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A Study on Vehicle-based Durability Evaluation for Weight-reduced Valve Parts of the Dual Clutch Transmission

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Abstract: A monotype valve body for a dual clutch transmission has the potential to reduce costs, weight, and manufacturing time by modularizing various parts, including those of existing solenoid packs and valve bodies, into one through the application of super-precision die casting technology. However, this approach may lead to challenges such as reduced rigidity and increased interference due to modularization and compactness, impacting both product performance due to the reduced weight as well as durability and reliability. Unlike existing products, this approach requires a high-precision thin-wall block to avoid more complicated flow line formation, interference between flow lines, and leaks, as well as a strict quality requirement standard and precise inspections including detection of internal defects. To conduct precise inspections, we built an equivalent model corresponding to a driving distance of 300,000 km. Testing involved simulating actual road loads using a real vehicle and a chassis dynamometer in the FTP-75 mode (EPA Federal Test Procedure). The aim of the study was to establish a vehicle load-based part durability model for manufacturing a mono-type valve body and to develop fundamental technology for part weight reduction through preliminary design by introducing analytical weight reduction technology based on the derived results.

Keywords: Dual clutch transmission, Valve-body, Mono type, Weight reduction, Fatigue analysis, Road load data acquisition

Subscripts

DCT : Dual Clutch Transmission
Mono Type Valve Body : Valve Body Combined with Solenoid Valve and Clutch Actuator
RLDA : Road Load Data Acquisition

1. Introduction

Recently, the die casting technology has shown a tendency to integrate parts with the same functional group or other peripheral functional groups in order to make products (automotive parts) more functional, lighter, and simplify the process (Kim and Kim, 2014; Na, 2002; Seo et al., 2008). In addition, major automobile makers are already attempting to unify multi-types of parts by integrating the housing of functional parts by taking into consideration the integration and combination of parts from the design stage of vehicle system parts. The automobile parts manufacturers are also trying to build up the testing and evaluation technology of integrated modularization to match that of high ranking manufacturers of assembled production modules in order to examine various problems caused by the combination of parts (Lee et al., 2011). In the case of

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dual clutch transmission (DCT) parts, domestic manufacturers have low-defect manufacturing technology that, to some extent, allows them to supply wet type DCT valves to advanced vehicle makers. However, concerns about the failure to ensure safety (reliability verification) are increasing due to the rigidity reduction caused by the structure of the mono valve body that gradually becomes complicated due to integration as well as the attempt for additional weight reduction (Woo, 2009). This study will discuss the technology of building the equivalent durability mode to that of an actual vehicle based on operation load of 300,000 km for the mono type valve body housing on which the actuator body is combined and integrated with the wet type DCT valve body along with securing the corresponding safety requirements. Based on this result, this study will discuss the weight reduction technology of the die cast housing responding to the fatigue strength safety over an operation load of 300,000 km. It is thought that such a technological leap will work advantageously for the safe settlement of the wet type DCT technology in Korea, or will contribute to the marketing power for obtaining orders by offering customer friendly proposals to vehicle makers and transmission manufacturers.

2. Chassis Dynamometer base RLDA Analysis

Fig. 1 shows pictures of the vehicle test and the overview of the chassis dynamometer to build the

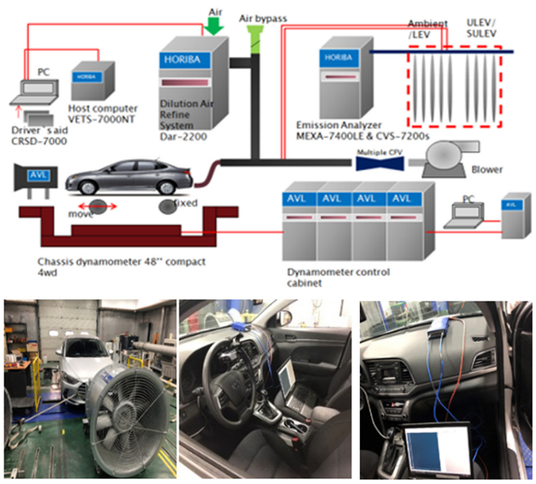

Fig. 1. FTP 75 base DCT valve-body working test bench.

