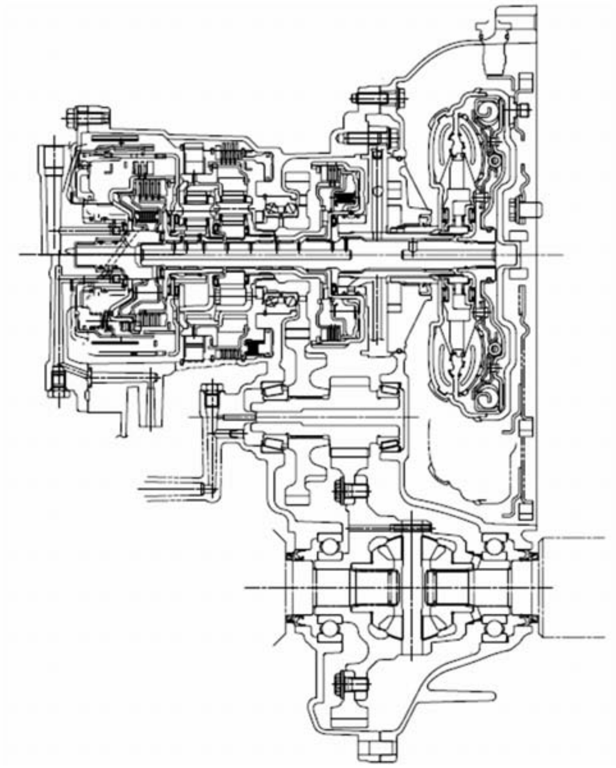


Fig. 1 Main cross-sectional view

The JF414E 4-speed AT for front-drive cars was adopted on the Nissan March for the Chinese market in August 2010. Its application has since been expanded to other models marketed in emerging economies and in North America. Sales of the JF414E to the Russian automaker AvtoVAZ were launched in 2012 for use on its new Lada Granta model that was released in Russia in September 2012. The JF414E achieves an optimal cost, compact and lightweight package, and ample functionality, durability and reliability to satisfy customers' performance requirements. It enjoys an excellent market reputation.

Table 1 Specifications of JF414E

Torque capacity		150 Nm
Control system		Electronic
Torque converter size		205mm dia.
Gear ratios	1st	2.861
	2nd	1.562
	3rd	1.000
	4th	0.697
	Rev.	2.310
Ratio coverage		4.1
Final gear ratio		4.081
No. of selector positions		6（P, R, N, D,2,1）
Overall length		344,2 mm
Center distance between engine and differential		183 mm
Weight (wet)		63 kg

■ Typical model fitted with the JF414E AT ■

New Lada Granta

ルノー三星自動車向け　FF車用CVT　Jatco CVT7の紹介

Introducing the Steel-belt Jatco CVT7 for Front-drive Cars

Jatco CVT7はルノー･日産のアライアンスプロジェクトとして開発し2012年9月から販売を始めたルノー三星自動車（株）の新型C セグメント（SM3）に搭載されております．

Jatco CVT7は副変速機を備えた独自の機能を採用することで世界一の変速比幅を実現し，ASC（アダプティブ･シフト･コントロール）によるレスポンスの良い発進，加速性能を確保しました．また，小型･軽量化と攪拌ロスの低減により，SM3が韓国C セグメント車両の中，燃費トップになることに大きく貢献し，お客さまに好評を得ています．

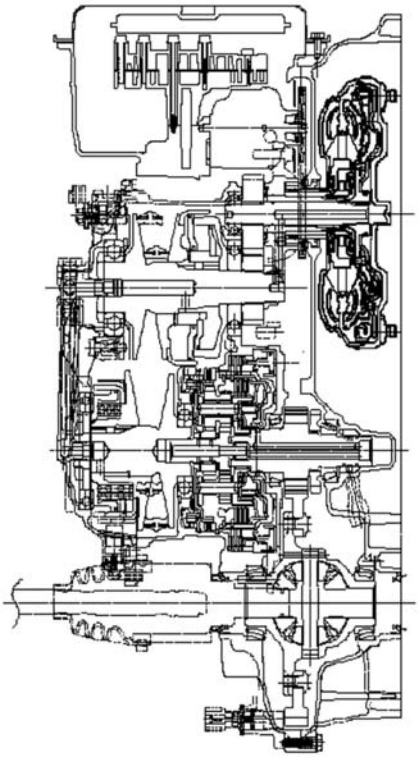


Fig. 1 Main cross-sectional view

Developed in a Renault-Nissan Alliance project, the Jatco CVT7 is mounted on the new SM3 compact sedan, a C-segment model that Renault Samsung Motors Co., Ltd. released in September 2012. The Jatco CVT7 achieves the world's widest ratio coverage, thanks to its architecture that features an auxiliary transmission. It incorporates Adaptive Shift Control (ASC) to deliver quick start-off response and smooth acceleration performance. Furthermore, its smaller, lighter package and reduced fluid churning loss contribute significantly to the SM3's class-leading fuel economy among C-segment vehicles in the Korean market. Its performance has earned high praise from customers in Korea.

