Carrier Durability Analysis using simple and system model

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***Abstract**:*

Generally, an automatic transmission is composed of various components in a complicated manner, and each component is subjected to various loads. Among them, the planetary gear, which is an essential component of the automatic transmission, has a particularly complicated structure. Simple models are often used for endurance analysis to evaluate specific parts of a gear set, because it takes a lot of time and resources to construct a system analysis model and perform FEM analysis. However, this approach is sometimes inconsistent with actual phenomena due to excessive boundary conditions and simplified loading conditions. This study compares the process and results between the simplification model for the 'carrier' part of the planetary gear set and the system model including the gear set. As a result, there are differences in the location of major stresses and the maximum stress level. After comparing the results, various methods are tried to reduce the analysis time. The most effective method was to change the mesh's order of the components that not the area of interest, to 1st order, and the analysis time was reduced by about 90%. The stress reference error was within 2%. It was shown that the analysis time was sufficiently feasible and the results were reliable. System analysis is essential to apply real operating conditions and to achieve realistic deformation and stress levels

***Keywords**: durability, planetary gear, carrier, stress, connectors, and solving time*

1. Introduction

For efficient analysis, it is very important to extract the necessary parts of a complex system and construct it with a simple model. But sometimes, in the course of these simplifications, the results are different from the actual results due to the boundary conditions and the inappropriate loads. Therefore the necessary parts and the parts that are not should be selected through deep understanding and analysis of the system.

This paper focuses the durability of the carrier in a set of planetary gears, which is the core part of an automatic transmission. It compared carrier deformation and stress distribution differences between a simple model consisting only of a carrier and shafts, and an assembled model including planetary gear set. In addition, it is studied that the methods for shortening the analysis time which is a huge disadvantage of the full assembled model.

2. Configuration of Carrier Durability analysis Model

2-1 simple carrier model with pinion shaft

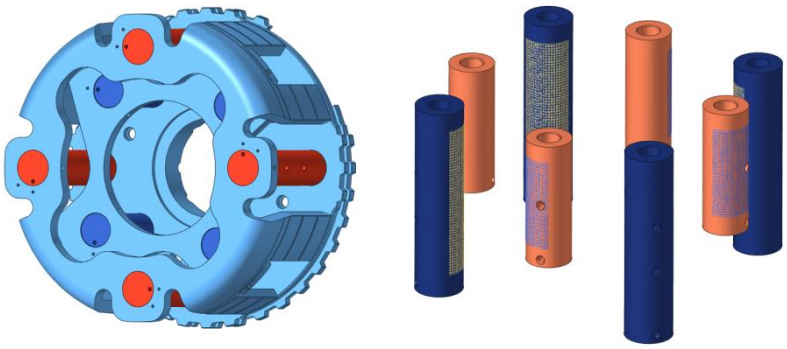

Figure 1. Simple model of carrier analysis and pressure surfaces of shafts

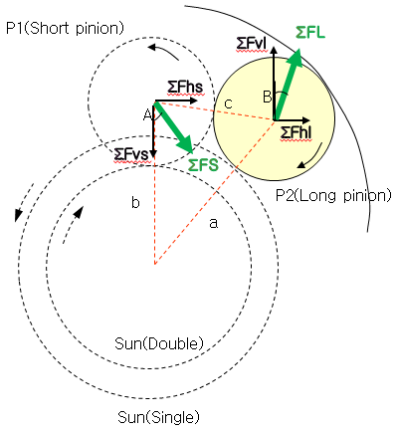

Figure 2. Load direction of pinion shaft

The medium that transfers the load to the carrier is the pinion shaft. Therefore, if the load applied to the pinion shaft can be calculated well, the analysis can be carried out with the configuration of only the carrier and the shaft. The load of the pinion shaft calculated in Figure 2 is directly applied to the shaft. Figure 1 shows the structure of the simple model. It consists of carrier and pinion shaft only. There are various methods of applying loads to the shaft, but in this study the method was to apply pressure to shaft surface. For more detail, make surface section at 1/3(120 °) of the contact area between the shaft and the bearing with normal direction of load that are calculated as Figure 2.

