

Development of Super Ultra Flat Torque Converter with Multi Plate Lock-up Clutch

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ABSTRACT

Three-dimensional CFD was used to optimize the torus section and stator blade shape, and newly developed stator blades were also employed to develop the fluid flow channels for a thin type torque converter with a flattening ratio of 50%, while maintaining torque converter performance. A multi-plate lock-up clutch with heat-resistant performance approximately twice that of a conventional single-plate lock-up clutch has been positioned in the space created by the use of these new fluid flow channels. The developed Super Ultra Flat torque converter with multi-plate lock-up clutch enables all-area LC control without increasing the overall width compared to the previous torque converter, and can be fitted in an FF vehicle. As a result, in real-world driving, the new system increased fuel efficiency by approximately 3% in US06 mode, and enabled a more direct driving feeling by shortening the time from 0 to 100 km/h at 100% throttle acceleration by 0.2 s, etc.

INTRODUCTION

Heightened awareness towards global warming in recent years has led to increased demands on torque converters, which are the launch device for automatic transmissions (AT). In particular, demands are

increasing to simultaneously achieve both smooth torque transfer characteristics, which are important when the vehicle launches, and direct torque transfer characteristics with little slip, which contribute to increasing fuel efficiency. At the same time, from the viewpoint of securing collision safety, design restrictions on the overall torque converter width are also important and should be observed to prevent the AT axial dimension from increasing.

The flattening ratio of fluid flow channels is generally in the 80% range, but Honda led the industry in commencing mass production of an Ultra Flat torque converter with a flattening ratio in the 60% range from 2001 year models. Now, a Super Ultra Flat torque converter with multi-plate lock-up clutch has been developed for the new type AT in next-generation models (Fig. 1). This new torque converter consists of a lock-up clutch (LC) that enables all-area LC control and new fluid flow channels that have been further flattened, and can be fitted in an FF vehicle.

This paper describes the development goals, technical issues and countermeasures for this Super Ultra Flat torque converter with multi-plate lock-up clutch, and reports the knowledge and effects gained as a result of this development.

DEVELOPMENT GOALS

In order to simultaneously achieve both smooth and direct torque transfer characteristics, the following goals were set.

1. Enhanced LC performance

Comparison with previous model:

- LC heat-resistant performance: Double
- LC operation performance

Operating range: $0.5 < \text{speed ratio} < 1.5$

Response time: 0.5 s or less

2. Torque converter performance equal to that of the previous model

3. Overall torque converter width equal to that of the previous model

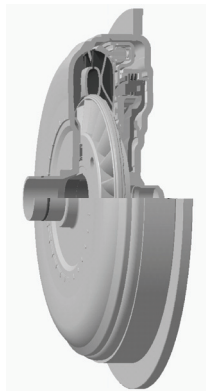


Fig. 1 Side view of developed torque converter

All-area LC control is employed to achieve direct torque transfer characteristics that contribute to increasing fuel efficiency. As shown in Fig. 2, the LC operates over a wider range than the conventional model, from the high throttle range to the low vehicle velocity range.

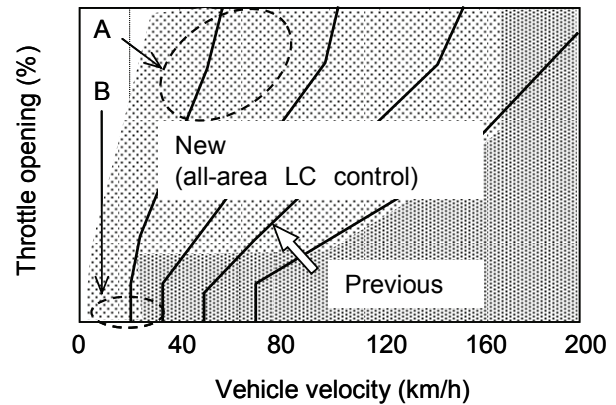


Fig. 2 Operating range of lock-up clutch

The development goal of LC heat-resistant performance is needed to enable unhindered LC operation and release in the high throttle range and while shifting gears (area A in Fig. 2). In addition, the development goal of LC operation performance is needed to reliably operate the LC when decelerating in order to extend the fuel cut time (area B in Fig. 2).

Furthermore, in order to shift to LC operation driving without placing an excessive thermal load on the LC facing material immediately after a smooth launch, the torque capacity factor, torque ratio and other torque converter performances should be the same level as that of the previous model.

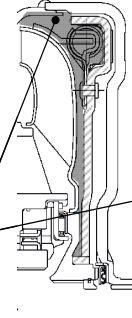
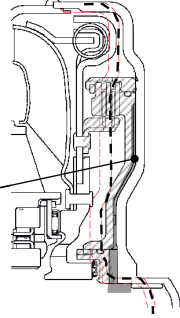
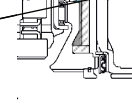
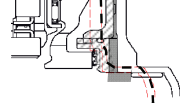
LC SYSTEM

To achieve the LC performance development goals, LC systems were investigated from the viewpoints shown in Table 1. Single-plate LCs have a simple parts configuration, so they have good space efficiency and are employed in the torque converters of FF cars.

