

Research on Reduction of Unusual Noise in Wet Multiple Disk Clutch for 4WD

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ABSTRACT

When AT clutches are utilized in torque-on-demand 4WD systems, in which rear wheel traction is controlled by pushing force from a wet multiple disc clutch, an unusual noise is generated during turning or takeoff by the continuous input of differences in speed. The status of lubrication in a clutch unit in isolation was analyzed to find the cause, and results showed that the lubrication flow rate to the clutch was low, and that the lubricant was not being uniformly supplied to every section. A test vehicle was set up to reproduce the conditions of the unit analysis, and the unusual noise occurring in the unit was effectively reproduced. It was determined that the noise is related to the ratio of porosity and the amount of deflection in friction materials. These results enabled the specifications of the lubricant to be improved. In addition, friction materials with increased porosity and deflection were developed to improve the oil retention characteristic in the clutch. Vehicle tests were repeated employing these measures, and no unusual noise was generated.

1. Introduction

Recently, wet multiple disc clutches have come into increasing use in FFD vehicle-based torque-on-demand type 4-wheel drive systems. Sometimes, automatic transmission clutches are used as wet multiple disc clutches, but there are considerable differences between the use conditions in AT and 4-wheel drive transmissions, so these components actually require quite different types of performance. Differences in speed in AT occur in a short period of shifting, while differences in speed constantly occur in torque-on-demand 4-wheel drive systems, due to slipping of the front wheels, so the engaging time of the clutch is long and the engaging frequency is high. Consequently, an unusual noise is sometimes emitted from the clutch during turning, when differences in speed occur continuously, and during takeoff.

This project consisted of three stages: The factors in the

unusual noise from the clutch during turning and takeoff were analyzed; a reproducing mode was constructed in an actual vehicle; and specifications were proposed to counter the issue.

2. Issues in Adoption of Automatic Transmission Clutches

2.1. Configuration of 4-Wheel Drive Systems

The dual-pump system (DPS) used by Honda is an example of the torque-on-demand 4-wheel drive systems.

As shown in Fig. 1, in this system, oil pressure generated by a rotation speed difference between the front and rear wheels is applied to a piston, which moves a multiple disc clutch through a mechanism.

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This is composed of the pump body which generates the oil pressure, the clutch which converts the piston thrust into torque, and the rear differential which distributes the torque to the right and left wheels.

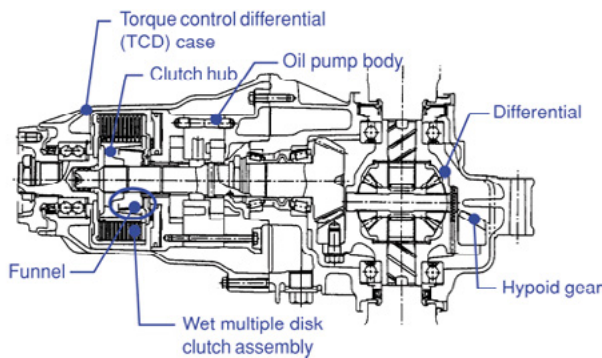


Fig. 1 Structure of DPS

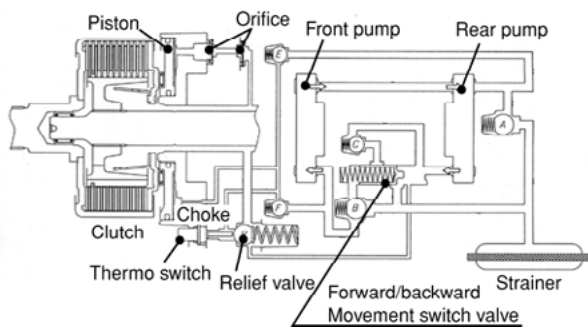


Fig. 2 Hydraulic circuit of DPS

2.2. Issues in Use Conditions of 4-Wheel Drive

A vehicle containing a DPS with an automatic transmission clutch was test-driven in continuous turns on pavement. Figure 3 shows the rear propeller shaft torque, difference of speed at the DPS clutch, and rear differential case vibration data. The unusual noise generated during clutch engagement was a metallic sound; as Fig. 4 shows, it had a frequency of about 500 Hz.

