Development of a new 9-speed automatic transmission for rear-wheel-drive vehicles

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Summary

JATCO launched production of a new 9-speed automatic transmission for rear-wheel-drive vehicles in September 2019. Since 2008, JATCO had been supplying a 7-speed automatic transmission for use on rear-wheel-drive vehicles, but higher environmental performance has been required of conventional transmissions in recent years. The new 9-speed automatic transmission was developed with the aim of achieving ultimate efficiency and ultimate response. In addition to environmental performance, driveability and vehicle mountability were also substantially improved.

1. Introduction

The new 9-speed automatic transmission (9AT) for rear-wheel-drive vehicles was developed around the themes of "ultimate efficiency and ultimate response". As vehicle manufacturers everywhere shift to transmissions with more speeds in pursuit of higher fuel economy, JATCO ultimately selected a 9-speed unit.

Adding more speeds enables wider ratio coverage for improved launch acceleration performance and a lower engine speed during high-speed cruising for improved fuel economy. On the negative side, the number of planetary gears, multi-plate clutches and other component parts increases, making the structure more complex and larger. Naturally, increasing the number of elements involved in transmitting torque also tends to worsen power transmission efficiency if nothing is done about it. In addition, shift patterns markedly increase, which can lead to more shift busyness and deterioration of response. In short, although there are advantages for launch acceleration and high-speed-cruising fuel economy, adding more speeds is meaningless unless efficiency and response are improved.

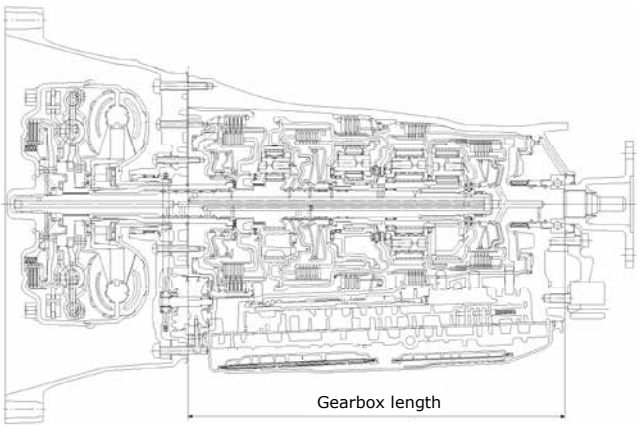

Fig. 1 Main cross-sectional view

This article describes the technologies adopted to achieve ultimate efficiency and ultimate response.

2. Overview of new 9AT

2.1 Development concept

The development concept consisted of the following three points, centered on the key themes of high efficiency and high response as mentioned above.

(1) To improve powertrain efficiency over that of the existing 7-speed automatic transmission (7AT) for rear-wheel-drive vehicles in order to ensure fuel economy competitiveness.

(2) To improve response and shift performance over that of the existing 7AT in order to provide immediate response to customers' driving operations and a smooth, delightful shift feeling.

(3) To suppress increases in size and mass due to the adoption of nine speeds.

2.2 Main cross-section and specifications

Figure 1 is a main cross-sectional view of the newly developed 9AT, and Table 1 lists the basic specifications of the unit in comparison with those of the existing 7AT. One major feature of the new 9AT is that it achieves class-leading ratio coverage of 9.1. In addition, despite having nine speeds, it has four planetary gear sets, the same number as the 7AT, and six shift elements, fewer than the

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Table 1 Comparison of specifications

		7AT	New 9AT
Torque capacity		560 Nm	700 Nm
Torque converter size		UUF 260 mm dia.	UF 260 mm dia.
Lock-up		Torsional damper	Torsional + Pendulum
Gear ratios	Ratio coverage	6.3	9.1
	1st	4.887	5.425
	2nd	3.170	3.263
	3rd	2.027	2.250
	4th	1.412	1.649
	5th	1.000	1.221
	6th	0.864	1.000
	7th	0.775	0.862
	8th	-	0.713
	9th	-	0.597
	Rev	4.041	4.799
Shift control		Mechanical	Park/Shift by wire
Oil pump		Mechanical	Mechanical + Electric
Transmission case		Aluminum	Magnesium
Oil pan		Steel	Plastic
Shift elements		7 Clutches/Brakes	6 Clutches/Brakes
Planetary gear sets		4	4
Weight (wet)		109 kg	99.5 kg
Gearbox length		501.5 mm	439.5 mm

7AT. The gearbox is also shorter in overall length than the 7AT. Moreover, the torque converter is fitted with a pendulum damper and the new unit also weighs less than the 7AT even though the electric oil pump (including the inverter) and the parking brake actuator are built in.

Figure 2 compares the ratio coverage of the 7AT and the new 9AT, and Fig. 3 compares their step ratios. The ratio coverage of the new 9AT has been expanded on both the Low and High gear ratio sides. The step ratio has been set with smaller differences between the preceding and following speeds than that of the 7AT and with close gear ratios on the frequently-used Low gear ratio side. This achieves delightfully rhythmical shifting during launch acceleration.

