

Advanced Technology for Dry Multi-Plate Clutch in FWD HEV Transmission (JATCO CVT8 HYBRID)

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ABSTRACT

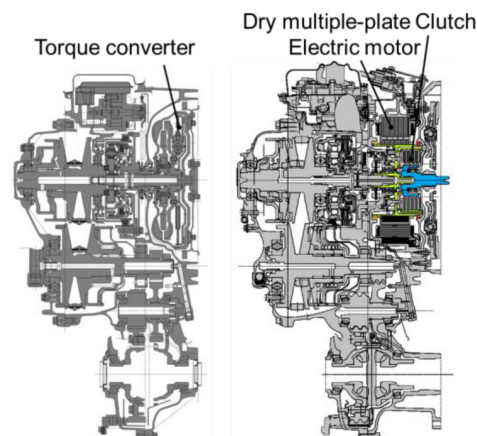
There has been a growing need in recent years to further improve vehicle fuel efficiency and reduce CO₂ emissions. JATCO began mass production of a transmission for rear-wheel-drive (RWD) hybrid vehicle with Nissan in 2010, which was followed by the development of a front-wheel-drive (FWD) hybrid system (JATCO CVT8 HYBRID) for use on a midsize SUV in the U.S. market. While various types of hybrid systems have been proposed, the FWD system adopts a one-motor two-clutch parallel hybrid topology which is also used on the RWD hybrid. This high-efficiency system incorporates a clutch for decoupling the transmission of power between the engine and the motor.

The hybrid system was substantially downsized from that used on the RWD vehicle in order to mount it on the FWD vehicle. This paper describes various seal technologies developed for housing the dry multi-plate clutch inside the motor, which was a key packaging technology for achieving the FWD hybrid system.

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1. AIM OF DEVELOPMENT

The engine and transmission are mounted transversely on FWD vehicles, the hybrid system must fit in the limited space available. To meet that requirement, the aim of this development work was to mount an electric drive motor and a dedicated multi-plate clutch in the space occupied by the torque converter of a conventional transmission (Figure 1).



2. TECHNICAL ISSUES TO BE RESOLVED AND SOLUTIONS

Mounting a clutch in-line for uncoupling the engine from the motor in order to secure the maximum amount of regenerative energy would make it impossible to fit both units in the space of a conventional transmission. To resolve that issues, a small dry multi-plate clutch was installed inside the motor to shorten the axial length of the motor.

The structure adopted for installing the dry multi-plate clutch inside the motor is shown in Figure 2. Both the motor shaft (denoted as 1 in the figure) that transmits the driving force of the motor to the transmission and the input shaft (denoted as 2) that transmits the driving force of the engine to the dry multi-plate clutch are supported by ball bearings (denoted as 3 and 4).

2.1. Requirements for Installing Multi-Plate Clutch Inside the Motor

The interior of the motor is divided into the following three spaces, each of which must be properly sealed.

1. Lubricated space for supplying lubrication oil to the bearings and for lubricating the piston that strokes to engage the dry multi-plate clutch (denoted as A)

Figure 1. Comparison of conventional transmission and hybrid transmission (JATCO CVT8 HYBRID)

- Non-lubricated space of the dry multi-plate clutch (denoted as B)
- Motor space that houses the motor stator and rotor (denoted as C)

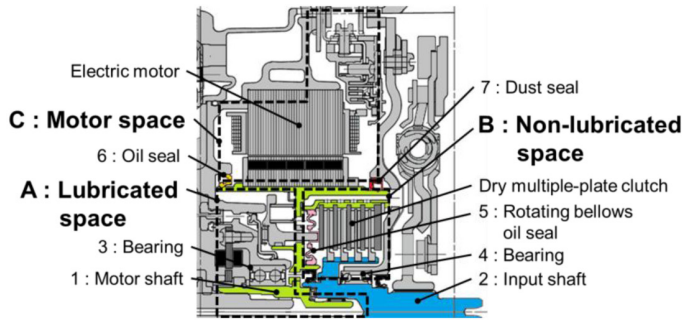


Figure 2. Cross-sectional view of hybrid transmission

2.2. Structure and Functions of Seals Inside the Motor

The seals used in the three spaces mentioned above have the following functions.