Table 1 Specifications of Jatco CVT7

Torque capacity	150 Nm
Control system	Electronic
Torque converter size	UUF 205 mm dia.
Pulley ratios	Low: 2.2　High: 0.55
Ratio coverage	7.3
Final gear ratio	3.882
No. of selector positions	5
Overall length	323.3 mm
Weight (wet)	67.5 kg

■ Typical model fitted with the Jatco CVT7 ■

New SM3

スズキ向け軽用　FF車用CVT　Jatco CVT7の紹介

Introducing the Jatco CVT7 for Front-drive Cars

2009年9月発売のスズキ株式会社パレットに搭載されたJatco CVT7は，ワゴンR，ラパン等の軽自動車だけでなく，スイフト，ソリオ等の小型車にも次々に搭載されています．

2012年9月に，新型ワゴンR，新型ワゴンRスティングレーの発売に合わせ燃費性能の改善を行い低燃費化に貢献しました．

特に，停車前の減速時にエンジンを停止する『新アイドリングストップ制御』を採用することでお客さまに好評を得ています．

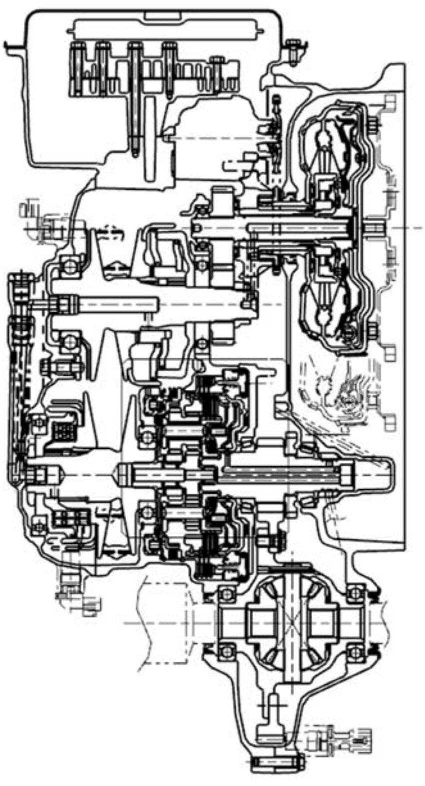


Fig. 1 Main cross-sectional view

The Jatco CVT7 was adopted on the Palette minivehicle released by Suzuki Motor Corporation in September 2009. It has since been adopted on other Suzuki minivehicles such as the Wagon R and Lapin and also on a succession of Suzuki small cars, including the Swift and Solio. In conjunction with the release of the new Wagon R and Wagon R Stingray in September 2012, measures were taken to improve the fuel economy obtained with this CVT. Those improvements contribute to the enhanced fuel economy of these new Suzuki models. One notable feature that is particularly popular among customers is the adoption of a new idling stop control function that shuts off the engine during deceleration before the vehicle comes to a stop.

Table 1 Specifications of Jatco CVT7

Torque capacity	100 Nm
Control system	Electronic
Torque converter size	UUF 185 mm dia.
Pulley ratios	Low: 2.2　High: 0.55
Ratio coverage	7.3
Final gear ratio	4.572
No. of selector positions	5
Overall length	313.3 mm
Weight (wet)	64 kg

■ Typical models fitted with the Jatco CVT7 ■

New Wagon R

New Wagon R Stingray

三菱向け　FF車用CVT　Jatco CVT7の紹介

Introducing the Jatco CVT7 Steel-belt CVT for Mitsubishi Front-drive Cars

三菱自動車の世界戦略車ミラージュに当社副変速機付Jatco CVT7が搭載され，2012年3月にタイ向け，2012年8月に国内向けが発売されました．アイドリングストップ機能の効果もあり，国内燃費モード（JC08）では，ガソリンエンジン登録車で最高水準となる27.2km/Lの燃費性能実現に貢献し，エコカー減税（免税）対象となることで好調な販売に寄与することができました．

さらに，燃費だけではなく変速レスポンスも向上させ，走りと燃費の両立で，お客さま満足度の向上にも大きく貢献することができました．

今後世界戦略車としてタイ，国内に続き，順次世界に展開される予定です．

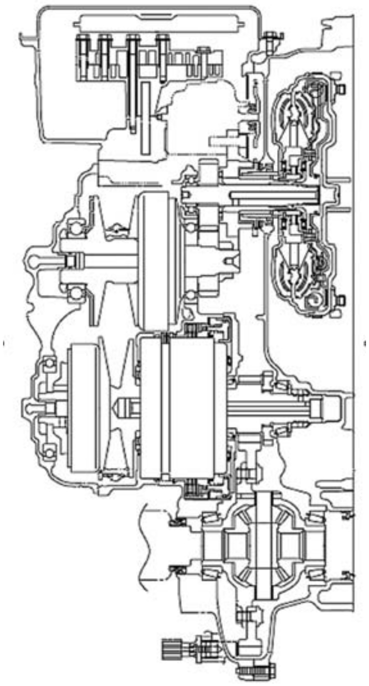


Fig. 1 Main cross-sectional view

The Jatco CVT7, featuring an auxiliary transmission, is mounted on the Mitsubishi Mirage, one of the automaker's global strategy models. This vehicle model was released in Thailand in March 2012 and in Japan in August 2012. The Jatco CVT7 helps the Mirage attain a fuel economy figure of 27.2 km/l under Japan's JC08 fuel economy test mode. That is the highest fuel economy among registered gasoline engine models in Japan and is due in part to the effect of the idling stop function incorporated in this CVT. As a result, the Mirage qualifies for a tax reduction/exemption, which has contributed to its brisk sales. Besides excellent fuel economy, the Jatco CVT7 also provides improved shift response, thereby reconciling fuel efficiency with driving performance. That has helped to improve customer satisfaction with the car significantly. Following the launches in Thailand and Japan, Mitsubishi plans to release the Mirage successively in other markets worldwide as a global strategy model.