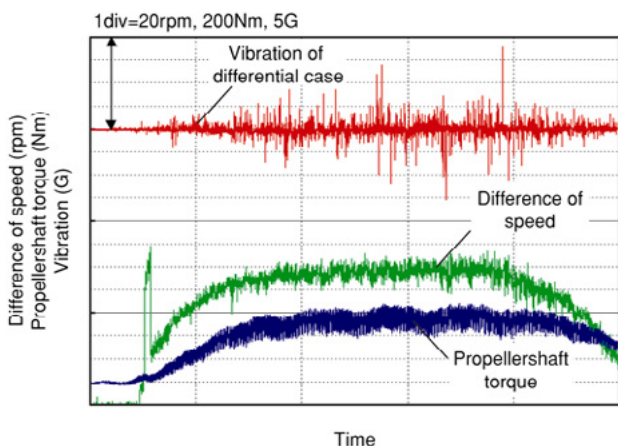


Fig. 3 Example of unusual noise

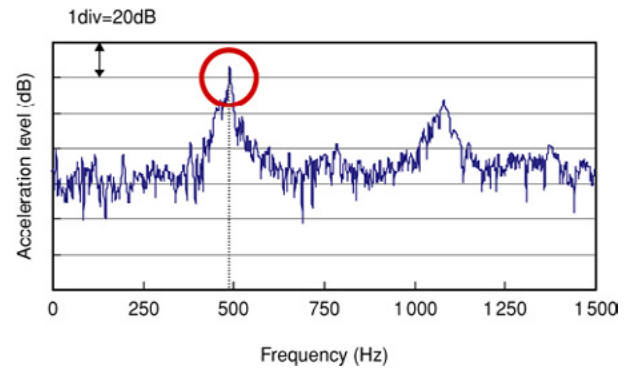


Fig. 4 Frequency characteristic of unusual noise

Visual confirmation of the clutch generating the unusual noise indicated, as shown in Fig. 5, that the plate had been polished to a mirror finished surface in contrast to the appearance of a normal (quiet) plate, and blemishes had been produced by local contacts. The surface roughness of the quiet plate and the plate producing the unusual noise are compared in Table 1. The arithmetical mean deviation of the profile on the quiet plate ranged $0.126\ \mu\text{m} - 0.252\ \mu\text{m}$, while that of the plate producing unusual noise was $0.088\ \mu\text{m} - 0.167\ \mu\text{m}$.

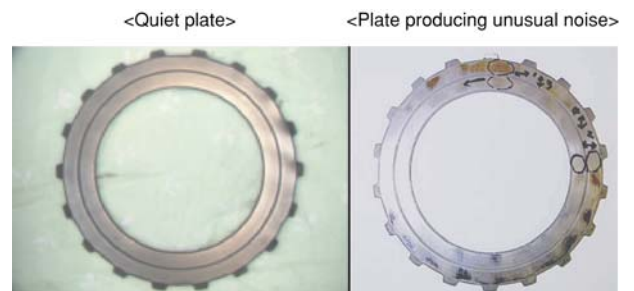


Fig. 5 Condition of clutch plate surface

Table 1 Comparison of surface roughness of clutch plates

Ra (μm)	Quiet plate	Plate producing unusual noise
Minimum value	0.126	0.088
Maximum value	0.252	0.167

3. Analysis of Factors

3.1. Measuring Lubricant Flow Rate

The flow rate of lubricant was checked as part of the analysis of factors in the polishing of the clutch plate surface. In the DPS, lubrication is done by supplying oil from the pump body, as shown in Fig. 6. It had been assumed that all the oil emitted by the pump body was supplied to the clutch, so the flow rate at the clutch had always been measured from pump body only. In this project, however, the flow actually passing through the clutch was measured to determine lubricant supply flow rate. Figure 7 diagrams the new method of measurement, and Fig. 8 furnishes a comparison of the calculated flow rate with the amounts actually measured at the pump body and at the clutch.

