한국기계가공학회지, 제18권, 제12호, pp.15～21(2019.12) ISSN 1598-6721(Print)
Journal of the Korean Society of Manufacturing Process Engineers, Vol. 18, No. 12, pp.15~21(2019.12) ISSN 2288-0771(Online)

https://doi.org/10.14775/ksmpe.2019.18.12.015

Study on Optimal Design and Analysis of Worm Gear and Casing of 5 Ton Class Worm Gear Reducer

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5톤급 웜기어 감속기의 워엄기어와 케이싱의 최적설계 및 해석에 관한 연구

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(Received 7 September 2019; received in revised form 8 October 2019; accepted 10 October 2019)

ABSTRACT

The worm reducer is capable of quadrature power transmission when the shafts are disposed at right angles to each other. Since a large reduction ratio can be obtained of up to approximately 1/100 and a sliding movement is performed during operation compared with other gears, the noise and vibration are small, and there is the advantage that reverse rotation can be prevented. On the other hand, severe wear and damage are displayed on the gear and worm tooth surface, and many defects, such as intense heat generation of the reducer, occur. In the reducer case, the four-piece casing method was selected to solve the problems of heat generation, transmission efficiency, and assemblability. In this paper, we analyzed the problems of the worm and worm wheel (the core parts of a 5-Ton worm reducer) and casing through these methods and researched how to solve them.

Key Words : Swing Reducer(스윙감속기), Worm Gear(웜기어), Transmission Efficiency(전달효율), Assembling Performance(조립성)

I. Introduction

Studies on worm gear reducer systems, especially cylindrical worm gear reducer systems with swing motion, are insufficient. In particular, the research related to the worm gear reducer system is insufficient, and the research on the worm gear, a key component of reducer, is insufficient recently. Although efforts are being made to develop warm gear reducer at some industrial sites, the research data that can be used as a basis for the development of warm gear reducer are being challenged by the lack of related technology and the lack of research data. Despite being used in your day, Warm Gear reducer are having difficulties in product development due to the lack of optimal design, system fabrication and performance test

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technologies for performance improvement of Warm Gear reducer. As mentioned above, while there are no replaceable equipment in various industries, the development of a worm gear reducer is urgently needed to make up for the maximum deficiencies at the base of the current system. Nevertheless, research on worm gear reducer is only being conducted on the design of some key components, and research on worm gear reducer systems is insufficient. The worm gear reducer to be studied in this paper is a five-ton worm gear reducer.[1-4] For the design of a 5-ton worm gear reducer. precise worm gear dent design, precision worm gear strength design, and shape analysis through worm gear simulation are required. The design technology of reducer structure requires the construction and design of the moderator structure, the design and manufacture of the reducer mechanical elements, and the technologies related to production machining and reliability evaluation require the precision gear manufacturing and processing technology, reducer module case and cover flow assembly technology, and the reliability assessment related technology. Based on this technology, an optimal 5-ton worm gear reducer was developed.[5-7]

2. Design and Simulation of Worm and Worm Wheel

2.1 Worm and Worm Wheel Specification Calculation

For the design of the worm gear reducer, the gear specifications of the worm gear and the worm wheel of the worm gear reducer are calculated as shown in Table 1 based on the theory.

2.2 Design and 3D Modeling Worm Wheel

In this study, the optimum gear value is calculated in the previous section to improve the transmission efficiency.

Table 1 Dimension of worm and worm wheel

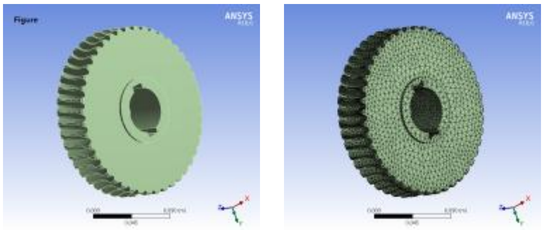
Calculated item	Worm	Worm Wheel
No. of worms & gear teeth	1	44
Axial module(mm)	4.2333	
Pressure angle(degree)	20	
Clearance ratio	0.25	
Gear tooth end height(mm)	4.2333	
Gear tooth front height(mm)	9.525	
Center distance(mm)	118	
Pitch circle diameter(mm)	49.7	186.3
Axial pitch(mm)	13.03	

