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

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Summary

A torque converter was newly developed for a new 9-speed automatic transmission for use on rear-wheel-drive vehicles for the purpose of improving the efficiency of the transmission. Various improvements were made compared with the torque converter of an existing 7-speed automatic transmission used on the same vehicle type. A pendulum dynamic vibration absorber was adopted as a damping mechanism in addition to the torsional damper. A hydraulic circuit structure for effectively cooling the lockup clutch friction material was adopted along with a structure for reducing the surface pressure of the friction material. As a result, quietness and anti-shudder durability were improved while expanding the region of lockup operation. This article describes the details of the newly developed torque converter.

1. Introduction

Various technical measures were taken to improve the vehicle fuel economy obtained with a new 9-speed automatic transmission (9AT) for rear-wheel-drive vehicles. More speeds were added, the vehicle speed for initiating torque converter (TC) lockup (LU) was lowered, and a low-viscosity automatic transmission fluid (ATF) was adopted for reducing friction.

The adoption of these technical measures made it necessary to solve two principal TC technical issues. One was to improve quietness in the speed range with large engine torque fluctuation owing to the lower vehicle speed for LU operation. The other was to improve the anti-shudder durability of the LU clutch friction material in connection with the use of a low-viscosity ATF different from existing transmission fluids.

This article describes the efforts undertaken to address these issues.

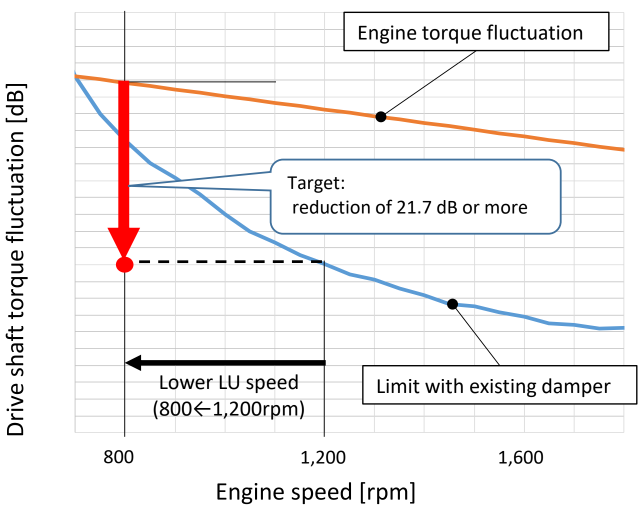

Fig. 1 Quietness target

2. Performance issues and solutions

2.1 Quietness

The reduction of the vehicle speed for LU operation involves using a low engine speed range with large torque fluctuation. This worsens booming noise, characterized as a vibration phenomenon producing a relatively low frequency noise with an oppressive feeling among various interior noises.

The engine speed for initiating LU operation of the new 9AT was changed to 800 rpm from 1,200 rpm of the existing 7-speed automatic transmission (7AT) for use on rear-wheel-drive vehicles. The lower speed increases the torque fluctuation level in the drive shaft, representing a typical characteristic of booming noise. In order to achieve the quietness target, it was necessary to obtain the same level of drive shaft torque fluctuation as that of the existing unit. To accomplish that, the target set for drive shaft torque fluctuation at 800 rpm was to reduce it by 21.7 dB or more compared with the level of engine torque fluctuation (Fig. 1).

The measures taken previously for the existing TC included increasing the amount of inertia, lowering the

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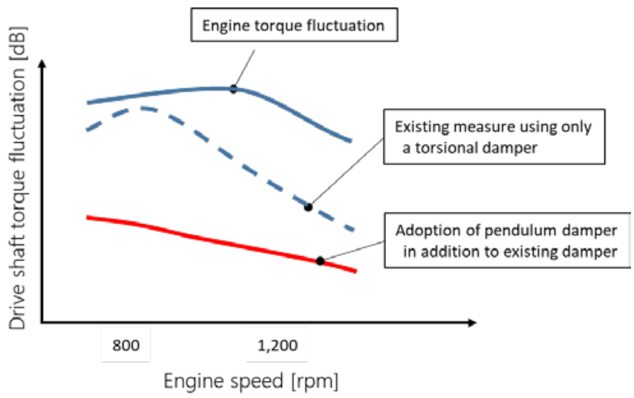