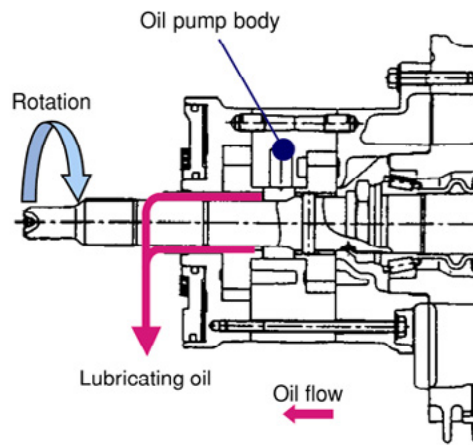


Fig. 6 Conventional lubrication measurement method

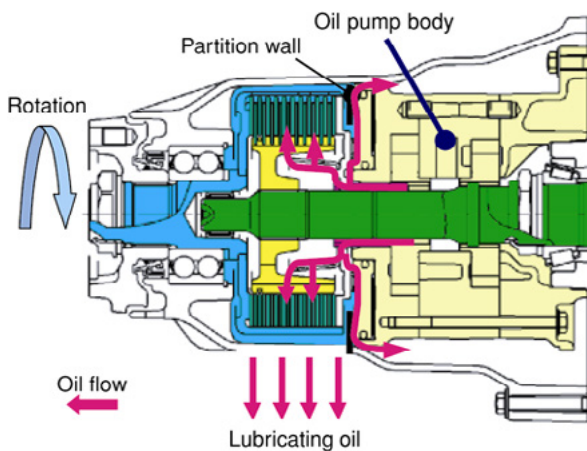


Fig. 7 Modified lubrication measurement method

In the conventional method, the flow rate reached its maximum value at vehicle speeds of 30 km/h or higher, and was close to the theoretical levels when the vehicle was moving at under 10 km/h, speeds normal during parking or takeoff from a junction. The new measuring method showed, however, that only about 70% of the theoretical flow rate of lubricant was supplied to the clutch at low vehicle speeds.

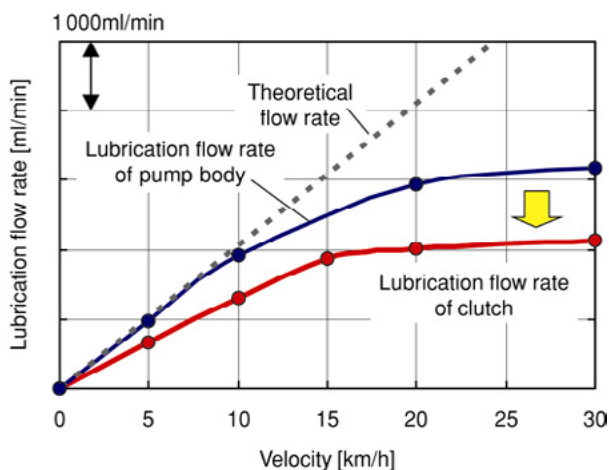


Fig. 8 Comparison of lubrication flow rate

3.2. Setting Reproducing Mode in Actual Vehicle

The results of the measurements of lubricant flow rate predicted that supply is low during parking and takeoff on snow-covered roads. This is expected, since the vehicle speed is low, and in turn, the oil pump runs at low RPM. The input torque is high in these running modes, however, as is clutch engagement frequency. Accordingly, it was attempted to create modes which would reproduce unusual noise and mirror-polishing of the clutch plate surfaces by combining the parking condition and takeoff from low- μ surfaces (see Fig. 9).

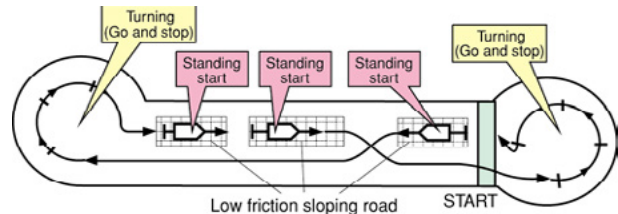


Fig. 9 Modified vehicle confirmation mode

3.3. Verification of Reproducing Mode in Actual Vehicle

On examining the vehicle after carrying out the reproducing mode, the unusual noise was noted during turning and takeoff on the low- μ surfaces. Also, as visible in Fig. 10, the clutch plate exposed to the reproduction mode showed the same mirror finished surface as the plate which had produced the unusual noise.

The results of roughness measurements of these plates shown in Table 2, indicate levels below $0.1 \mu\text{m}$. This indicates that the conditions creating the plate which had produced the unusual noise had been reproduced.