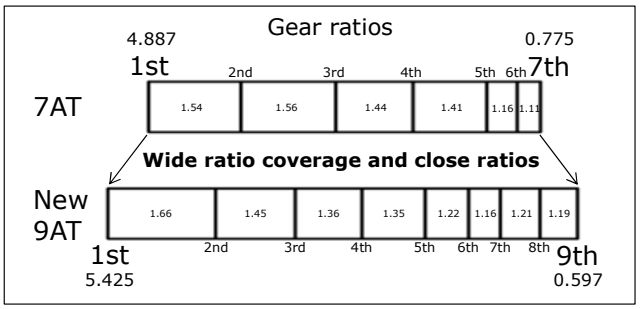

Fig. 2 Gear ratio comparison

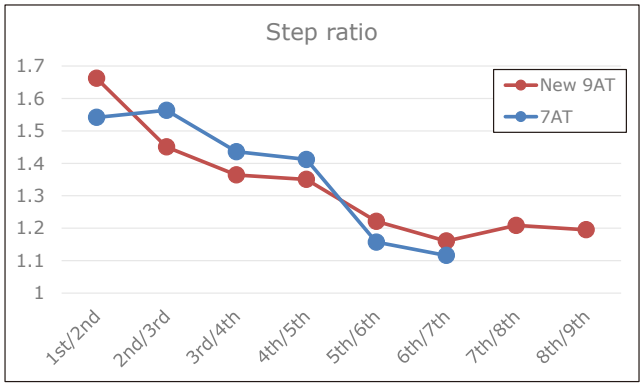

Fig. 3 Step ratio comparison

3. Technologies adopted to achieve the development concept

3.1 Contributions to higher efficiency

• Full bearing support structure

All of the rotating elements are positioned on the long input shaft. The support structure has been changed from the previous bushings to a full bearing support structure for reducing friction (Fig. 4).

• Pendulum damper

A pendulum damper has been adopted inside the torque converter in addition to the existing torsional damper.