2-2 System model with planetary gear

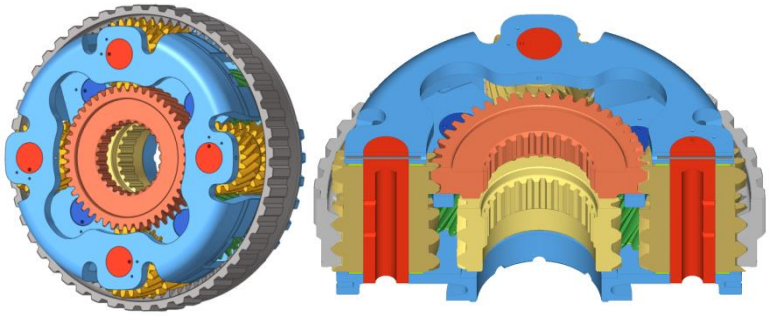

Figure 3. Assembled model and section view

The carrier system model (assembled model) is constructed as shown in Figure 3. It contains all planetary gear's component like gears, shaft-pin, and washer. The connections between the whole parts are composed of contacts except for tie condition between washer and pinion gears.

There are disadvantages in the preprocessing that takes a long time to construct the model, and human error can be occur in this process.

3. Difference between simple and system model

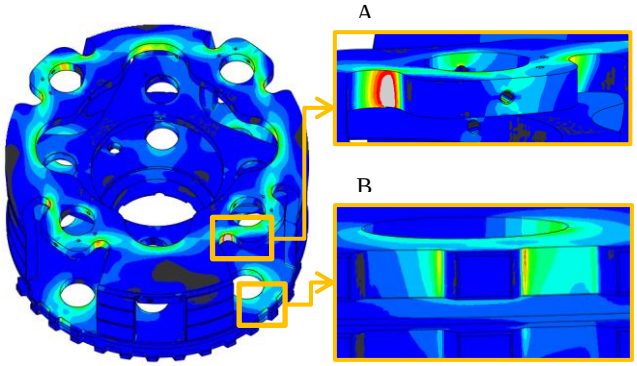

Figure 4. Simple model stress contour

Figure 4 shows the stress distribution of the simple model. High stresses are generated near the top of the carrier-cup near shaft contact area. When the stress contour and deformed shape were observed, it was found that the direction of the load was correctly entered.

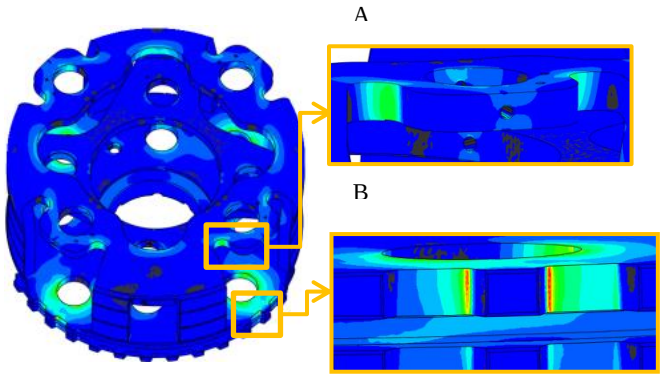

Figure 5. system model stress contour

Figure 5 shows the stress distribution of the assembled model. High stresses are generated at spline tooth fillet. The stresses of the carrier cup were significantly lower than those of simple model. It is about 65% less than simple model. But for the spline fillet, it is about 15% higher than simple model. For the analysis time, it took about 2 hours for the simple model and about 107 hours for the assembled model.

4. Improvement of assembled model

4-1 Use 1st order for gears

In the assembled model, the role of the planetary gear is to naturally transmit the torque coming through the sun gear to the pinion shaft. Since they are not interested in their stress or deformation, if 1st order element is applied to them, model can be constructed lightly and analysis time is drastically shorten. It took about 10 hours for it.