Fig. 2 Effect of adding a pendulum damper

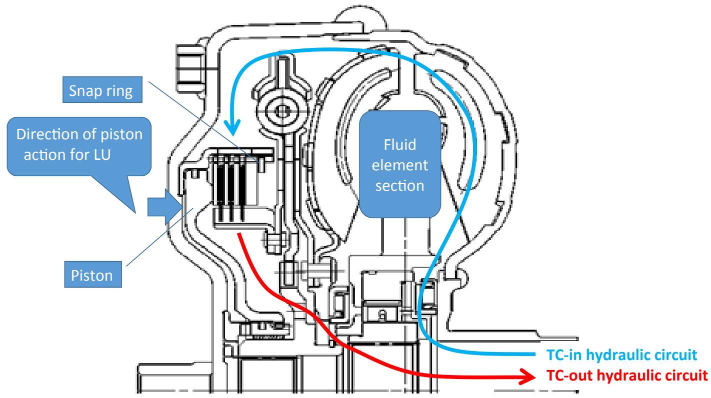
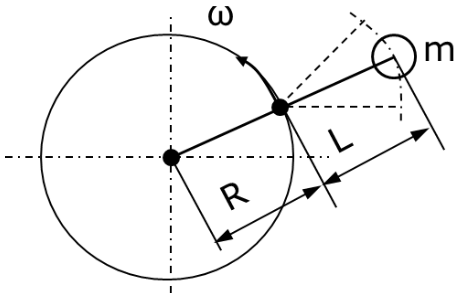


Fig. 4 Structure of hydraulic circuits and LU clutch of existing 7AT



ω: angular velocity
m: mass
R: distance from spindle rotation center to pendulum damper rotation center
L: distance from pendulum damper rotation center to mass center of gravity

Fig. 3 Principal pendulum damper parameters

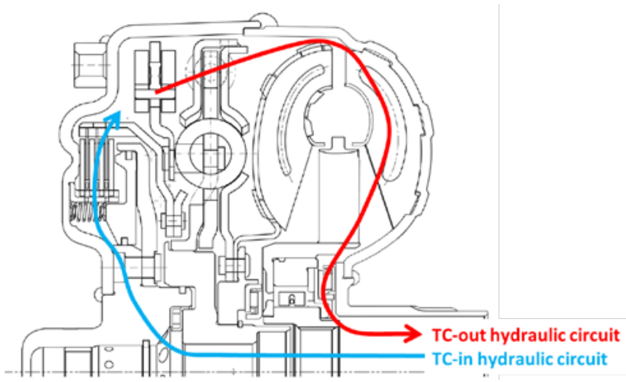


Fig. 5 Structure of hydraulic circuits and LU clutch of new 9AT

stiffness of the torsional damper and reducing hysteresis torque. However, because the quietness target could not be achieved with these measures, it was decided to newly adopt a pendulum damper as a damping mechanism for the new 9AT.

A pendulum damper generates damping force by activating the pendulum in the opposite phase according to the input vibration frequency. Reducing the damper stiffness and other previous measures only served to shift the resonance point, so a pendulum damper was added in addition to the existing torsional damper with the aim of reducing the level of drive shaft torque fluctuation itself (Fig. 2).

Figure 3 shows the principal parameters needed for designing the pendulum damper. In order to apply these principal parameters to the design of the pendulum damper, it was necessary to determine the natural frequency in Eq. (1) and the damping force T in Eq. (2).

$$f = \frac{\omega}{2\pi}\sqrt{\frac{R}{L}} \quad (1)$$

$$T = m(R+L)\omega^2 R\theta \quad (2)$$

The natural frequency is defined to match the number of engine cylinders using the ratio of R to L, where R is the distance from the pendulum center to the center of rotation and L is the distance from the mass to the pendulum center. In order to obtain large damping force, it is necessary to set the mass M and the distances R and L as large as possible.

Given the layout restrictions in this project, an effort was made to achieve the target set for drive shaft torque fluctuation by suitably allocating the damping force and order factors so as to obtain the maximum damping effect.

2.2 Anti-shudder durability

The most important factor for improving the anti-shudder durability of the LU clutch friction material is to reduce the sliding surface temperature when the friction material slides on the mating clutch plate. To reduce the sliding surface temperature of the friction material, the hydraulic circuit structure and the LU clutch structure were improved.