Table 1 Specifications of Jatco CVT7

Torque capacity	100 Nm
Control system	Electronic
Torque converter size	UUF 205 mm dia.
Pulley ratios	Low: 2.2　High: 0.55
Ratio coverage	7.3
Final gear ratio	3.757
No. of selector positions	6
Overall length	343 mm 366 mm (with Automated Sequential Gearbox)
Weight (wet)	68 kg 69 kg (with Automated Sequential Gearbox)

■ Typical model fitted with the Jatco CVT7 ■

Mirage

日産自動車向け　FF車用CVT　JF010Eの紹介

Introducing the JF010E CVT for Front-drive Cars

'12年12月発売の日産自動車(株)のJX35より搭載されたJF010E-Nは，FF CVT初のインフィニティーブランド車両であり，I-DRIVEスイッチが搭載されています．

Normal，Sport，Eco，Snowの4モードが選択でき，モードにあわせてASC(Adopted Shift Control)によって，ドライバーの運転スタイルや走行環境に応じた最適な変速をします．

特にスポーツモードでは高回転を使用したスポーティーな走行が可能です．

The JF010E-N CVT is mounted on the Infiniti JX35 that Nissan Motor Co., Ltd. released in December 2012. This is the Infiniti brand's first front-drive car to be fitted with a CVT. An I-Drive switch is provided on the center console for selecting the drive mode from among four choices: Normal, Sport, Eco and Snow. According to the mode selected, Adaptive Shift Control (ASC) shifts to the optimum ratio matching the driver's driving style and the driving conditions. High-speed sporty driving is possible especially in the Sport mode.

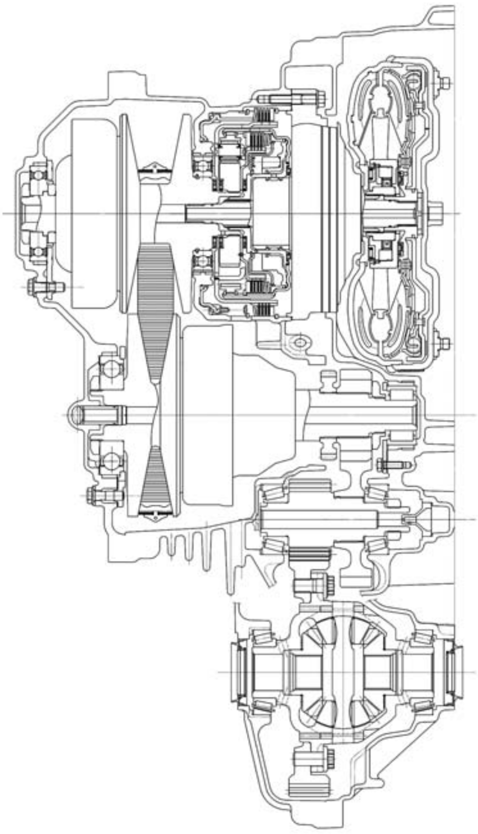


Fig. 1 Main cross-sectional view

Table 1 Specifications of JF010E

Torque capacity		350 Nm
Control system		Electronic
Torque converter size		250 mm dia.
Gear ratios	Pulley ratio	2.371～0.439
Final gear ratio		4.878～6.327
No. of selector positions		6
Overall length		389.1 mm
Weight (dry)		102.5 kg

■ Typical models fitted with the JF010E CVT ■

Infiniti JX35

Murano

ジヤトコ 一年間のトピックス

Highlights of the Past Year

1. とくり盃サークル全国選抜大会へ

7月14日，QCサークル近畿支部選抜大会が行われ，八木･京都工場技術課 保全係の“とくり盃（さかずき）サークル”が，『"ONE for ALL，ALL for ONE"「技能集団」が気づいたチームワークの大切さ』というテーマで発表し，見事代表として選出された．

全日本選抜大会は，QCサークルの運営事例（人の成長，職場の活性化，QCDの改善などの2～5年間の活動の成果）を競うもので，地区大会，支部大会を勝ち抜いた18サークルのみが駒を進めることができる，QCサークル最高峰の大会となっている．

当社からは昨年度初めて，八木第1製造課の“サイド･バーンズサークル”が出場し，金賞を受賞したが，これで2年連続出場の快挙となった．

2. 学生フォーミュラ

9月5日～9日の5日間，静岡県小笠山総合運動公園（エコパ）にて，公益社団法人自動車技術会主催の第9回全日本学生フォーミュラ大会が開催された．本大会は，ものづくりの総合力を競い，産学官民で支援して，自動車技術ならびに産業の発展に資する人材を育成するための事業の一環として1981年より米国SAE主催で開始され（現在世界12か国で開催），2003年より日本大会も開催されている．

1. Tokuri Sakazuki QC Circle advances to All-Japan Invitational Conference

The Kinki regional QC circle invitational conference was held on July 14, 2011. The Tokuri Sakazuki QC Circle, consisting of maintenance personnel from the Yagi and Kyoto plant production engineering sections, gave an impressive presentation on the theme of "One for All, All for One — Skilled Employees Group Realizes the Importance of Teamwork." They were admirably selected as a delegation to the national conference.

The All-Japan Invitational Conference is the pinnacle QC circle event to which only 18 QC circle teams that have won at local and regional qualifying conferences can advance. Participating teams compete over the results attained in QC activities conducted over a period of 2-5 years with respect to employee development, energizing workplaces, QCD (quality, cost, delivery) improvements and other aspects.