Fig. 1 3D modeling of separate-type worm wheel

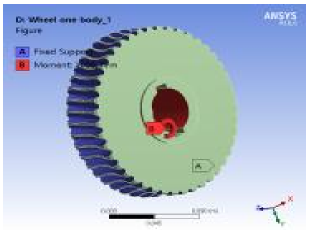
The worm wheel of the existing worm gear reducer is composed of AIBC2 material, which is not only heavy but also has many disadvantages such as abrasion and breakage in the worm boss part. Therefore, in order to improve the life, weight and cost of the worm wheel, separate worm wheel of AIBC2 material and worm boss of FC20 material were designed and fired. Fig. 1 shows the optimization approach of the worm wheel.

2.3 Simulation of Worm Wheel Based on FEM

In the previous section, we designed the optimum gear in CAD/CAM based on the analysis result of worm gear characteristics. The worm wheel was designed in CAD and the tooth profile was designed considering the module, pressure angle and number of teeth. In this section, we have analyzed the

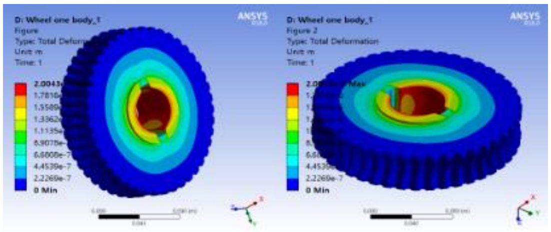


(a) Model (b) Mesh

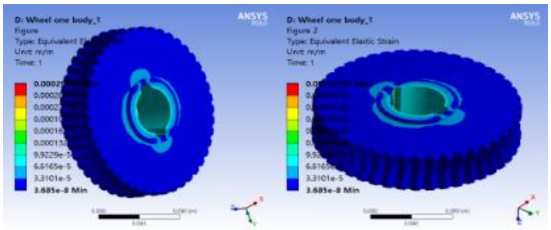


(c) Boundary condition

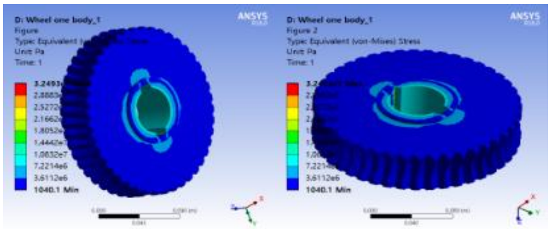
Fig. 2 Analysis preparation of worm wheel



(a) Total deformation



(b) Strain distribution



(c) Stress distribution

Fig. 3 Analysis results of worm wheel

worm wheel modeled using ANSYS. In this study, the worm wheel was composed of AIBC2 worm wheel and FC20 worm boss for weight reduction and cost reduction. The modeling, mesh, and boundary conditions of the worm gear made by combining the existing copper alloy worm gear, AIBC2 material worm wheel and FC20 material worm boss are as shown in Fig. 2.[8-10]

The worm gear can obtain a large gear ratio at the same center distance as compared with other gears. In this chapter, the analytical results for the worm gear system modeled using ANSYS are shown in Fig. 3 In this figure, analysis results such as deformation, strain, and stress are shown. In case of deformation, maximum 2.0043e-7 m was shown, and in case of strain, maximum 2.9761e-4 m/m was shown, and maximum stress was 3.2493e7 Pa.