- A rotating bellows oil seal (denoted as 5) serves to prevent incursion of oil into the space of the dry multi-plate clutch. This seal isolates the non-lubricated space of the dry multi-plate clutch (B) from the lubricated space (A), while following the stroking of the piston for engaging the clutch.
- An oil seal (denoted as 6) prevents incursion of oil into the motor space (C) by sealing it from the lubricated space (A).
- A dust seal (denoted as 7) serves to seal the motor space (C) from the space of the dry multi-plate clutch (B), thereby preventing incursion into the former space by the large volume of wear powder produced on the clutch's friction material surface.

2.3. Technical Issues of Each Seal and Solutions

2.3.1. Rotating Bellows Oil Seal that Follows the Piston Stroke

2.3.1.1. Technical issues

The rotating bellows oil seal moves together with the piston for clutch engagement. The seal and piston separates the lubricated space and the space of the dry multi-plate clutch. This seal must satisfy the following functional requirements imposed by the usage and surrounding environment.

- Resistance against heat from the clutch and resistance against the high-temperature oil
- Assurance of stable hardness against wide-ranging temperature changes in order to suppress reaction force fluctuation in hot and extremely cold environments
- Durability and ability to follow deformation induced by the stroking of the piston to engage/disengage the clutch

2.3.1.2. Solution

The material properties of various seal materials were compared in order to resolve the first and second issues noted above. The results are presented in Figure 3. The properties that are especially important

for the rotating bellows oil seal are elongation and resistance to high and low temperatures. Therefore, an acrylic rubber with improved elongation performance was selected as the material best suited to satisfying these requirements.

Item	Target	Silicone rubber	Hydrogenation nitrile rubber	Chloroprene rubber	Fluorinated rubber	Acrylic rubber	Acrylic rubber (Elongation improvement)
Normal condition level	Hardness	—	○	○	○	○	○
	Tensile strength	—	△	◎	○	△	○
	Expansion	—	◎	△	◎	△	○
High temperature proof	140°C MIN	◎	◎	×	◎	◎	◎
Low temperature proof	-40°C MAX	◎	×	◎	×	○	○
Oil proof (CVTF)	Oil immersion 4000Hr	×	◎	○	◎	◎	◎
Fatigue resistance	—	○	△	◎	○	△	○

Figure 3. Material property comparison

With regard to the third issue of ensuring durability and the ability to follow deformation induced by the piston stroke, several seal shapes were prepared and their viability was investigated, in addition to the selection of a suitable material as described above. In selecting the seal shape, it was necessary to take into account the following damage modes that might occur when the seal is subjected to centrifugal force produced by the piston stroke and rotation (Figure 4).

- Cracking caused by strain in the seal material exceeding the allowable level
- Damage due to interference with parts surrounding the bellows film
- Cracking caused by increased local strain due to reversal of the bellows film

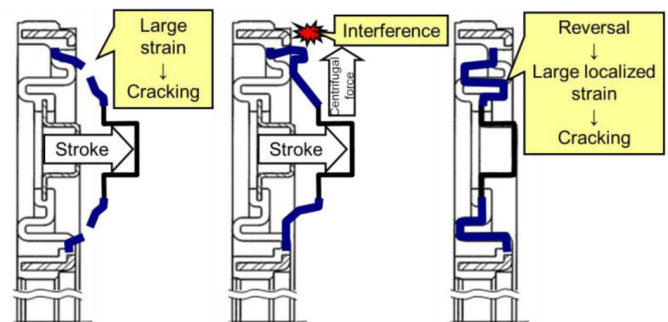


Figure 4. Damage modes of bellows film

Figure 5 compares the shapes of the seal specifications that were investigated. Multiple types of shapes were prepared and performance evaluations were conducted to select the most suitable shape.

The results revealed that, at the time of the maximum piston stroke, bellows film interference occurred with specification 1 and film reversal occurred with specification 2. A strength analysis was conducted to investigate in detail the specific nature of the film deformation during actual operation.