

Development of CVT for 2008 Model Year FIT

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ABSTRACT

A newly developed 1.3 L, 1.5 L class CVT with a torque converter was mounted in the second generation FIT, which is aimed at realizing both higher fuel economy and exhilarating acceleration performance. The main technologies used in the new CVT are the changeover of the start-off method from the conventional start-off clutch to a torque converter, the increase of the pulley distance from 143 mm to 156 mm, the adoption of a high gear ratio, and the adoption of an oil pump driven with a small radius rotor via a chain, a creep control system, and a start-off lockup clutch (L/C) control system.

As a result of these technologies, the transmission efficiency was 1.7% higher than that of the previous FIT CVT, and the torque amplification effect of the torque converter during launch enabled the achievement of higher fuel economy and exhilarating acceleration performance.

1. Introduction

In recent years, amid the attention being paid to countermeasures for global environmental issues, the enhancement of fuel economy is becoming increasingly important from the viewpoint of reducing CO₂ emissions. At the same time, exhilarating acceleration performance, a sought-after car feature, is being demanded. In order to satisfy these needs, a CVT^{(1), (2)}, which realizes highly efficient fuel economy, has been installed in Honda's 1996 and subsequent models. Along with the full model change of the FIT, a CVT with a torque converter designed for the FIT which simultaneously realizes high fuel economy and exhilarating launch performance was developed. This technology is described below.

2. Development Goals

The following three items were established as development goals in order to realize both top level fuel economy and exhilarating launch performance.

- (1) High transmission efficiency due to friction reduction, adoption of high gear ratio, creep control, and L/C control
- (2) Smooth and powerful launch performance due to the use of a torque converter
- (3) A compact CVT suitable for FIT-class vehicles

3. Basic Layout and Main Specifications

Figure 1 shows a main cross-sectional diagram of the CVT fitted with a torque converter for the new model FIT (hereafter called "the new CVT").

The main points in which the new CVT differs from the 2002 model "Fit" (hereafter called "the previous CVT") are the adoption of a torque converter for the start-off mechanism, the use of a large capacity, high-efficiency oil pump driven with a small radius rotor via a chain, the relocation of the pulley bearing, and the increased distance between the pulley shafts in order to reduce metal V-Belt friction. Figure 2 shows an image of the CVT, and Table 1 shows the main specifications.

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Table 1 CVT specifications

		2008 model FIT	2002 model Fit
Engine specifications	Type	1.3L i-VTEC	1.3L i-DSI
	Max. power [kW/rpm]	73/6000	63/5700
	Max. torque [N·m/rpm]	127/4800	119/2800
Ratio	LOW OD	2.419 0.421	2.367 0.407
	Secondary	1.266	1.333
	Final	3.875	4.333
	RVS planetary	1.024	1.785
Dimension	Overall length [mm]	361	349
	Pulley axis length [mm]	156	143
Weight (Wet) [kg]		77.6	74.5

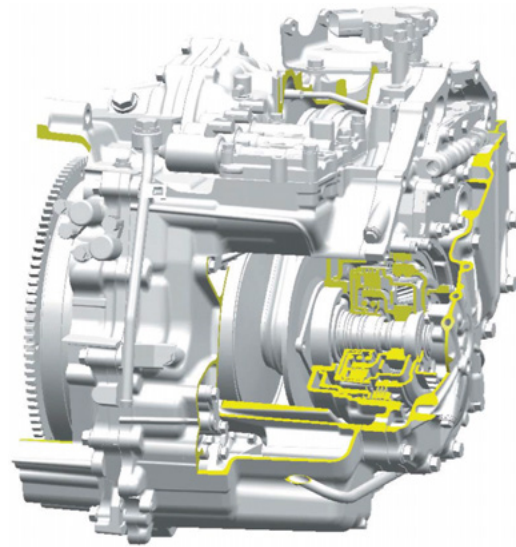


Fig. 2 Image of CVT for new FIT

4. Main Structure

4.1. Packaging Philosophy

The new CVT, which was fitted with a torque converter, has the same case configuration, shaft layout, and hydraulic system layout⁽¹⁾ as those of the previous CVT.