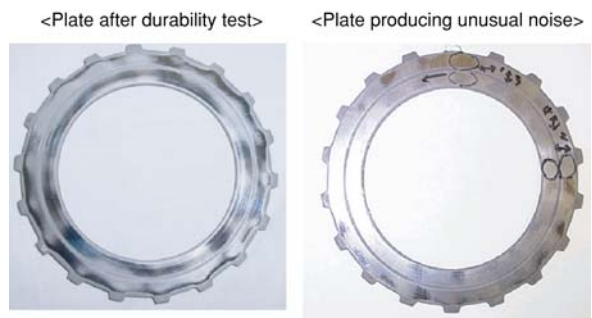


Fig. 10 Comparison of clutch plate condition

Table 2 Comparison of surface roughness of clutch plates

Ra (μm)	Plate after durability test	Plate producing unusual noise
Minimum value	0.017	0.088
Maximum value	0.106	0.167

4. Specifications for Measures against Unusual Noise

4.1. Improving Lubricant Specifications

4.1.1. Lubricant flow rate

The causes for the ineffective supply of lubrication at the

clutch were confirmed visually. When the pump is isolated, ordinarily, lubricant is only ejected in the direction of the clutch; with the clutch installed in place, however, lubricant was seen to be leaking in the opposite direction, as shown in Fig. 11.

This turned out to be due to blockage of the lubricant when the clutch was attached; oil was found to be leaking through the key slot for driving the rear pump. A collar was attached over the key slot, as in Fig. 12, to prevent the leak. This increased the flow in the low-speed region by about 20% as shown in Fig. 13.

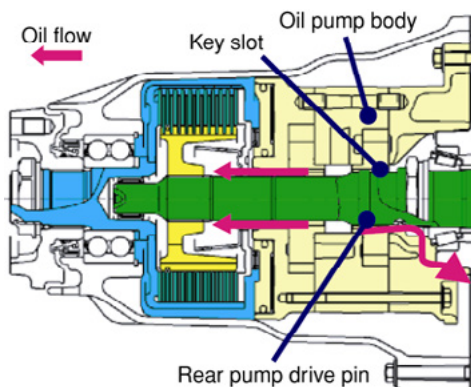


Fig. 11 Lubricating oil flow in DPS assembly

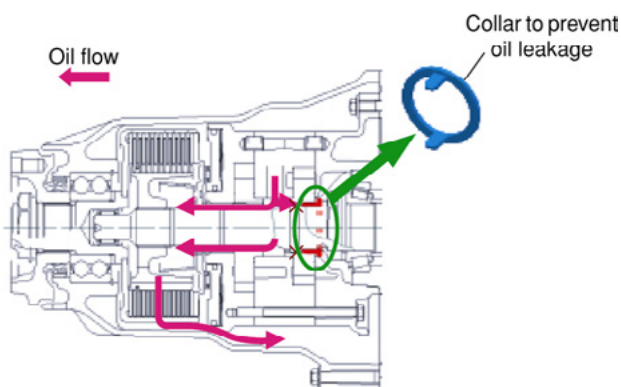


Fig. 12 Modified lubricating oil flow

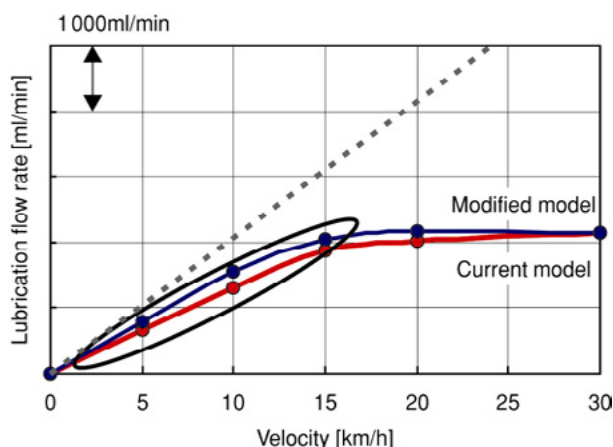


Fig. 13 Comparison of lubrication flow rate

4.1.2. Distribution of clutch lubricant

Next, a visual confirmation of lubricant distribution in the clutch showed that there was a large flow emitted from the clutch guide from the side close to the oil pump to the vicinity of the center, but lower volumes were seen farther from the pump.

This can probably be attributed to the oil flying off under centrifugal force when passing through the funnel, whose purpose is to distribute the oil (see Fig. 14).

A wall was added to partially obstruct the slit of the hub in the clutch, as shown in Fig. 15, to catch flying oil and maintain a better supply of oil in the locations distant from the oil pump.