The Sideburns QC Circle from Yagi plant's Production Section No. 1 was JATCO's first participant in the national conference in the previous fiscal year and won a gold medal. With this latest success, JATCO has now sent a QC circle team to the all-Japan conference two years in a row.

2. Student Formula Japan

The 9th Student Formula SAE Competition of Japan, sponsored by the Society of Automotive Engineers of Japan, was held over a five-day period from Monday-Friday, September 5-9, 2011 at the Ogasayama Sports Park (ECOPA) in Shizuoka prefecture. Jointly supported by government, industry and academia, this competition contests overall manufacturing capabilities and is one of the projects undertaken to cultivate human resources capable of contributing to the advancement of automotive engineering and industry in general. The Society of Automotive Engineers in the U.S. has been

今回は過去最多の87チーム（国内73校，海外14校）がエントリーし，その内書類審査を通過した75チームが優勝を狙い，熱戦が繰り広げられた．

本大会は国内自動車メーカーをはじめとする約130社がスポンサーをしており，当社もスポンサーとして支援するとともに，社員3名も審査員として大会に協力した．

3. 家族見学会

9月25日，富士地区において社員の家族を招いて会社見学会を実施した．

本イベントのきっかけとなったのは「土曜日曜操業は，お父さんお母さんの働く姿を見てもらう良いチャンスになるのでは?」という一人の社員の声から．その声を受け，多くの社員が協力しあって実現できたもの．参加者からは「ひとつのミッションを作るために，ハードの面からもソフトの面からもたくさんの人の力が集結して成り立っているんだと感じました．」「お父さんの会社でがんばっているすがたをみて，ぼくもがんばろうとおもいました」などの感想をもらうことができ，大変価値のある一日となった．

conducting Formula SAE® since 1981, and similar competitions are now held annually in 12 countries around the world. Student Formula Japan has been held every year since 2003.

This year's event recorded the largest number of entries ever with 87 teams participating, 73 of which were from schools in Japan and 14 from schools overseas. Intense competition for the championship unfolded among the 75 teams that cleared the documentation screening. Some 130 companies, notably domestic automakers, were sponsors of this event. JATCO also provided support as one of the sponsors, and three employees cooperated by serving as judges.

3. Family Day Open House

The families of employees in the Fuji Area were invited to a Family Day Open House held on Sunday, September 25, 2011. The impetus for starting this event was an opinion voiced by one of the employees that it would provide a good chance for children to see their fathers or mothers at work during plant operations on Saturday or Sunday. Moved by that opinion, many employees cooperated in making it a reality. One child who came to the Open House commented that she realized the task of making one transmission is accomplished through the collective efforts of many people working together on both hardware and software aspects. A boy said that he wanted to do his best after seeing how people at his father's company were all striving to do such good work. These and other comments indicated that the Open House was an extremely valuable day.

4. キッズエンジニア石巻

「キッズエンジニア」は，自動車を中心とした様々な分野の科学技術やものづくりに興味を持ってもらおうと，自動車技術会が主催している子供向けの体験型学習イベント．今年は8月にインテックス大阪で行われた「キッズエンジニア2011」に続いて，10月26日，宮城県石巻市立開北小学校での「ミニキッズエンジニア in 石巻」にも教室型プログラムを開設した．

石巻市は3月11日に発生した，東北地方太平洋沖地震の大津波で甚大な被害をうけた地域であるため，企業が現地の小学校に出向く「出前教室形式」でプログラムを実施．今回は日産自動車，トヨタ自動車，三菱自動車工業，ヤマハ発動機，ジヤトコの5社が参加．1プログラム55分で4回，合計37名の「未来のエンジニア」に科学やものづくりの楽しさを体験してもらった．

当社の提供したプログラムは「遊星ギヤって何だろう」．関係者からは「子供には難しいのでは?」と当初危惧されたが，被災地に夢を届けたいとの熱い志を持った若いスタッフが，親しみやすさと工夫された教材で子供たちの信頼を勝ち取り，教室での

4. Kids Engineers in Ishinomaki

Kids Engineers is a hands-on event for children sponsored by the Society of Automotive Engineers of Japan to foster an interest in manufacturing and various fields of science and technology, focusing on automobiles. Following Kids Engineers 2011 that was held at the INTEX Osaka International Exhibition Center in August, a classroom-style program called Kids Engineers in Ishinomaki was also conducted at the Kaihoku Municipal Elementary School in Ishinomaki, Miyagi on Wednesday, October 26, 2011.

Ishinomaki is located in an area devastated by the massive tsunami triggered by the Great East Japan Earthquake that occurred in the Pacific off the northeastern coast on March 11, 2011. Companies have been dispatching personnel to conduct classroom-style programs for children at local elementary schools in the city. Five companies — Nissan Motor Co., Ltd., Toyota Motor Corp., Mitsubishi Motors Corp., Yamaha Motor Co., Ltd. and JATCO — participated in this event. One program continued for 55 minutes and was conducted four times. A total of 37 "future engineers" had an opportunity to experience first-hand the joys of

一体感は群を抜いていた．まだまだ震災の傷跡が随所に残る石巻だったが，キッズエンジニアをきっかけに，幾多の困難に負けず，この子供たちの中から日本を支える技術者が生まれることを期待したい．

5. アグアス州知事訪社

10月27日，アグアスカリエンテス州の州知事であるCarlos Lozano氏がジヤトコ本社を訪問．

Carlos氏は州知事に選ばれた直後の2010年10月にもジヤトコを訪れており，今回が二度目の訪問となった．

Carlos氏に加え，アグアスカリエンテス大学の学部長とその関係者6名を，秦社長をはじめとする役員が迎え入れた．

その後の役員とのミーティングで，Carlos氏から，自動車産業にとって重要な電気，ガス，交通などのインフラについての計画，また自動車関連会社からの要望に応じて適切な大学のプログラムを作って応えるつもりであるなどの説明があり，JATCO Mexico S.A.de C.V.発展の後押しを約束して下さった．

州知事は「アグアスカリエンテス州へのサプライヤー誘致をさらに促進したい」ともコメントされた．

science and manufacturing.