The LU clutch structure was improved so as to enhance the cooling performance of the LU clutch friction material. The existing hydraulic circuit is structured such that ATF heated in the fluid element section is supplied to the LU clutch section. In contrast, the improved hydraulic circuit supplies ATF directly to the LU clutch friction material from the cooled TC-in hydraulic circuit for supplying ATF to the TC.

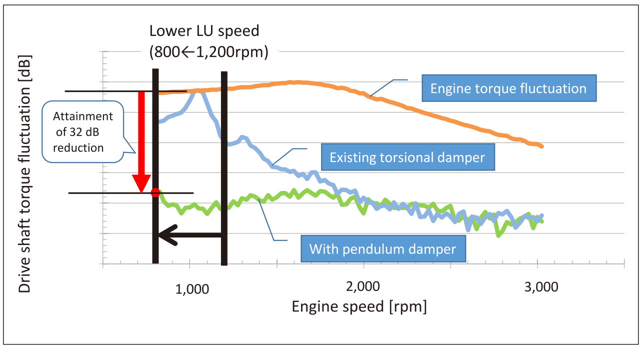


Fig. 6 Effect of quietness improvement

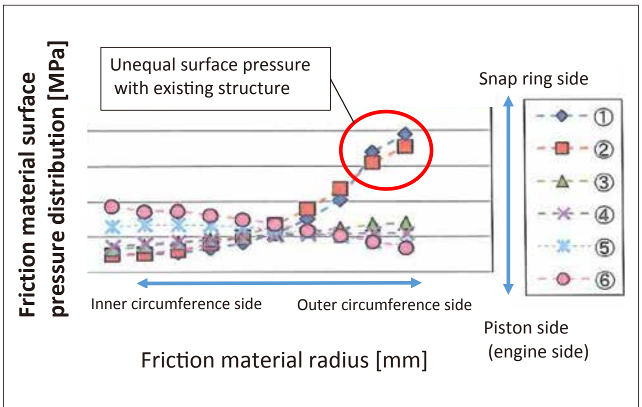


Fig. 7-1 Surface pressure distribution of friction material with existing structure

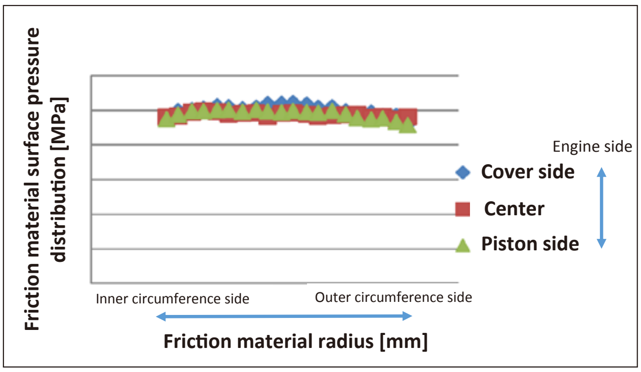


Fig. 7-2 Surface pressure distribution of friction material with new 9AT

In the existing 7AT, the LU clutch is structured such that a snap ring receives the load applied by the LU piston. In the new 9AT, the piston and the TC cover both receive the load at the center of the inner and outer diameter of the LU clutch friction material. The LU clutch structure was improved so that it equalizes the surface pressure on the sliding surface of the LU clutch friction material (Figs. 4 and 5).

3. Effects of improvements

3.1 Quietness

As a result of adding a pendulum damper in addition to the existing torsional damper, torque fluctuation was effectively reduced by 32 dB, exceeding the reduction target of 21.7 dB. This enabled the vehicle speed for LU operation to be reduced, thus contributing to improving vehicle fuel economy (Fig. 6).