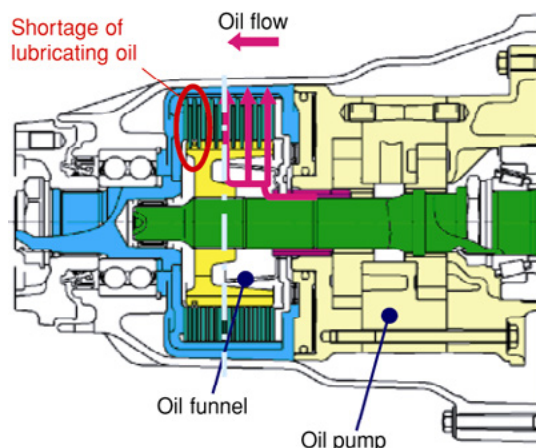


Fig. 14 Lubricating oil flow of DPS

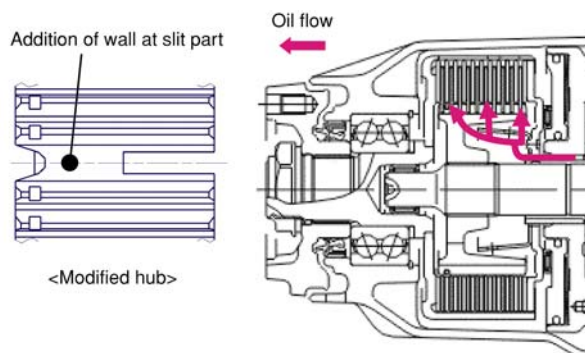


Fig. 15 Configuration of modified clutch hub and lubricating oil flow in DPS clutch

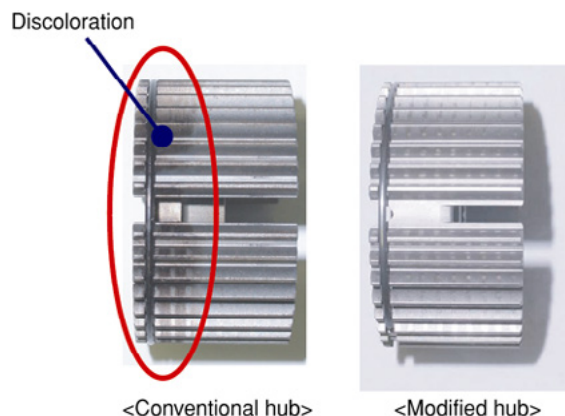


Fig. 16 Result of clutch continuously sliding test

When the results of the specifications revised to promote lubrication were confirmed visually, the lubricant was found to be evenly distributed. A vehicle test was carried out in which abrupt rotation speed differences were continuously induced to heat the clutch on purpose. As the results show in Fig. 16, the rear portion of the clutch in the vehicle with standard specifications became discolored, while the same location in the improved clutch showed no particular discoloration. This measure was concluded to be effective.

4.2. Development of New Clutch Friction Material

4.2.1. Relation between unusual noise and friction material characteristics

Next, the porosity and deflection of the clutch friction material were analyzed as a factor of the unusual noise.

The porosity was measured with a mercury porosimeter. The method for measuring deflection is shown in Fig. 17. The deflection was defined as the displacement occurring when the same load is applied on the clutch assembly as in an actual vehicle.

The analysis showed that, as shown in Fig. 18, the higher the porosity, or the greater the deflection, the less tendency there was for unusual noise generation.