JATCO's program was entitled: "What is a planetary gearset?" The event organizers were initially concerned that this subject might be too difficult for children to understand. However, young JATCO employees, fervently desiring to deliver dreams of hope to the devastated area, gained the children's trust by using well designed teaching materials that the children could easily relate to. That resulted in an exceptional feeling of unity in the classroom. While the scars of the disaster still remain everywhere in Ishinomaki, it is hoped that engineers capable of overcoming numerous adversities and supporting Japan in the future might emerge from among the children, inspired by this Kids Engineers program.

5. Aguascalientes Sate Governor Carlos Lozano visits JATCO

Carlos Lozano, governor of the Mexican state of Aguascalientes, visited JATCO's head office on October 27, 2011. This was Governor Lozano's second visit to JATCO, following his first visit in October 2010 soon after he was elected state governor. In addition to Governor Lozano, the dean of the Autonomous University of Aguascalientes and six other related persons were welcomed by JATCO President Takashi Hata and other company executives.

In the subsequent meeting with President Hata and the executives, Governor Lozano explained his state's plans regarding electricity, gas, transportation and other infrastructure elements vital to the automotive industry. He also indicated that the state government intended to support the creation of suitable university programs in response to requests from automotive industry-related companies. He pledged support for the further development of JATCO Mexico S.A. de C.V. (JMEX) in this regard.

Governor Lozano also noted that he wanted to invite more supplier companies to locate in the state of Aguascalientes.

6. GSOオープン

11月18日，新横浜にグローバル･サテライト･オフィス（GSO）がオープンした．

GSOは「ジヤトコのすべての社員が，部署に関係なく自由に使用することのできるオフィス」としてオープン．

急速にグローバル化するジヤトコのビジネスを効率的に推進，遂行するために，増大する首都圏へのアクセスが容易な前進基地を築くことを狙いとし，社内のコミュニケーションの量，社外からの情報量が飛躍的に増えることが期待されている．

7. タイ義援金

11月17日，10月初めよりタイ中部を中心に発生した洪水を受け，ジヤトコ タイランド社（JATCO（Thailand）Co., Ltd.）（以下「JTL」とする．）はプミポン国王基金（Foundation of King）に義援金を寄付した．JTLは「プロジェクトの立ち上げによりタイの復興に貢献する」という強い思いで，日々一歩ずつ前進している．

8. ジヤトコ タイランド社定礎式

ジヤトコ タイランド社（JATCO（Thailand）Co., Ltd.）の定礎式が12月9日に行なわれた．

ジヤトコ タイランド社は，メキシコ，中国に次ぐ3番目の海外生産拠点であり，タイにおける最初のCVTメーカーとなる予定．生産開始は2013年半ばを予定しており，生産能力は年間約50万台，生産立ち上がり時の従業員数は500名を予定しており，2014年度中には約1300名に増員する計画．

6. Opening of Global Satellite Office

JATCO opened a Global Satellite Office (GSO) in Shin-Yokohama on Friday, November 18, 2011. This GSO was opened as an office that all JATCO employees can readily use regardless of their department. The aim behind the GSO is to establish an advanced base for easy access to the expanding volumes of information in the Tokyo metropolitan area, in order to promote and execute JATCO's business efficiently, which rapidly becoming more global in scope. It is expected that the volume of internal communication and the volume of external information will increase dramatically in the coming years.

7. Donation to Thailand

JATCO (Thailand) Co., Ltd. (JTL) donated 100,000 Thai bahts (about 250,000 yen) to the King of Thailand Foundation on November 17, 2011 in response to the flooding that occurred in the central part of Thailand beginning in early October. JTL is steadily moving ahead with the work of launching the CVT production project, firmly convinced that it will contribute to Thailand's recovery.

8. Cornerstone laying ceremony at JTL

A cornerstone laying ceremony was held on December 19, 2011 at JATCO (Thailand) Co., Ltd. (JTL), the company's manufacturing subsidiary in Thailand. JTL is JATCO's third overseas production center after the plants in Mexico and China and is set to become Thailand's first CVT manufacturer. Production is scheduled to begin in the second half of 2013 with an annual production capacity of

9. プレスツアー開催

3月6日に日産自動車と共同で，ジャーナリスト，自動車評論家，雑誌編集者など約100名を対象にマスコミ向けの「ジヤトコ取材会」を実施した．

秦社長からは今後のジヤトコのさらなるグローバル展開について，薄葉副社長からはJatco CVT8を初めとした当社の商品，技術力について，本田副社長からはジヤトコチャレンジやBCM（Business continuity management）についてのプレゼンテーションがそれぞれ行われた．

また，富士第1地区のJatco CVT7生産ラインで行われた工場見学は，「魅せる工場」プロジェクトのお披露目の場ともなり，一行はCVTの生産ラインを極めて興味深く見学していた．

10. AvtoVAZとの供給契約調印式

ジヤトコとロシアの自動車メーカー，AvtoVAZ社*はAT供給契約の調印式を4月9日に実施した．

ジヤトコは，小型FF車用4速AT（JF414E）を2012年6月より，ロシアのAvtoVAZ社へ供給する．この4速ATは，AvtoVAZ社として初めてのAT搭載車として8月よりロシアで発売された同社のラーダ グランタに搭載され，供給台数は年間約8万台の予定．

これに伴い2012年6月にAvtoVAZ本社のあるトリヤッチにこのAT供給のための営業拠点を設立した．

*AvtoVAZ社：1966年設立のロシア最大の自動車メーカー．本社サマラ州トリヤッチ市．2011年の生産台数は約56万台．

approximately 500,000 units. The workforce at the time production is launched will be 500 employees, but it is planned to expand that number to some 1,300 employees by the middle of fiscal 2014.