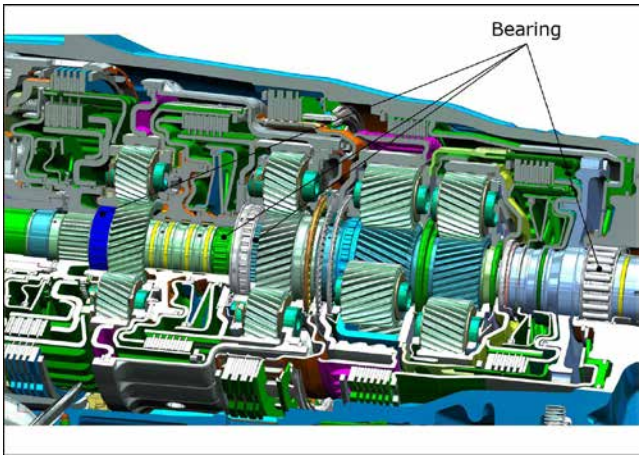

Fig. 4 Full bearing support structure

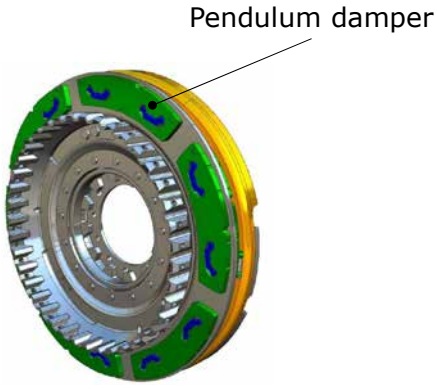

Fig. 5 Pendulum damper

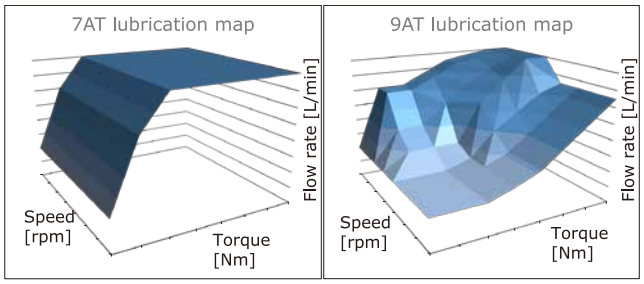

Fig. 6 Lubrication map comparison

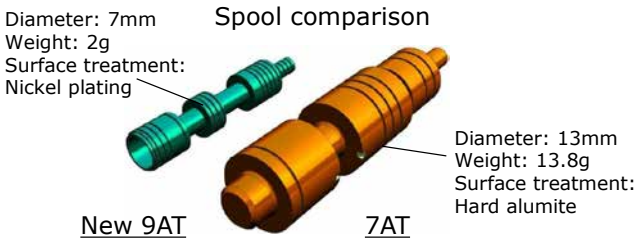

Fig. 8 Spool comparison

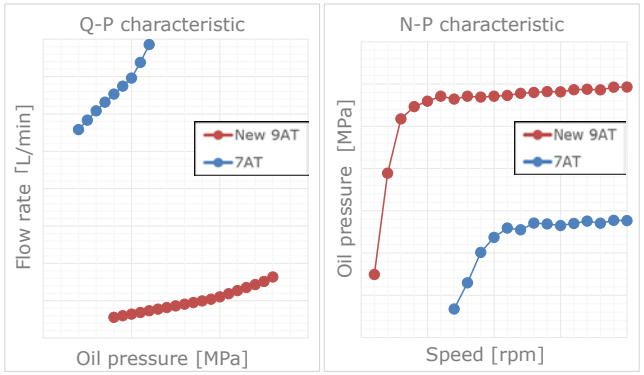

Fig. 7 Comparison of hydraulic characteristics

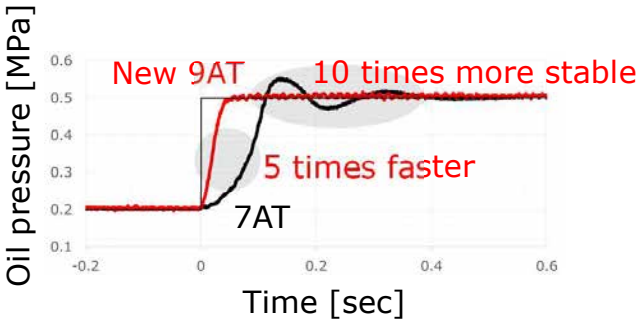

Fig. 9 Hydraulic response comparison

This has improved noise, vibration and harshness (NVH) performance and enabled expansion of the lockup region (Fig. 5).

• Waved drive plate

All shift elements adopt a waved drive plate that reduces drag friction when pulled away from the driven plate during disengagement. It also ensures durability in the high speed range owing to the optimum lubricant flow rate setting described below.

• Optimum lubricant flow rate setting

A lubricant pressure solenoid and a pressure regulator were adopted so that the lubricant flow rate can be controlled unrelated to the line pressure. This makes it possible to regulate the necessary lubricant flow rate to match the driving situation and achieves both a friction reduction and durability (Fig. 6).

3.2 Contributions to improving response

• Reduction of hydraulic circuit leakage

The clearance between the control valve bore and spools was made smaller for the purpose of reducing the amount of fluid flow leakage. The necessary level of hydraulic pressure is obtained at a low flow rate in combination with a small vane oil pump driven by a chain from the input shaft. This enables efficient hydraulic pressure control from the low speed range, thereby improving response (Fig. 7).

• Improvement of clutch control pressure response and stability

A lightweight, small-diameter nickel-plated spool was adopted for each clutch valve to enable variable dither control in all pressure ranges. It also dramatically improves response and stability (Figs. 8 & 9).

3.3 Contributions to size and weight reductions

The technical measures noted below were among those adopted to reduce the size and weight of the new 9AT, thereby suppressing increases in size and weight relative to the existing 7AT.

• Weight reduction through material substitution

  • Magnesium alloy case
  • Plastic oil pan
  • Aluminum bolts

• Use of high-density layout for shortening overall length (Fig. 10)

  • Thin-walled, press-formed parts made of high tensile strength steel sheet
  • Rotation detection by magnetic encoder

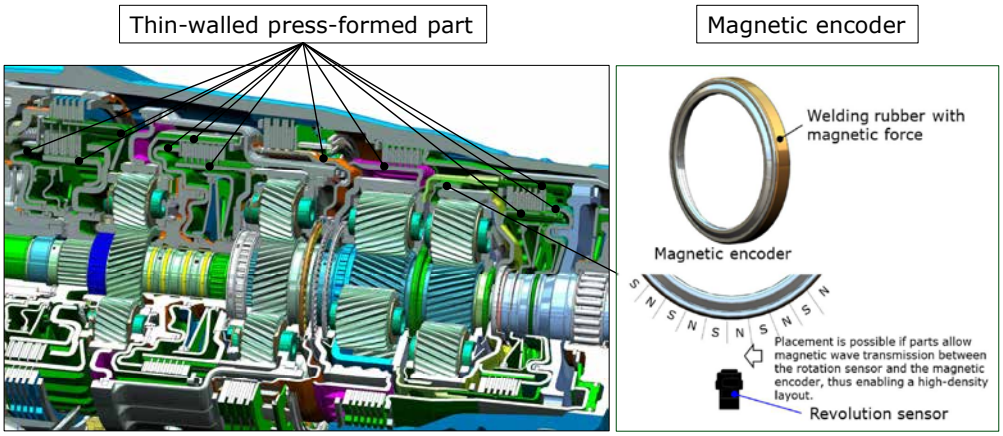

Fig. 10 Techniques for shortening axial length

4. Conclusion

Automotive transmissions today must be developed to provide higher power transmission efficiency. That was a prerequisite condition for the addition of more speeds to create the new 9AT described here.

Moreover, it was also essential to improve response in order to take full advantage of higher efficiency. The ultimate efficiency and ultimate response targets set for the newly developed 9AT were attained through the adoption of the technical measures described in this article.

There were many technical measures and engineering methods that JATCO adopted for the first time, thus providing a stockpile of technologies that can be fed back for developing and manufacturing new products in the future.

In future work, efforts will be made to further improve the competitiveness of conventional engine-AT combinations and also to prepare for a shift to electrification.

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