Table 1. Specifications of testing chassis dynamometer

Rollersize	48 Inch Single Roll (4WD)
Max. Generation Power	Permanent: 153 kW from 92km/h to 200 km/h
	10S: 258 kW from 92 km/h to 146 km/h
Inertia Range	2WD: 400 kg ~ 3,500 kg
	4WD: 800 kg ~ 5,400 kg
Max. Speed	200 km/h Max.
Accuracy	Speed: 0.01% FS
	Torque: 0.1% FS
	Repeatability: 0.02@ FS
Cooling Fan	Variable Speed

equivalent model of the actual vehicle's road load matching the warranty period of parts corresponding to a driving distance of 300,000 km using the FTP-75 mode. Table 1 indicates the specification of the chassis dynamometer used. The vehicle used for the test is an AVANTE AD 1.6 e-VGT equipped with a 7-speed automatic DCT. Vehicle speed, engine RPM, and brake ON/OFF signals were measured via the CAN port of the OBED2 terminal. The FTP-75 mode (EPA Federal Test Procedure), commonly known as the driving mode, which represents urban driving cycles, is a test procedure defined by the U.S. Environmental Protection Agency (EPA) to measure the emissions and fuel economy of a car(Lee et al., 2002). The FTP-75 urban driving mode refers to a city driving mode with a total distance of 17.77 km, a maximum speed of 91.2 km/h, and an average speed of 34.1 km/h. The total time required is 1,874sec. The motorway driving mode uses a warmed up engine and drives at a maximum speed of 97 km/h and an average speed of 77 km/h over a distance greater than 16 km, and the car does not stop. The total distance is 16.45 km, and the total time required is 765 sec.

Fig. 2 shows the gear stage for each driving mode according to the FTP-75 and the shifting count at this time. The use count for each clutch identified through the shifting pattern is 80+30+8 count for Clutch 1 (total of 118), and 80+30+8 for Clutch 2 (total of 118). The total driving distance for the FTP-75 road is 17.77+16.45 km (34.22 km) and the clutch working frequency count, if calculated according to the vehicle's warranty period (a driving distance of 300,000 km), indicates a 1,034,482 working count during the warranty period. From this working count, subtract 34,482 and

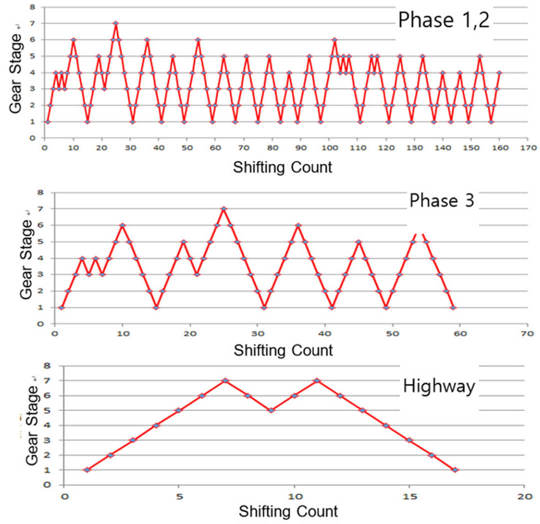

Fig. 2. DCT actuation on FTP-75 mode to extend 300K equivalent load cycle.

regard the 1,000,000 working count as the durability limit standard of a DCT part with a warranty of 300,000 km driving distance, and use these values as the basis for the design improvement for the fatigue analysis base and weight reduction of the mono valve body housing.