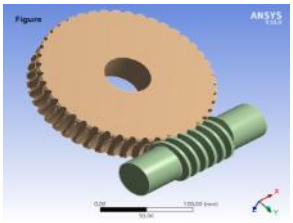
2.2 Simulation of Worm Based on FEM

The worm gear is in sliding contact with other gear transmission devices, the worm is designed by SCM440, which is relatively flexible material according to the worm wheel. Fig. 4 shows three-dimensional model of worm and worm wheel

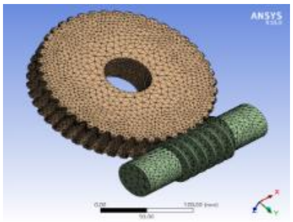
(a) Worm gear

(b) Worm and worm wheel

Fig. 4 3D modeling of worm gear

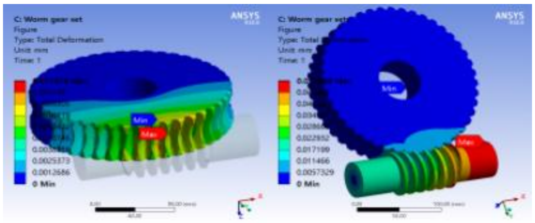


(b) Mesh

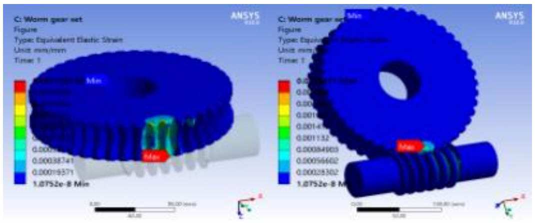


(a) Model

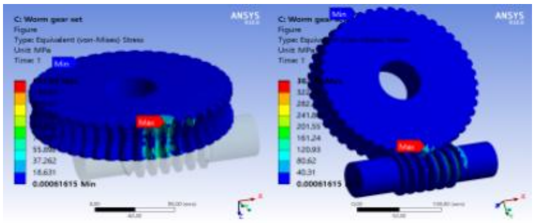
Fig. 5 Analysis preparation of optimized worm gear pair



(a) Total deformation



(b) Strain distribution



(c) Stress distribution

Fig. 6 Analysis results of optimized worm gear pair

Table 2 Analysis results of worm gear pair

	Max. deformation (m)	Max. Strain (m/m)	Max. Stress (Pa)
Integral type before optimized	2.0043e-6	2.9761e-4	3.2493e7
Separation type after optimized	1.9696e-6	3.3052e-4	3.6158e7
Worm / Wheel Gear Pair	5.1596e-4	2.5471e-3	3.6279e8

modeled using CATIA V5. The worm wheel and the worm were assembled by combining the worm wheel of the AIBC2 material and the worm boss of FC25, The modeling and mesh of the worm gear pair are shown in the Fig. 5. Fig. 6 shows the analytical results of the worm gear system modeled previously using ANSYS. In this figure, analysis results such as deformation, strain, and stress are shown. In the case of deformation, the maximum was 5.1596e-4 m and the maximum strain was 2.5471e-3 m / m and the maximum stress was 3.6279e8 Pa. Compared with the integral type, the maximum stress and the maximum pressure are somewhat large, but they are within the allowable range. As a result of the analysis of the worm gear pair, the maximum strain was 5.1596e-4 m and the maximum strain was 2.5471e-3 m/m and the maximum stress was 3.6279e-8 Pa. The results are shown in Table 2.

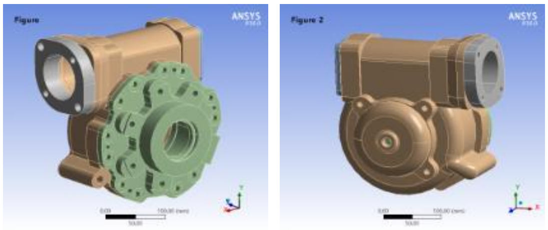
3. Reducer Casing Design

3.1 Design and 3D Modeling Reducer Casing

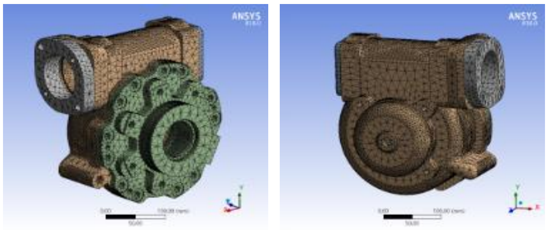
In this paper, we have developed a reduction gear casing technology considering light weight, heat control, and assemblability. First, the housing surface area in terms of structural stability and thermal convection of the housing by the worm gear analysis was examined for the housing design. The worm gear reducer has a lot of defects such as severe heat generation, heavy wear or damage to the gear and worm tooth surface, heavy weight, difficult to assemble. In this paper, a 5-ton worm gear reducer is designed to solve heat, transmission efficiency and assembly problems. We designed the reducer casing considering the assemblability, light weight, and heat control by 4 piece casing method.