The increase in length due to the torque converter was compensated for by adopting the small oil pump and technology of the drive pulley cover bearing support mechanism, which have enabled a compact construction.

4.2. Torque Converter

4.2.1. Goal of using a torque converter

The previous CVT employed a multi-plate wet clutch for the start-off method. Because a torque amplification mechanism was not applied, it was necessary to set a low gear ratio to enable the necessary drive force for launch. For this reason, the gear ratio while cruising would also decrease. The engine speed would then rise, providing a margin for an increase in fuel economy.

Because the new CVT uses a torque converter, the gear ratio was increased by 14% compared to that of the previous CVT, to be able to realize both higher launch drive force, and, greater fuel economy, which was achieved by decreasing the cruising engine speed.

4.2.2. Reduced diameter of the torque converter

In contrast to the conventional automatic transmission torque converter for a 1.3 L engine, the blades of pump, turbine, and stator in the new CVT were optimally designed, resulting in a 15% reduction of the flow path diameter ($\phi 190$), and an 18% reduction of weight.

Also, the lock up clutch diameter was increased to $\phi 208$ in order to permit lock up from low speed range.

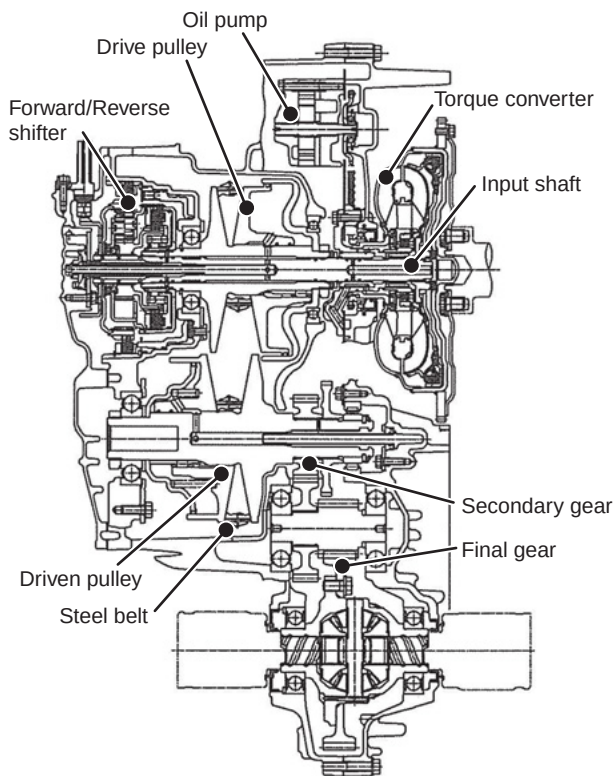


Fig. 1 Main section of CVT

Figure 3 shows the cross-section of the torque converter.

4.3. Oil Pump

4.3.1. Basic layout of the oil pump

In the previous CVT, layout of the oil pump was such that it was driven directly from the input shaft⁽¹⁾. In contrast, the oil pump of the new CVT was driven by the sprocket via a silent chain. This sprocket is connected to the input shaft. Structure of the oil pump is shown in Fig. 4.

With this new layout, the transmission width was reduced, and the diameter of the oil pump rotors was also reduced, thereby reducing friction.

4.3.2. Management of high pressure

The use of a torque converter triggers an increase in the discharge flow and the discharge pressure, which necessitates oil pump increase.