3.2 Anti-shudder durability

As a result of making structural changes, the surface pressure distribution on the friction material was improved from that shown in Fig. 7-1 to the distribution in Fig. 7-2. In addition, together with the effect of the improved cooling

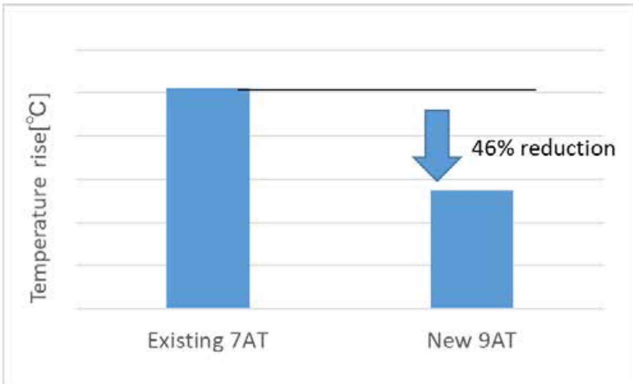


Fig. 8 Effect of reducing friction material temperature

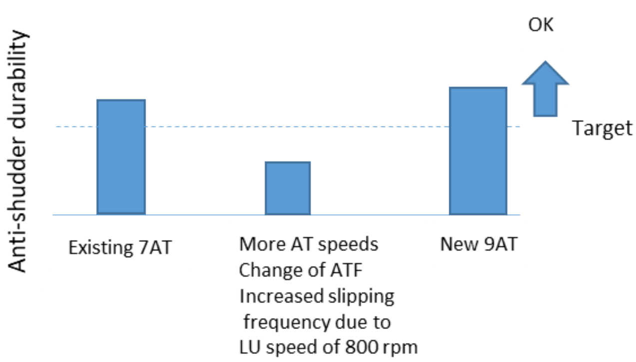


Fig. 9 Effect of improving anti-shudder life

performance, the rise in friction material temperature at the same level of heat generation was reduced by 46% with the improved structure compared with that of the existing AT (Fig. 8).

The reduction of the temperature rise resulted in a difference in ATF performance. As a result, anti-shudder durability was improved over that of the existing 7AT even under conditions where slipping occurs more frequently (Fig. 9).

3.3 Satisfying both performance and layout requirements

Simply combining the pendulum damper for improving quietness and the structural changes to the hydraulic circuit and the LU clutch for improving anti-shudder durability would increase the axial length of the new unit. Accordingly, the pendulum damper was positioned on the outer circumference side for the purpose of securing the desired damping force, while the position of the LU clutch was kept as it was on the inner circumference side. This had the effect of eliminating dead space inside the TC. In addition, with regard to the torsional damper, the parent spring that always receives torsional torque was positioned on the inner circumference, and the secondary spring that is only used against excessive inputs was positioned on the outer circumference. These specifications made it possible to satisfy the required performance without extending the axial length (Fig. 10).

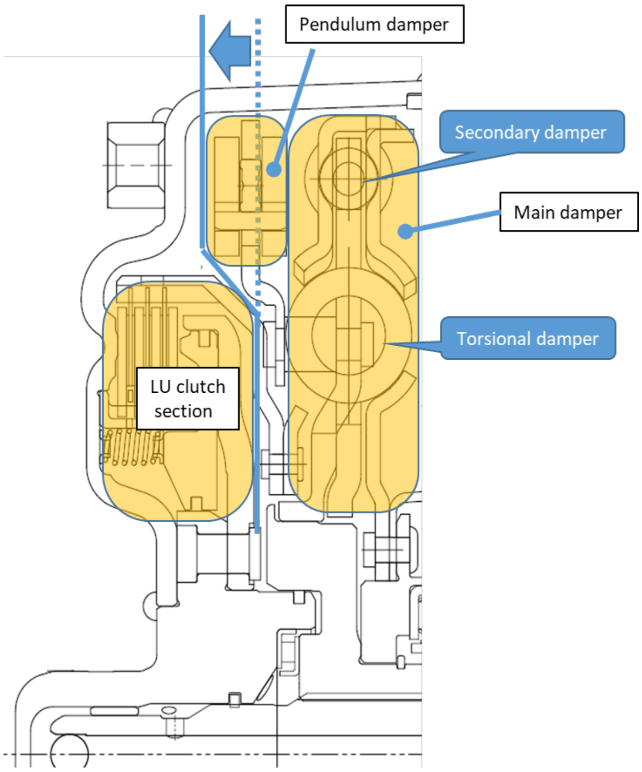


Fig. 10 Layout of new 9AT

4. Conclusion

The TC developed for the new 9AT adopts a pendulum damper to enhance quietness as well as improved structures for the hydraulic circuit and the LU clutch to improve anti-shudder durability.

The pendulum damper, hydraulic circuit and LU clutch structure designed for this TC represent basic JATCO technologies, and the application of the same structures to other new units is now being considered.

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