On the other hand, Table 1 shows that in contrast to single-plate LCs, the LC operating pressure in a multi-plate LC acts on the piston chamber, which is a closed space, so there is no need for the facing material to seal the working fluid pressure. This makes it possible to establish lubrication grooves on the facing material surface, which increases the heat-resistant performance [Table 1 (1)]. In addition, the LC piston operation is not affected by the fluid flow inside the torque converter, which is advantageous in terms of LC operating range and operating time [Table 1 (2)]. Moreover, the multiple facing surfaces also provide a large clutch capacity, which is advantageous for use in high displacement engines [Table 1 (3)].

Therefore, in consideration of the above performance comparisons and the displacement of the target engines, a multi-plate LC system was selected.

Table 1 Comparison of LC Systems

	Single-plate type (previous)	Multi-plate type
Typical layout		
LC operating pressure		
Comparison	○ : Good ⊙ : Very good	
(1) LC heat resistant-performance	○ 	⊙ 
(2) LC response time operating range	○	⊙
(3) Torque capacity	○	⊙
(4) Width	⊙	○

In addition, care was taken in the detailed design of the multi-plate LC to obtain an even contact pressure distribution over the clutch material surface in order to provide good slip control over a wide lock-up torque capacity range. The specifications of the clutch guide, clutch plate, end plate and snap ring, which are the main parts of the multi-plate clutch, were also optimized while suppressing the increase in the axial dimension. As shown in Fig. 3, the entire multi-plate clutch was modeled and FEM analysis was performed to investigate the contact pressure distribution.

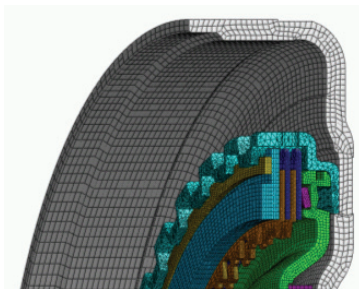


Fig. 3 FEM model of LC system

Figure 4 shows the calculation results, before and after multi-plate clutch optimization, for the contact pressure distribution on the clutch material surface during LC slip control in the low and high throttle ranges. Before optimization, when the multi-plate clutch performs LC slip control in the high throttle range, the contact

pressure increases around the periphery of the clutch material surface. In contrast, the optimized multi-plate LC secures an even contact pressure distribution even in the high throttle range, and can support slip control over a wide lock-up torque capacity range.

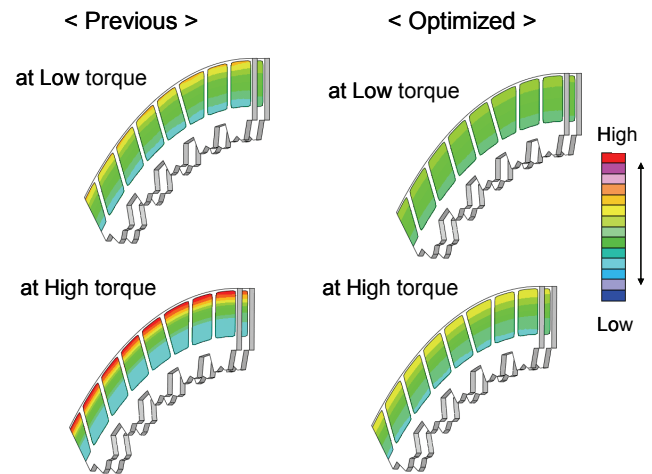


Fig. 4 Calculation results of contact pressure distribution

In this manner, multi-plate LCs have a functional advantage compared to single-plate LCs. However, multi-plate LCs have many parts such as a piston chamber, multiple clutch plates and a clutch guide, so using the conventional fluid flow channel width would unavoidably increase the axial dimension of the torque converter. Therefore, the axial dimension of the fluid flow channels, which consist of the blades and the torus section, should be shortened to enable them to fit into an FF vehicle.

DEVELOPMENT OF SUPER ULTRA FLAT FLUID FLOW CHANNELS

Torque converter performance is represented by the torque capacity factor and the torque ratio. The larger the torque capacity factor, the smaller the energy loss during torque transmission, and the larger the torque ratio, the larger the driving force at launch. These torque converter performances are determined by the change in fluid momentum produced by turning the flow using the elements of the pump, turbine and stator.

To obtain high torque converter performance, the flow should be turned within a rotating three-dimensional space while minimizing not only the secondary flow produced by imbalances between the centrifugal force and pressure gradient, but also separation flow and other flow loss factors.