3.2 Simulation of Reducer Casing Based on FEM

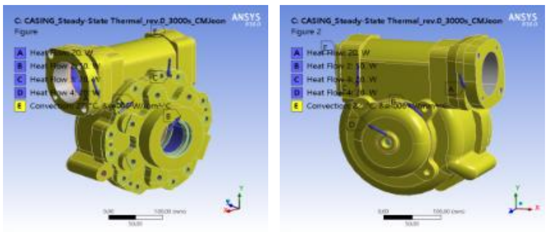
In this paper, we design the gearbox case considering the assemblability, light weight, and heat control. To measure the thermal performance of the designed case, we modeled the case using CATIA V5 and then analyzed the 4 piece casing modeled previously using ANSYS. The reducer case modeling, mesh and boundary conditions are shown in Fig. 7. In the case of boundary conditions, the



(a) Model of case

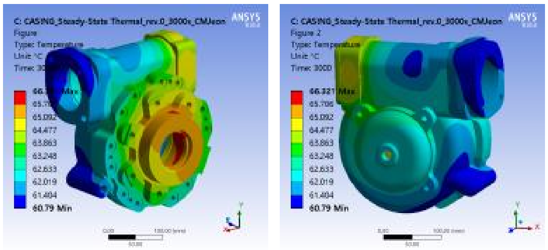


(b) Mesh of case

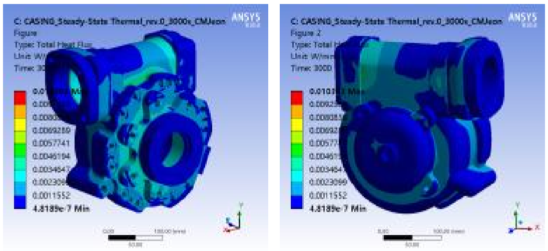


(c) Boundary condition of case

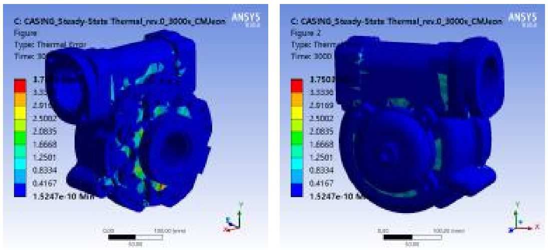
Fig. 7 Analysis preparation of case



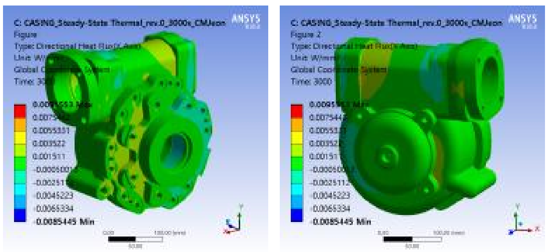
(a) Temperature distribution (3,000 s moment)



(b) Total heat flux (3,000 s moment)