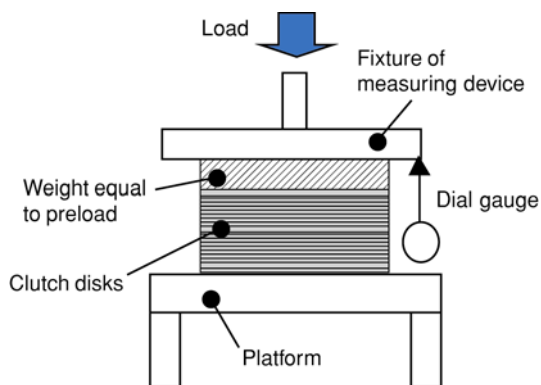


Fig. 17 Measurement method

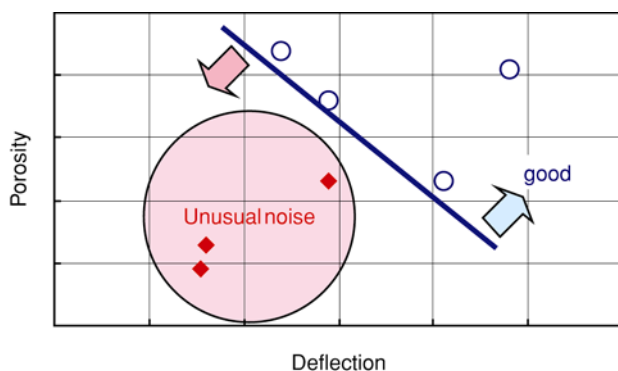


Fig. 18 Relation of porosity and deflection to unusual noise

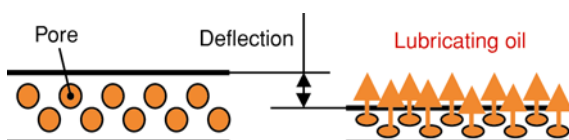


Fig. 19 Model of clutch lubrication

Figure 19 explains this; when the clutches engage, pores filled with lubricant are compressed, which tends to squeeze out the lubricant. Even when there is little lubricant supply, the material then self-lubricates, reducing the occurrence of the unusual noise.

4.2.2. Friction material characteristics

A friction material was developed with four times the porosity of the conventional material. Figure 20 indicates that this has 2.5 times the deflection of the conventional material.

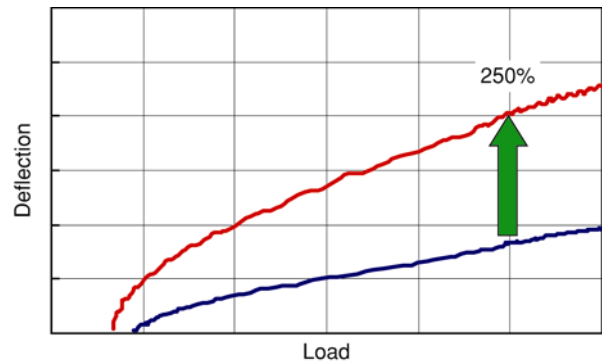


Fig. 20 Comparison of deflection characteristic

4.3. Verifying Effect of Countermeasures

No unusual noise was noted in reproducing mode when the newly developed friction material with improved lubrication specifications was tested in an actual vehicle.

Also, as shown in Fig. 21, no mirror finished surface was found in the clutch plate used in reproducing mode. The surface roughness was measured and found to equal that in quiet plates, as shown in Table 3.

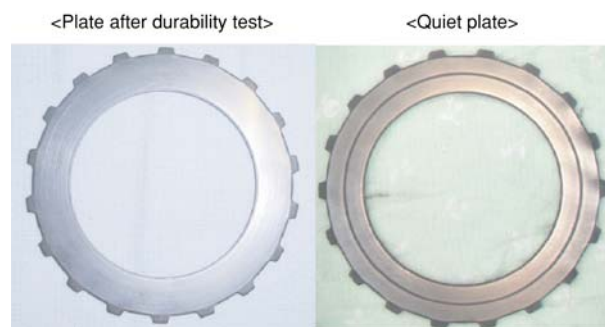


Fig. 21 Comparison of clutch plate condition

Table 3 Comparison of surface roughness of clutch plates

Ra (μ m)	Plate after durability test	Quiet plate
Minimum value	0.114	0.126
Maximum value	0.187	0.252

5. Conclusion

Research was carried out to find ways to reduce the unusual noise occurring on turning and takeoff when an automatic transmission clutch is used in a torque-on-demand

type 4-wheel drive system. The following results were obtained:

- (1) It was found that the clutch plate in a product emitting the unusual noise had been polished to a mirror finished surface, and that this was due to insufficient flow rate of the lubricant used at the clutch.
- (2) A reproducing mode of an actual vehicle in which the clutch lubricant is low and the load is high was constructed by combining parking and takeoff on low- μ surface conditions; this enabled verification of the unusual noise and the mirror surface finish on the clutch plate.
- (3) As a measure against unusual noise and mirror surface finish of the clutch plate, an oil leak to the parts other than the clutch was stopped, which increased the lubricant flow rate, and steps were taken to ensure a uniform distribution of lubricant inside the clutch.
Also, a friction material with greater porosity and deflection was developed to improve its capacity to hold lubricant.
A vehicle was installed with these improvements and tested in the reproducing mode; the unusual noise and mirror surface finish of the clutch plate were eliminated.

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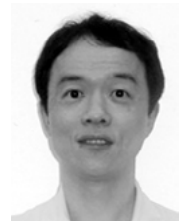
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