Strength Analysis of the Complex Planetary Gears

Sung Gil Han, Yoo-In shin, Chan Heon Yoon, and Chul Ki Song

***Abstract*—**Although planetary gear systems are operating in small volumes, it possesses huge efficiency because of the compact combination of gears in the planetary gear system. It also has an outstanding efficiency of just 3% for power transmission tantamount to the power loss that occurs on each of the shift stages.

Structure equipment requires to obtain higher efficiency and lager torque, recently. According to these needs, we have designed the complex planetary gear system to make lager torque.

In this paper, a strength design evaluation for the complex planetary gear system was performed to ensure the gears' stability and durability during operation time.

***Keywords*—**Complex planetary gear system, Strength verification, Durability, Reduction gear

I. Introduction

PLANETARY gear systems normally consist of a centrally pivoted sun gear, a ring gear, and several planet gears found between the sun gear and ring gear. Compared to traditional gear boxes, the planetary gear systems have some advantages.

Planetary gear systems possess larger efficiency in small volumes because of the compact combination of gears in the planetary gear system. They also have an outstanding efficiency of just 3% for power transmission tantamount to the power loss that occurs on each of the shift stages. Through this aspect, we can figure out that the rate of transmissible input energy in the planetary gear system is smaller than the mechanical loss which comes from a gear box. Based on the advantages mentioned above, the planetary gear system has been designed. [1]-[6]

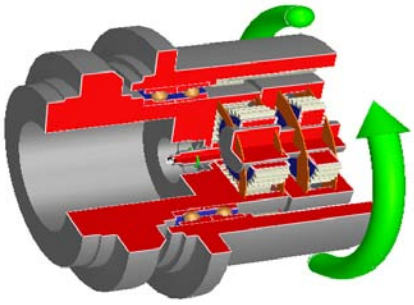
Optimum modeling for analysis is needed to carry out a more precise analysis result. Therefore, the modeling for strength and durability analysis is focused on gear train part.[7]

This research was financially supported by the Ministry of Education and Korea Institute for Advancement of Technology (KIAT) through the Human Resource Training Project for Regional Innovation and "the export-strategic FGCV R&D project" conducted by the ministry of knowledge and economy and the Korea Institute of Industrial Technology.

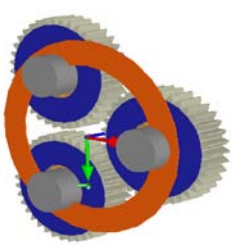
Sung Gil Han, Yoo-In Shin, Department of Mechanical and Aerospace engineering, Graduate School, Gyeongsang National University, 501, Jinju-daero, Jinju, Gyeongnam, 660-701, Korea (bohemian_gil@nate.com)

Chan Heon Yoon, Youngdong Tech Co., Changwon, Gyeongnam, 641-847, Korea (yd1938@yahoo.co.kr)

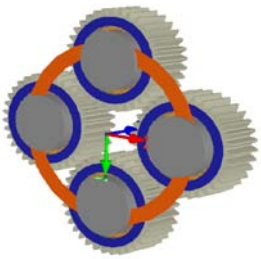
Chul Ki Song, Department of Mechanical Engineering, ERI Gyeongsang National University, 501, Jinju-daero, Jinju, Gyeongnam, 660-701, Korea (cksong@gnu.ac.kr)



a. Reduction gear



b. 1st planetary gear system



c. 2nd planetary gear system

Fig. 1 3D modeling of the reduction gear (Romax DESIGNER)

II. Strength Analysis of Planetary Gear System

A. Boundary Conditions and Load conditions

In this research, SCM420H is applied to the planetary gear system as its materials.

SCM420H is widely used as a component material of industrial reduction gear. The material properties are shown in Table 1.

Power to drive the planetary gear system is generated from the hydraulic motor of the driving system. The maximum output of hydraulic motor is 210.5 Nm and 1,294.5 rpm. Analysis for stability and durability of the planetary gear system design should be performed under extreme load conditions. Thus, outputs in maximum torque are applied as input conditions for analysis. The average temperature in the planetary gear system is established at 60˚C, and the lubricant is established SAE 80W grade which is generally used for planetary gear systems as well.[8]-[9]