9. Joint press tour

JATCO and Nissan Motor Co., Ltd. held a joint JATCO Press Tour on March 6, 2012, to which around 100 members of the mass media were invited, including journalists, automotive industry commentators, magazine editors and others. JATCO President Takashi Hata gave a presentation on JATCO's plans for further global expansion. Executive Vice President Yo Usuba explained JATCO's product lineup, especially the new Jatco CVT8 series, and the company's technical capabilities. Executive Vice President Seiji Honda talked about the challenges facing JATCO and business continuity management. A tour of the CVT7 production line in Fuji Area No. 1 was conducted, which served as the unveiling of JATCO's Attractive Plant project. All of the press visitors expressed deep interest in the CVT production line during the tour.

10. Contract signing ceremony for AT supply to AvtoVAZ

JATCO and AvtoVAZ* held a contract signing ceremony on April 9, 2012 for AT supply to the Russian automaker. JATCO began shipping its JF414E 4-speed AT for small front-drive cars to AvtoVAZ in June 2012. This AT is fitted on AvtoVAZ's new Lada Granta, which was released in the Russian market in August 2012 and is AvtoVAZ's first AT-equipped model. Approximately 80,000 AT

11. JF405Eが生産累計500万台を達成

3月19日，JF405Eが生産累計500万台を達成したことを祝い，掛川工場にて記念式典が行われた．

旧ジャトコ時代の1998年，世界初となる軽自動車用の電子制御4速ATとして誕生したJF405Eは，生産当初から，ワゴンRの好調な販売とあいまって，増産につぐ増産を続けた．その後スズキに加え，GM-korea，現代など採用メーカーも増え，13年以上の長きにわたり，掛川工場を支え，掛川工場の代名詞にまでなっている．ステップATの500万台達成は，F03A，F04Aにつぐ3種目．

units are to be supplied annually. In this connection, in June 2012, JATCO opened a sales office for the supply of ATs in Togliatti where AvtoVAZ's headquarters is located.

*AvtoVAZ is Russia's largest automaker, established in 1966. Headquartered in Togliatti, Samara Region, AvtoVAZ produced some 560,000 vehicles in 2011.

11. Cumulative production of JF405E reaches five million units

A commemorative ceremony was held at the Kakegawa plant on March 19, 2012 to celebrate cumulative production of the five millionth unit of the JF414E AT. The JF405E was created in 1998, at the time of the former JATCO Corporation, as the world's first electronically controlled 4-speed AT for use on minivehicles. From the time production was launched, the production volume has been increased again and again, coupled with the brisk sales of the Suzuki R Wagon. In subsequent years, this AT was adopted by an increasing number of automakers, including GM Korea, Hyundai and others, in addition to Suzuki. That popularity supported production operations at the Kakegawa plant over a long period of 13 years, and the JF405E even became synonymous with the plant itself. This is JATCO's third stepped AT model to reach cumulative production of five million units after the F03A and F04A.

12. JF011E富士2地区での累計生産台数 300万台達成

JF011Eは2004年3月のSOPから，100万台まで49ヶ月，200万台まで76ヶ月，300万台まで98ヶ月と，加速度的に累計生産台数を伸ばして，富士2地区での累計生産は記録的な早さで300万台を達成した．（グローバルな生産台数は800万台を超えている）

13.キッズエンジニア2012開催

2012年8月3日パシフィコ横浜（展示ホールD）8月3日･4日の二日間，自動車技術会の主催する「キッズエンジニア2012」が実施され，ジヤトコも参加．夏休み期間，絶好のお出かけ日和ということもあり，開場前から入場を待つ家族連れが列を作った．

「遊星ギヤってなんだろう」と題する，ジヤトコのプログラムは，実物模型を分解･組立て，歯車を交換するなどして，遊星ギヤの基本的な仕組みを理解してもらうもの．ちょっと難しいかな…とも思える内容だが「これはサンギア，こっちはリングギア」と子供たちの理解力･記憶力は驚くほどのスピード．この中から未来のエンジニアが誕生することを期待する．

12. Cumulative production of JF011E in Fuji Area No. 2 reaches three million units

Cumulative production of the JF011E in Fuji Area No. 2 reached three million units at a record-setting pace. Following the start of production in March 2004, the one millionth unit was reached in 49 months, the two millionth unit in 76 months and the three millionth unit in 98 months. The cumulative production volume continued to increase at an accelerating pace. The global production volume of this unit now exceeds eight million units.

13. JATCO participates in Kids Engineers 2012

JATCO took part in Kids Engineers 2012, which was organized by the Society of Automotive Engineers of Japan at Pacifico Yokohama (Exhibition Hall D) on Friday-Saturday, August 3-4, 2012. Partly because it was such fine weather for an outing during the summer vacation, families waiting to get in formed a long line in front of the entrance.