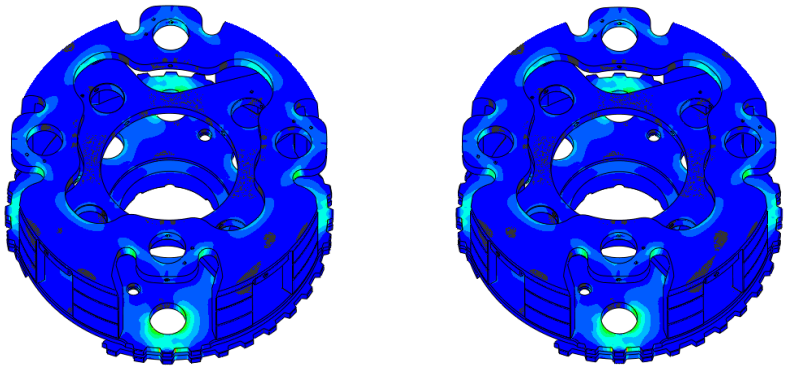

Figure 5. Original assembled model(LEFT) and gear 1st order model(RIGHT)

As shown at figure 5, the difference between the two was found to be equal level to the visually in contour. The difference of the actual stress value was also found to be equal to within 2%.

4-2 Use connector element for gear contact

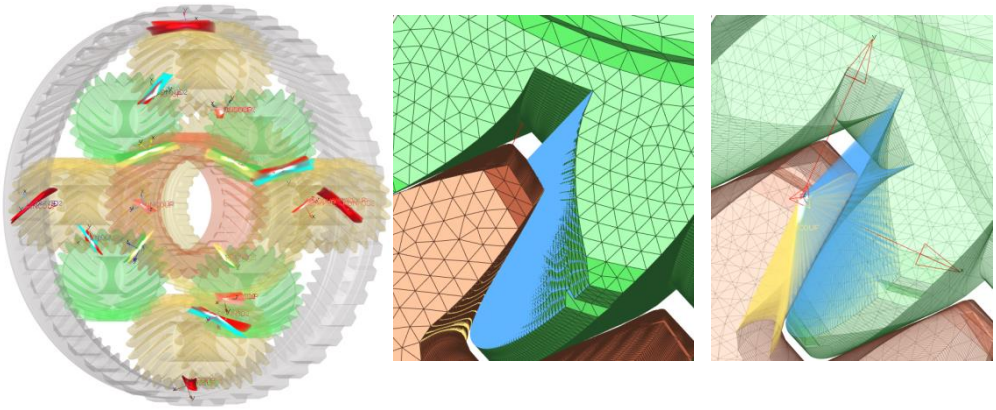

Figure 6. Connector at gear contact surface

Since a considerable part of the analysis time is spent on the gear contact, it was also effective to replace it with a connector. In the case of the connector, since it is created at the position calculated by the design specification, it can be easily made to the correct position by using Excel or the like. The connector used in this study was plane-slide. As shown in 4-1, the first order element was applied to the gears, and the contact between the gears was replaced with the connector, thereby shortening the time again. This analysis took about 7hours as 90% less than original assembled model. Also it has same result in stress and deformation.

5. Conclusion

The analysis using the simple model has advantages such as light model construction and quick analysis time. However, as described above and depends on the driving condition, it is inappropriate to use it in the carrier analysis because the behavior and the deformation are different from the actual one. However when assembled with all the parts related to the carrier, the model is too heavy and the analysis time is too long. In order to solve this problem, this study tried two methods and got satisfactory results. It has been found that the use of the primary component in the case of parts that carry loads or parts not of interest does not affect the analysis results of the carrier of interest. Replacing the contact calculation, which requires a lot of analysis time, with connector also confirmed that, is confirmed that it shortens the analysis time once more.

Table 1.Comparing of system model

Model type	Size of model	Solving time
Original system model	1.5Gb	107.6 hours
Gear 1st order model	739.8Mb	9.16 hours
Gear 1st order + connector model	731.3Mb	6.9 hours