The necessary oil pressure increased from 3.5 MPa for

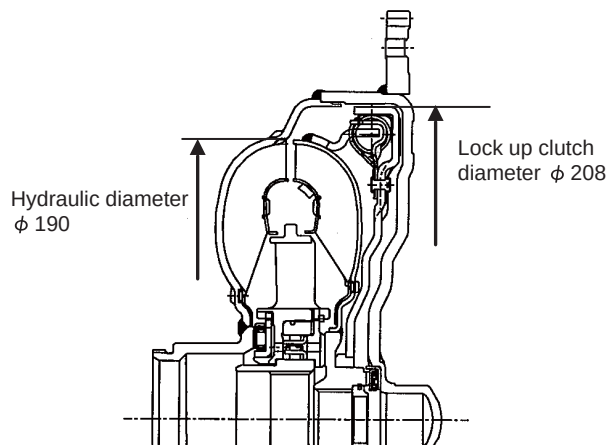


Fig. 3 Structure of torque converter

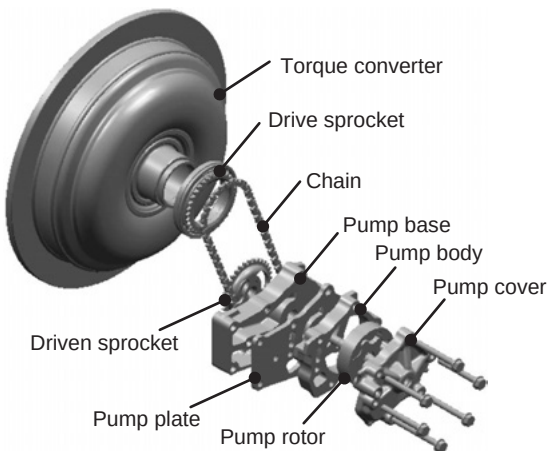


Fig. 4 Structure of oil pump

the previous CVT to 5.5 MPa. In order to help prevent reduced discharge performance due to deformation of the housing, FEM analysis was used to optimize the stiffness of the aluminum die-cast pump cover.

4.4. Bearing Support Structure of Drive Pulley Cover

The bearing to support the drive pulley was mounted on the pulley cover instead of being fitted directly to the shaft. As a result, the entire length of the drive pulley was reduced by 18 mm. Figure 5 shows the layout of the drive pulley bearing.

Whereas the pulley cover of the previous CVT was subjected to the load from the oil pressure alone, the pulley cover of the new CVT is subjected to the bearing support load as well. The shape of the pulley cover was designed to account for the bearing support load, thus enabling the bearing to be mounted on the pulley cover.

4.5. Pulley Strength

Regarding the pulley, stress analysis and deformation analysis using the FEM were carried out in each of the drive and driven assembly conditions in order to establish the optimum shape.

Previously, the support part of the driven pulley was located between the V-surface and the secondary gear. In the new CVT, the bearings were located on outside of the secondary gear. Therefore, the stress at bottom of the V-surface on the driven pulley shaft was reduced by 15%, resulting in optimization of the strength and deformation on the driven pulley. Figure 6 shows the bearing arrangement and the results of stress analysis.