JATCO's program focused on the theme: "What is a planetary gearset?" It was designed to give children a basic understanding of the mechanism of a planetary gearset by having them disassemble, assemble and replace the gears of life-size models. While there was some concern that the content might be too difficult for children, they understood and remembered the parts with astonishing speed. In no time they were able to say, "This is a sun gear and that's a ring gear." It is hoped that engineers will emerge from among them in the future.

特　許　紹　介

Patents

1. 自動変速機の変速制御装置

（Fig. 1）

出　願：出願日　2006.3.29　特願2006-90318
登　録：登録日　2010.9.10　特許第4584856号
名　称：自動変速機の変速制御装置
発明者：木村優典，小林淳文，落合辰夫，若林秀一，牧山明裕（日産自動車），門野亮路（日産自動車）

【目的】

変速段のオートアップ機能を維持しながらシフトビジーによる違和感を抑制する．

【発明の構成】

本発明の自動変速機の変速制御装置は，マニュアル変速モードで走行中に変速段のダウンシフト要求が行われた場合，当該ダウンシフト要求に基づいてダウンシフトした場合の変速機の入力軸回転速度を演算し，演算される回転速度が回転速度制限値より大きいと判定されると，入力軸回転速度が演算される回転速度より低くなる変速段にダウンシフトさせる．

【作用・効果】

ダウンシフトした直後に入力軸回転速度がオートアップ回転速度に達してアップシフトすることがなくなり，変速段がアップダウンすることによる違和感を防止できる．

1. Speed change control device for automatic transmission and control method thereof

(Fig. 1)

Application Number: 2006-90318
Application Date: 3.29,2006
Patent Number: 4584856
Registration Date: 9.10,2010
Title: Speed change control device for automatic transmission and control method thereof
Inventor: Kimura Yusuke; Kobayashi Atsufumi; Ochiai Tatsuo; Wakabayashi Shuichi; Makiyama Akihiro (Nissan); Kadono Ryoji (Nissan)

【SUMMARY OF THE INVENTION】

A speed change control device for an automatic transmission according to this invention determines whether or not a request to downshift a gear position of the transmission exists during traveling in a manual speed change mode, and calculates an input shaft rotation speed of the transmission following a downshift based on the downshift request. When it is determined that the calculated rotation speed is higher than a rotation speed limit value, the speed change control device performs a downshift to a gear position at which the input shaft rotation speed of the transmission is lower than the calculated rotation speed.

A situation in which the input shaft rotation speed of the transmission reaches an auto upshift rotation speed such that an upshift is performed immediately after the downshift can be prevented. As a result, the sense of discomfort felt by a driver due to rapid changes in the gear position can be prevented.

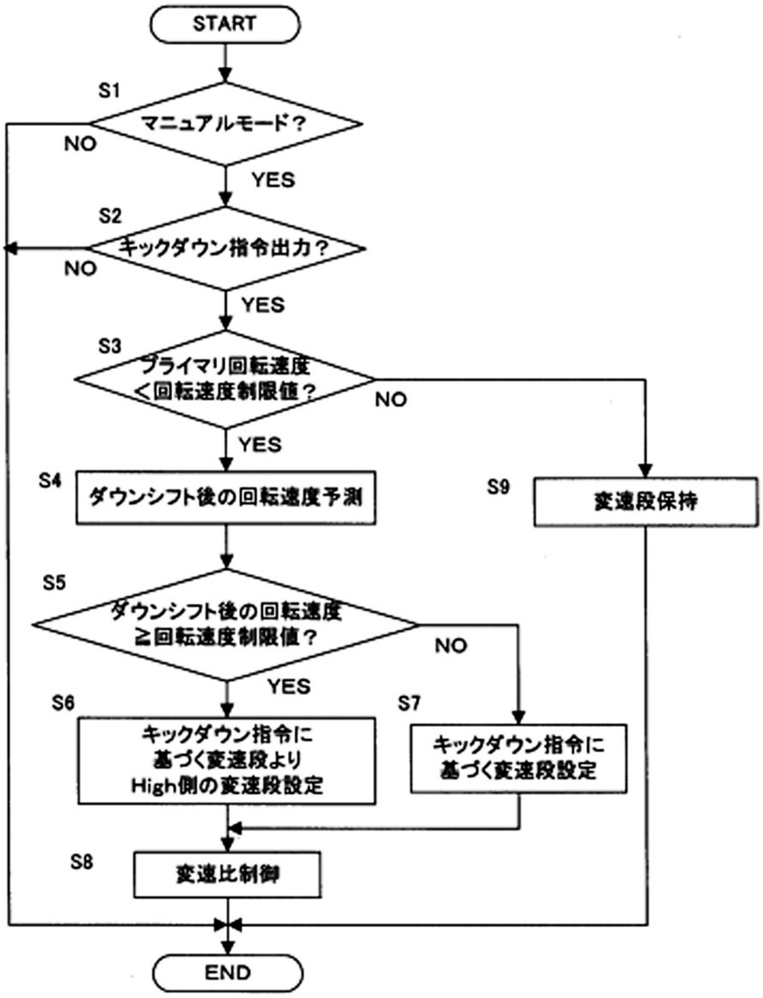

START
S1
マニュアルモード？
NO
YES
S2
キックダウン指令出力？
NO
YES
S3
プライマリ回転速度
＜回転速度制限値？
NO
YES
S4
ダウンシフト後の回転速度予測
S9
変速段保持
S5
ダウンシフト後の回転速度
≧回転速度制限値？
NO
YES
S6
キックダウン指令に
基づく変速段より
High側の変速段設定
S7
キックダウン指令に
基づく変速段設定
S8
変速比制御
END