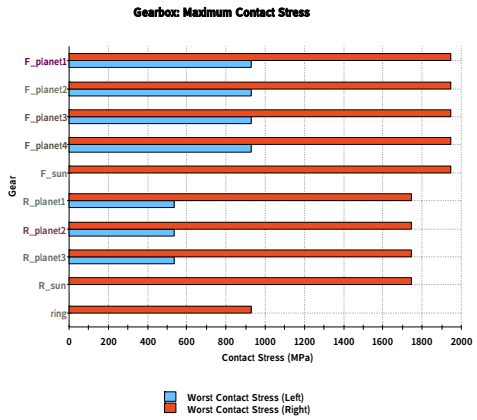
ISBN: 978-1-61804-242-2

Table 1 Material properties

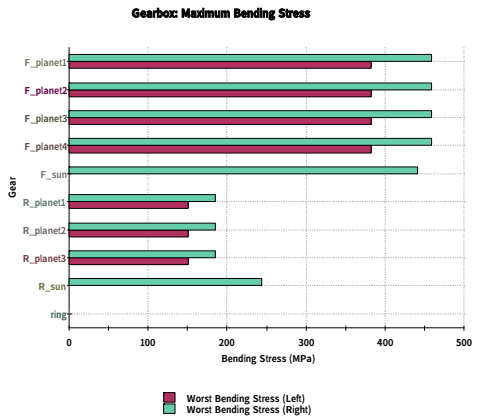
Material	Tensile strength (MPa)	Yield strength (MPa)	Heat treatment	Surface hardness (Hv)
SCM420H	932	792	annealing, carburizing	800

Table 2 Input conditions

Precondition	Test load case
Temperature (C)	60
Speed (rpm)	1,294.5
Torque (Nm)	210.5
Lubricant	SAE 80W



a. contact stress



b. bending stress

Fig. 2 Stress of the planetary gear system

In addition, according to evaluation standards for the lifetime of RS B 0095, the standard of track drive units for small excavators [10], input conditions are established to verify durability for driving over 1,000 hours. The input conditions are arranged in Table 2 and applied to the three researches.

B. The Results of Strength Analysis for Gears

Strength analysis is performed to evaluate the stability of gears in the planetary gear system. The result of the strength analysis is shown in Figure 2 and Table 3.

III. Durability Analysis of Planetary Gear System

Durability analysis for driving over 1,000 hours is performed by the standard of RS B 0095. The results are arranged in Figure 3 and Table 4.

Table 3 Strength analysis result

Gear		Contact stress (MPa)		Safety factor
		left	right	
Ring		-	930.0	2.289
1st	**Sun**	-	1,745.0	0.981
	Planetary	534.2	1,745.0	1.054
2nd	**Sun**	-	1,947.0	1.000
	Planetary	930.0	1,947.0	1.038

Gear		Bending stress (MPa)		Safety factor
		left	right	
Ring		-	-	+Infinity
1st	**Sun**	-	243.8	2.002
	Planetary	150.6	185.1	1.925
2nd	**Sun**	-	440.7	1.193
	Planetary	382.9	458.6	0.820

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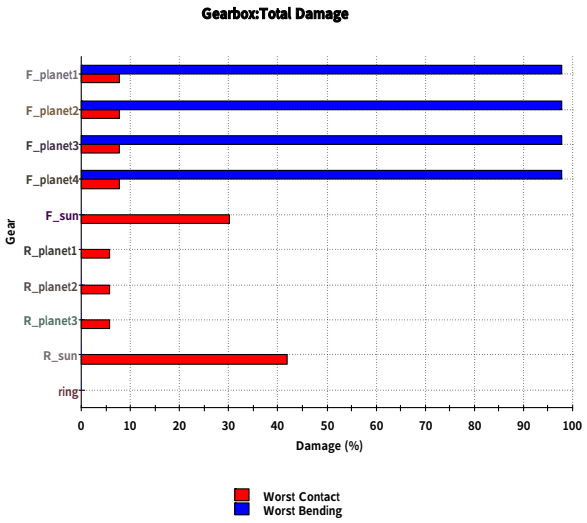

Fig. 3 Bending·Contact damage

Table 4 Durability analysis result

Gear		Pass /Fail	Combined life (hr)	Contact life (hr)		Bending life (hr)	
				Left	Right	Left	Right
Ring		Pass	N/A	N/A	N/A	N/A	N/A
1st	S	Pass	2,385	N/A	2,385	N/A	N/A
	P	Pass	1.7e4	N/A	1.7e4	N/A	N/A
2nd	S	Pass	3328.0	N/A	3328.0	N/A	1.4e7
	P	Pass	1,023	N/A	1.3e4	6.6e4	1,023

IV. Conclusion

In this research, complex planetary gear system which is used in the driving system of excavator has been performed to analyze the durability and stability. At the result of the strength analysis, the sun gear in 1st planetary gear set and the planetary gear in 2nd planetary gear set are not achieved to safety factor 1.0. Those gears are not satisfy the safety factor, but nevertheless those gears has a enough durability over 1,00 hours.

Acknowledgment

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