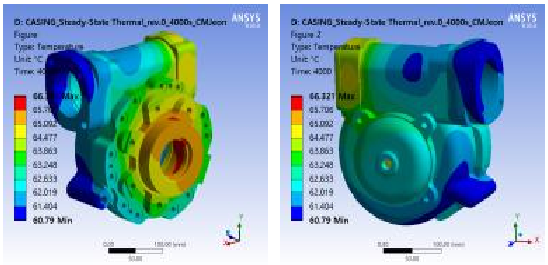


(c) Thermal error

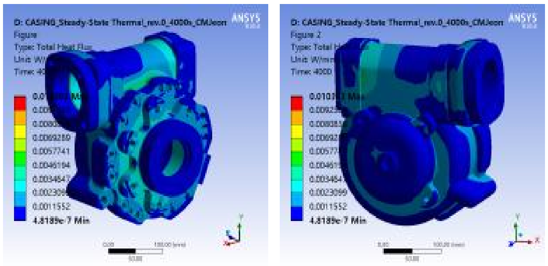


(d) X directional heat flux

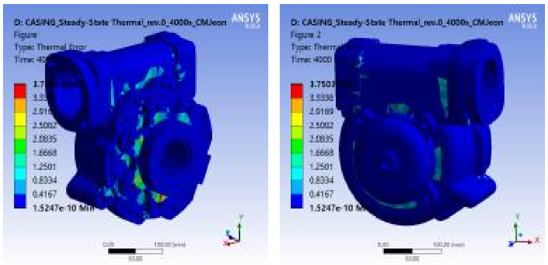
Fig. 8 Analysis results of case(3,000 s)



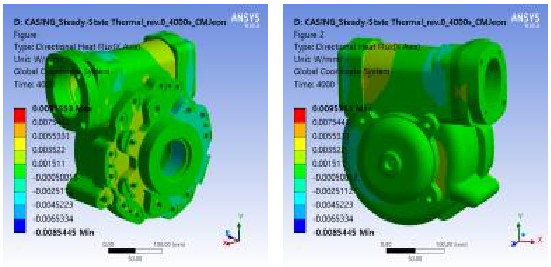
(a) Temperature distribution



(b) Total heat flux (4,000 s moment)



(c) Thermal error



(d) X directional heat flux

Fig. 9 Analysis results of case(4,000 s)

amount of heat generated by the worm gear, bearing, and lubricating oil is estimated, Convection coefficients were set for the part in contact with the air considering the tropospheric flow. Fig. 8 showed the results of temperature distribution, total heat flow, thermal error and x-axis heat flow at 3,000 s. The maximum temperature was 339.3 K for the temperature distribution and the upper part of the output shaft. The total heat flux for the total heat flux was 10,393 W/m2. Fig. 9 showed the results of temperature distribution, total heat flow, thermal error and x-axis heat flow at 4,000 s. The results of temperature distribution, total heat flow, thermal error and x-axis heat flow at 4,000 s were similar to those at 3,000 s. This proves that the designed case system is thermally balanced.

4. Conclusions

In this paper, the improvement of the transmission efficiency of the worm gear reducer, the wear and tear of the worm and the worm wheel are improved, and the core parts of the worm gear reducer for weight reduction and heat control of the reducer are studied. Worm and worm wheel were designed to improve the transmission efficiency. Worm wheel was designed by combining worm wheel of AIBC2 and worm boss of FC25 for weight and cost reduction. In the casing technology, 4 piece casing method which can be assembled, light weighted and controlled for heat is used. In order to maximize the surface area, the axial flow was designed to be externally pin shaped and the following conclusions were obtained.

1. The results of the integrated worm wheel analysis show that the maximum deformation is 2.0043e-6 m, the maximum strain is 2.9761e-4 m / m, and the maximum stress is 3.2493e7 Pa.
2. For the separate type worm wheel, the maximum deformation was 1.9696e-6 m, the maximum strain was 3.3052e-4 m / m, and the maximum stress was 3.6158e7 Pa.
3. The results of the analysis of the worm gear pair showed that the maximum deformation was

5.1596e-4 m, the maximum strain was 2.5471e-3 m / m, and the maximum stress was 3.6279e8 Pa.

4. Results of analysis of the casing The maximum temperature was 339.3 K, the peak heat flux was 10,393 W / m2, the thermal error was 3.7503, and the maximum heat flux was 9,555.3 W / m2 at 3,000 s. The temperature distribution, total heat flux, The result of thermal error and x-axis flow was the same as at 3,000 s. The maximum temperature in thermal equilibrium was 339.3 K.

Acknowledgments

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea goverment(MSIT)(No. 2019R1A5A808320111).

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