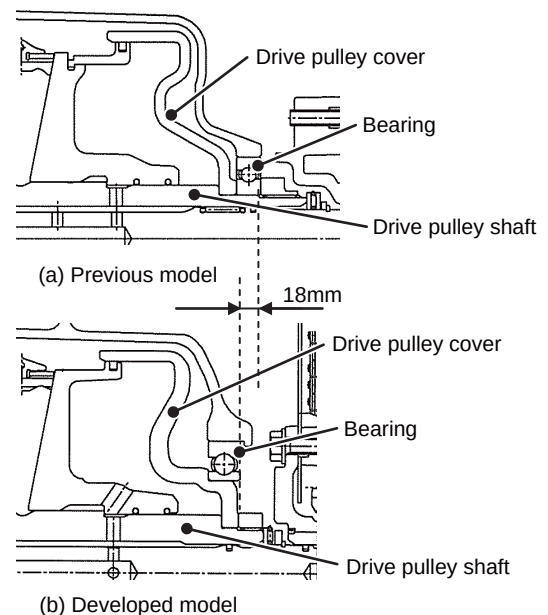


Fig. 5 Comparison of drive pulley bearing layout

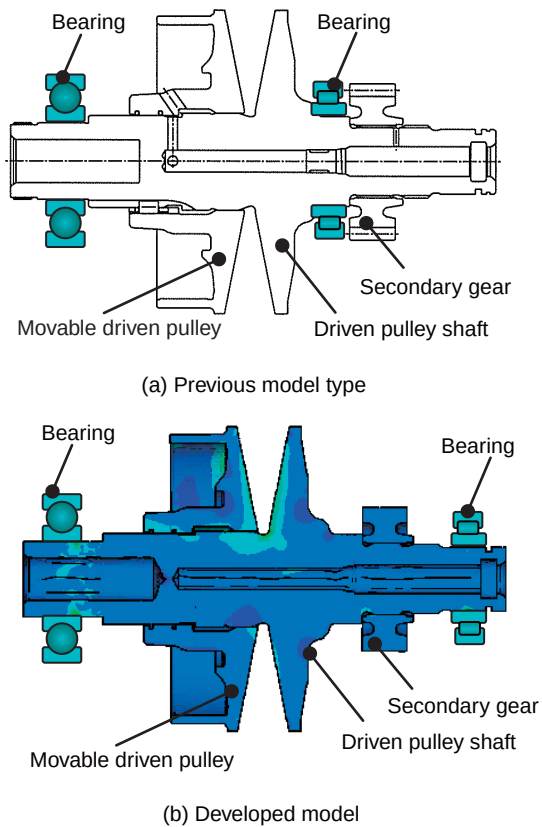


Fig. 6 Comparison of driven pulley bearing layout

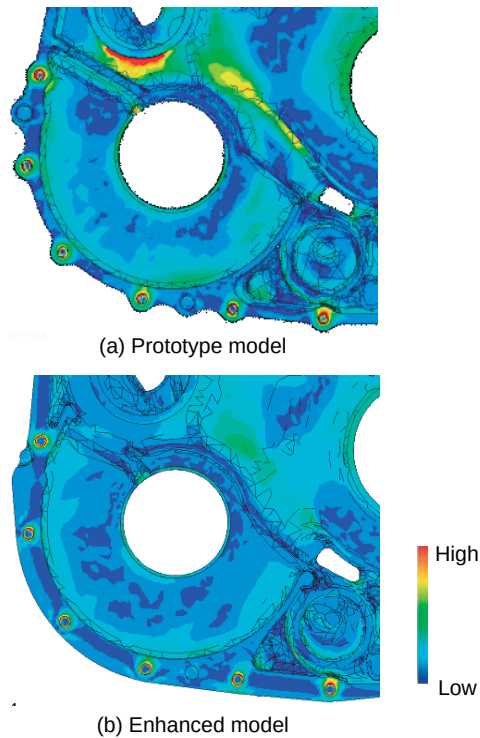


Fig. 7 Transmission case stress distribution

4.6. Metal V-Belt Strength

To enable a 24 mm V-Belt to cope with the high torque resulting from the use of a torque converter, the new CVT adopted torque harmonization control employing an electronically controlled throttle (DBW) to help prevent too large input torque from being applied to the V-Belt during the in-gear transient.

As a result, the V-Belt load was able to be reduced by 50% compared to that generated in the case of conventional control, enabling adequate durability to be obtained with a 24 mm V-Belt.

4.7. Case Strength

In order to cope with the high torque, stress analysis and alignment face sealing analysis using FEM were carried out, and shape of each part of the case was optimized.

Figure 7 shows the results of the analysis for stress in the vicinity of the final gear. It can be seen that adequate case strength was obtained by increasing thickness of the case in vicinity of the final gear and optimizing layout of the ribs.

5. Technology for Enhancing Transmission Efficiency

5.1. Friction Technology

Three main factors that affect CVT friction are metal V-Belt, oil pump, and oil agitation. Technologies used to reduce CVT friction resulting from each of these factors, are described below.

5.1.1. Metal V-Belt

The V-Belt friction tends to decrease when the distance between the pulley shafts is increased. Figure 8 shows the change in friction along with the change in the distance between the drive and the driven pulley shafts. If the distance between the shafts is increased, however, the size of the transmission will also increase. The distance between the pulley shafts in the new CVT was set to 156 mm as the optimum setting for friction

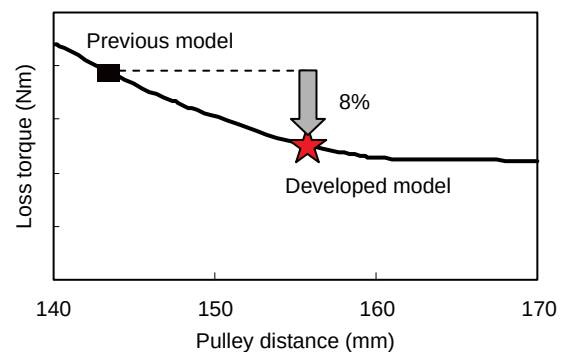


Fig. 8 Loss torque of CVT belt

reduction and transmission size. As a result, an 8% reduction of friction compared to the previous CVT was achieved.