Fig. 1

2.無段変速機，およびその変速制御方法

（Fig. 2）

出　願：出願日　2009.7.17　特願2009-169142
登　録：登録日　2012.1.27　特許第4914467号
名　称：無段変速機及びその変速制御方法
発明者：野々村良輔，田中寛康，井上拓市郎，
　　　　関　丈二，井上真美子，
　　　　高橋誠一郎（日産自動車）

【目的】

副変速機構の変速段の変更を伴うキックダウン変速時に，駆動力の立ち上がり遅れ，変速フィーリングの悪化を防止する．

【発明の構成】

コントローラーは，副変速機構の変速段を変更する場合，変速機のスルー変速比が目標スルー変速比となるよう，副変速機構の変速比を変化させつつ副変速機構の変速比の変化方向と逆方向にバリエーターの変速比を変化させる協調変速を行う．一方，副変速機構の変速段の変更を伴うキックダウンのとき，協調変速に代えて，協調変速のときよりも速い速度で副変速機構の変速段を2速から1速に変更する非協調変速を行う．

【作用・効果】

キックダウン変速のときには，協調変速ではなく非協調変速を行うため，スルー変速比は速やかに変速比大側に変化し，駆動力が速やかに立ち上がり，変速フィーリングが向上する．

2. Continuously variable transmission and control method thereof

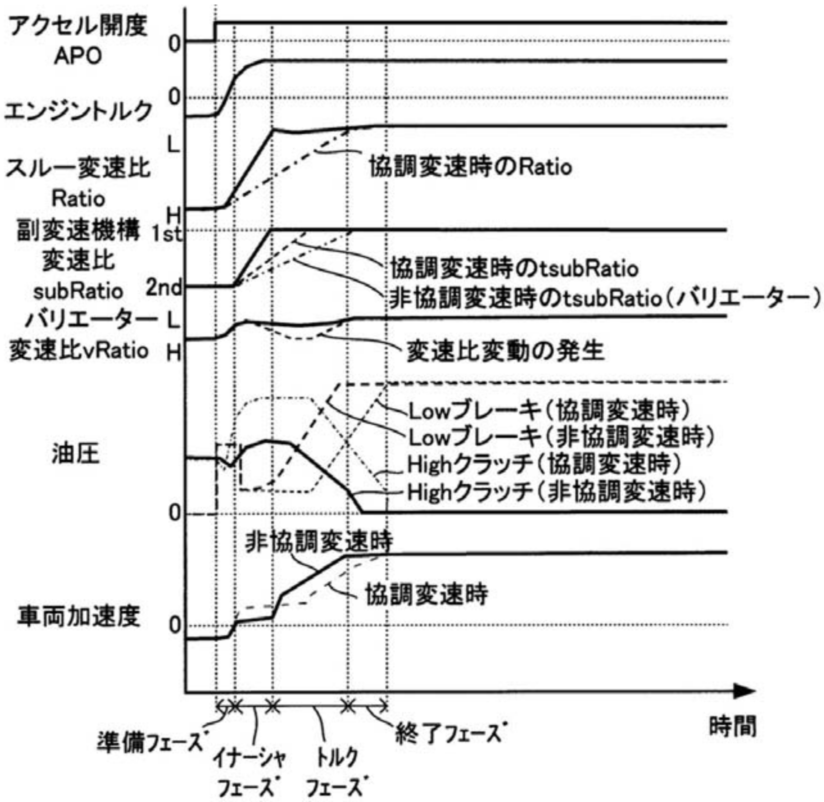
(Fig. 2)

Application Number: 2009-169142
Application Date: 7.17,2009
Patent Number: 4914467
Registration Date: 1.27,2012
Title: Continuously variable transmission and control method thereof
Inventor: Ryousuke Nonomura; Hiroyasu Tanaka; Takuichiro Inoue; Seki Joji; Mamiko Inoue; Takahashi Seiichiro (Nissan)

【SUMMARY OF THE INVENTION】

The transmission controller performs a non-coordinated shift, in which the gear position of the subtransmission mechanism is modified from the second gear position to the first gear position at a higher speed than when the gear position of the subtransmission mechanism is modified by a coordinated shift while permitting a deviation between the through speed ratio and the target through speed ratio, instead of the coordinated shift when it is determined that the second speed kick down shift is to be performed.

When a second speed kick down shift accompanied by a 2-1 shift in the subtransmission mechanism is performed, the non-coordinated shift is performed instead of the coordinated shift, and therefore the through speed ratio of the transmission can be varied to the large speed ratio side quickly, enabling rapid driving force increase and an improvement in shift feeling.



アクセル開度
APO
0
エンジントルク
0
スルー変速比
Ratio
L
H
協調変速時のRatio
副変速機構
変速比
subRatio
1st
2nd
協調変速時のtsubRatio
非協調変速時のtsubRatio（バリエーター）
バリエーター
変速比vRatio
L
H
変速比変動の発生
油圧
0
Lowブレーキ（協調変速時）
Lowブレーキ（非協調変速時）
Highクラッチ（協調変速時）
Highクラッチ（非協調変速時）
車両加速度
0
非協調変速時
協調変速時
時間
準備フェーズ
イナーシャ
フェーズ
トルク
フェーズ
終了フェーズ

Fig. 2

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