3. Mono Valve Body Weight Reduction Technology Based on Fatigue Safety Factor

Fig. 3 shows the modeling of the mono valve body target model for fatigue analysis, which indicates an initial weight value of 1.664 kg. In Fig. 4, the boundary condition is set for the working flow line based

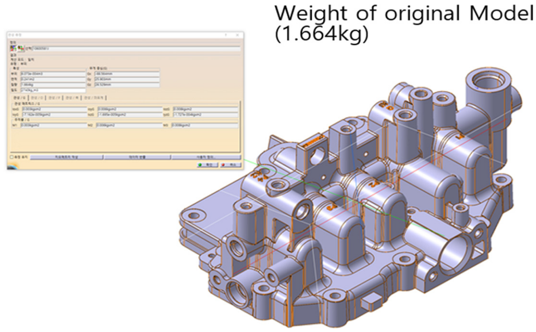

Fig. 3. Fatigue base analysis for mono valve body target model.

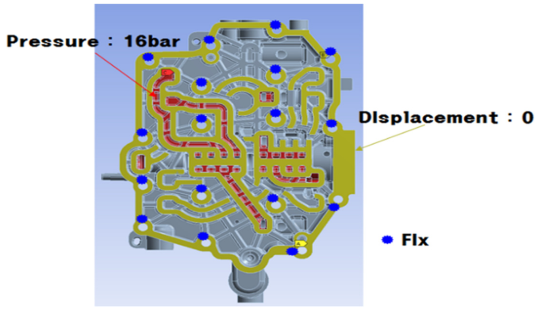

Fig. 4. Boundary conditions of hydraulic load according to clutch actuation.

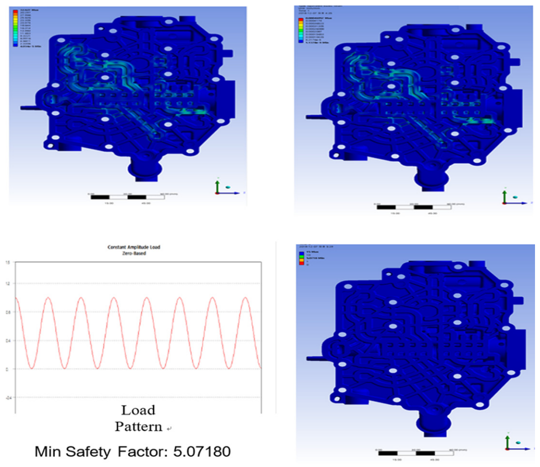

Fig. 5. Weight reduction capability demonstration based on over design safety factor(SF = 5.07).

on the working pressure applied to the mono valve body housing during actuator operation, and the load condition of the 16bar is set to be applied to the pressurized hydraulic path.

Fig. 5 shows the results of fatigue analysis for the mono valve body and stress analysis for the DCT actuator load condition considering the 300,000 km equivalent working frequency based on the actual vehicle's DCT actuator operation. Given the hydraulic load within the Valve body, it was found that the stress and deformation existed within the material's safe stress and strain area sufficiently and that the fatigue-based safety ratio was very high (SF=5.07180), indicating that an excessive design condition was applied. Based on these results, it can be seen that the additional weight reduction design will be available for the thin-wall block.

It is thought that the methodological results of this study can be used as a logical basis for the weight reduction of parts when performing additional weight reduction in the future.

4. Conclusions

This study provided a methodological discussion of the weight reduction of a valve body, a key component of a wet type DCT. In particular, when designing an actuator body as a mono type valve body by applying a method different from the existing method by which the actuator body is manufactured and assembled separately. It must be accompanied by a durability examination of the hydraulic load related to clutch actuator operation. In this study, the durability mode corresponding to 300,000 km driving of the DCT actuator was derived based on the actual vehicle load RLDA of the FTP75 mode, and the fatigue analysis was performed on the target model based on the derived durability mode. It was found from the analysis that additional weight reduction of the thin-wall block was available according to the result of over-design since the safety factor exceeded 5.0. In addition, it is thought to be possible to infer an additional reduction point besides the wall face through this methodological approach and that it can be utilized as a useful weight reduction design method at the initial design stage through analysis.

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