5.1.2. Oil pump

The diameter of the outer rotor compared to the previous model was reduced by 13%, and the discharge per revolution of the rotor was increased by 26%, enabling roughly the same drive torque as that of the previous model.

5.1.3. Oil agitation

Reducing the total amount of transmission oil so as to lower oil level is an effective way to reduce the agitation of the oil. However, lubrication performance is an issue. In order to help ensure that the differential section has adequate lubricating performance, the new CVT was provided with ribs and grooves to feed oil that was lifted up (indicated by A) by the gear, as shown in Fig. 9. This construction helps ensure adequate lubricating performance even if the oil level is reduced, thus enabling friction to be reduced.

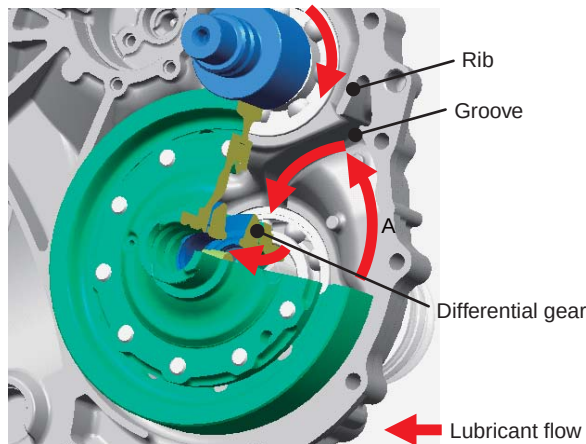


Fig. 9 Lubricant flow at differential gear

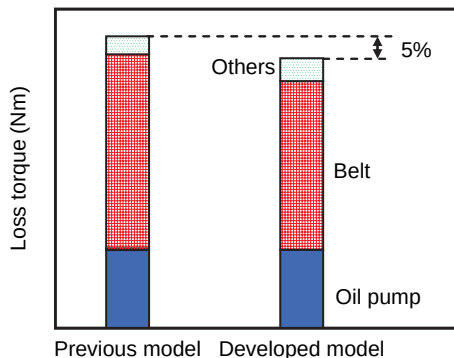


Fig. 10 Comparison of loss torque

5.2. Transmission Friction

As a result of employing enhancement technology for each of the factors mentioned in the previous sub-section, the friction of metal V-Belt was reduced 8% compared to that of the previous CVT, and the friction in the oil pump remained roughly the same. In addition, the friction of each gear due to oil agitation, increased along with the increase in gear size due to the use of a torque converter, but increase of friction was kept to minimum by reducing agitation resistance.

The transmission friction was 5% less than that of the previous CVT. Figure 10 shows a breakdown of this friction.

5.3. Electronic Control Technology

5.3.1. Creep control

By reducing the forward clutch capacity in order to reduce creep torque during idling, friction during idling was reduced. Figure 11 shows the creep motive power

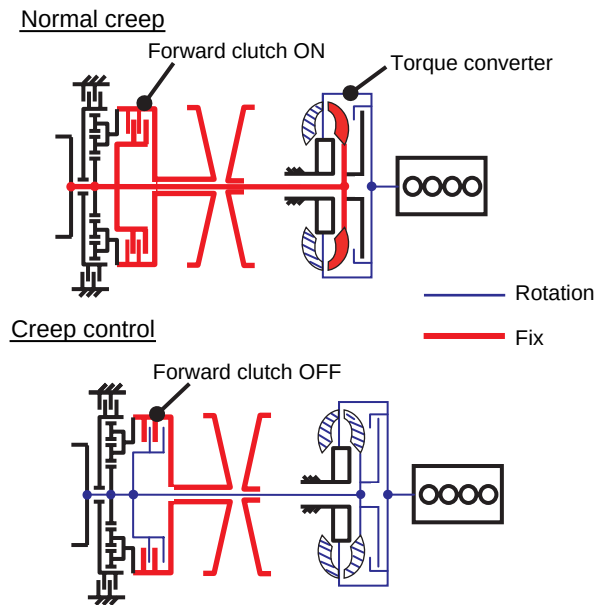


Fig. 11 Power transfer at creep control

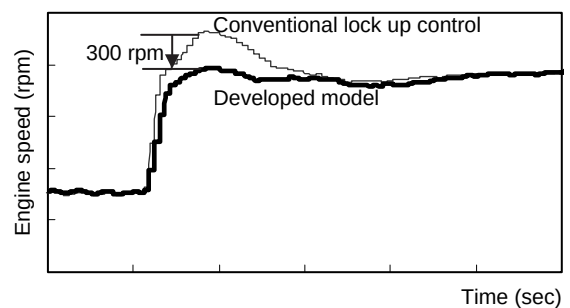


Fig. 12 Comparison of engine speed at launch

transmission condition. Under an idling condition in which creep occurs, the rotating elements downstream of the turbine are completely stopped. However, when a creep control condition occurs, the forward clutch capacity is reduced, after which the turbine begins rotating. As a result, the relative rotational speed between the pump of the torque converter and the turbine falls, and as a result, friction decreases. In this way, the friction during idling was reduced by 70%.

When the vehicle is on slope, the inclination sensor detects the gradient, stops creep control, and applies the normal creep force, thus achieving a drive feeling equivalent to that of the conventional automatic transmission.

5.3.2. Start-off LC control

In the new CVT, the efficiency at launch was enhanced by expanding the lock up region in the low speed region.

By increasing size of the lock up clutch and expanding the lock up region, slip loss of the torque converter during launch was reduced, and engine speed at launch also fell by about 300 rpm. Figure 12 shows the engine speed characteristics during launch.

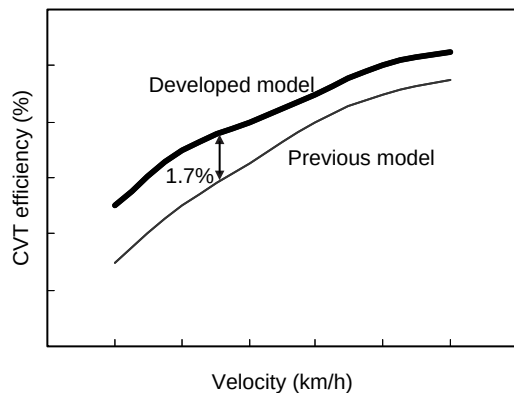


Fig. 13 Comparison of CVT efficiency

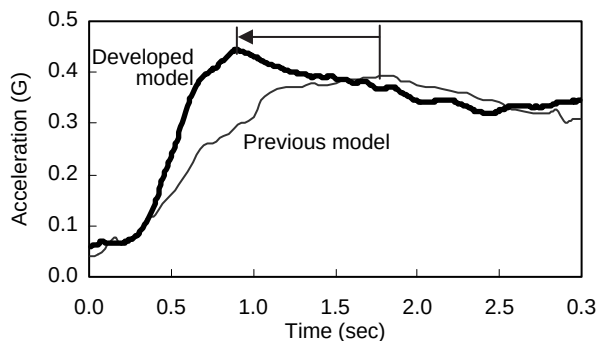


Fig. 14 Comparison of launch acceleration characteristics

6. Conclusion

The CVT with a torque converter for the FIT was developed, and the following results were obtained.

- (1) The efficiency was 1.7% higher than that of the previous CVT due to the reduction of friction, use of a high gear ratio (Fig. 13).
- (2) As a result of adoption of a torque converter, rise time of peak G was reduced compared to the previous CVT (Fig. 14), thus realizing powerful launch performance.
- (3) As a result of adoption of compactness technology, the CVT with good mounting ability with minimum size increase was produced, while utilizing a torque converter.

7. References

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