BMT turret 구동장치의 구조해석 및 최적화 설계
Finite Element Analysis and Geometry Optimization of the BMT Driving ASS'Y

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1. Introduction

The driving ASS’Y assembled in BMT turret transfers driving force generated by motor to the rotary tools mounted on BMT turret. A good driving ASS’Y can provide faster tool positioning and improve productivity by reducing tool changeover time. With this in mind, it is essential to design the BMT turret including its driving ASS’Y to meet the ever-increasing demand of precision machine tools.

The wide application of driving ASS'Y in BMT turret is limited due to by its high vibration and generated noise. In this study, finite element method ANSYS/Workbench 10.0 is adopted to evaluate the systematic driving ASS'Y.(1) First, a three-dimension finite element model of driving ASS'Y and solutions methods are determined. Then the static characteristics, dynamic characteristics and fatigue behaviors of the driving ASS'Y are predicted. Under working conditions, if dynamic vibration of the driving ASS'Y is near its natural vibration frequency, resonant vibration will happen, fatigue cracks can be formed and more acoustic noise will also be induced. After applying modal analysis of driving ASS'Y, its dynamic characteristics, such as the natural frequencies and corresponding modal shapes can be obtained. By modulating these frequencies, resonance at high rotational speed can be avoided, thus the vibration level of driving ASS'Y can be reduced.(1) Moreover, optimum design through analysis-evaluation-modification cycles has been performed in this study to determine the optimal geometrical parameters of driving ASS'Y with higher efficiency and stability.

2. Modeling and analysis of driving ASS'Y

2.1 Static Analysis

The primary components of driving ASS’Y used in this study conclude a pair of meshed spiral bevel gears and a driving shaft. They are modeled with their actual dimensions by using UG NX3.0 and then imported into ANSYS/Workbench 10.0 for analysis. Fig. 1 shows its mesh model and boundary conditions used in simulation. The mesh model has total 30571 elements and 55369 nodes. Table 1 lists the detailed material specification of driving ASS'Y.

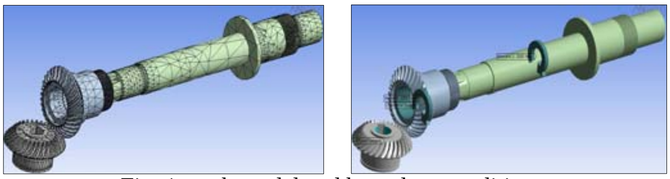

Fig. 1 mesh model and boundary conditions

Table 1 Detailed specification of driving ASS'Y

Mass	2.07 kg
Material	SCM440
Young's Modulus	200GPa
Poisson's Ration	0.3
Density	7850 kg/m^3

Fig. 2 shows the static analysis results on meshed spiral bevel gears. The maximum value of von-Mises stress is 76.8 MPa and the maximum value of total deformation is 0.00264mm. Both of them occur at the same place on the tooth root of meshed gears.

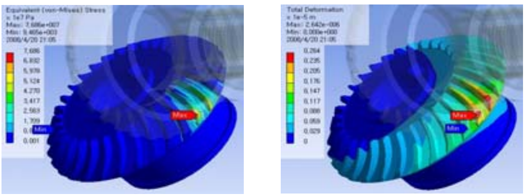

Fig. 2 Equivalent (von-Mises) stress and total deformation

2.2 Fatigue analysis

Fig. 3 is the S-N curve which shows fatigue properties of SCM440 in terms alternating stress versus number of cycles. Fatigue life of meshed gears is calculated based on Goodman in this study. Equivalent (von-Mises) stresses obtained from static analysis are used in fatigue life calculations. All fatigue analyses are performed according to infinite life criteria. Fig. 4 shows the result of safety factor when driving ASS'Y is working under 10^6 cycles. The calculated minimum safety factor is 1.8899.

Fig. 3 S-N curve

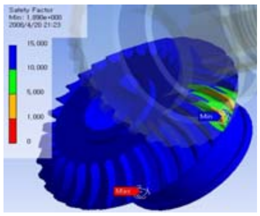

Fig. 4 Result of safety factor

2.3 Modal analysis

Six vibration natural frequencies and their corresponding mode shapes of the driving ASS'Y are obtained. The values of natural frequencies are listed in Table 2.

Table 2 Natural frequencies

Natural frequencies (Hz)					
1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
189.65	190.05	1429.08	1430.43	1830.10	3495.45

According to the results of natural frequencies, harmonic analysis is conducted by setting range Maximum at 3510Hz and solution intervals at 100Hz. Fig. 5 to Fig. 7 show the schematic diagrams of frequency response function of driving ASS'Y. It can be seen that when the frequency is at 1830.10Hz, the amplitude is highest. It is deduced that resonance is likely to happen around 1830.10Hz and its corresponding mode shape contributed significantly to the system response. Fig.8 shows the mode shape at 1830.10Hz and Fig.9 shows the Equivalent (von-Mises) stress of driving ASS'Y at 1830.10Hz. The maximum value of Equivalent (von-Mises) stress, which occurs on the male spline on the driving shaft, is 39.2GPa.

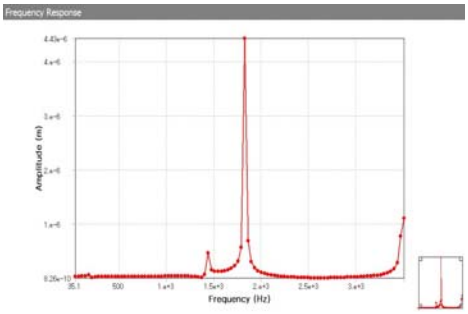

Fig. 5 Frequency response function (x-direction)

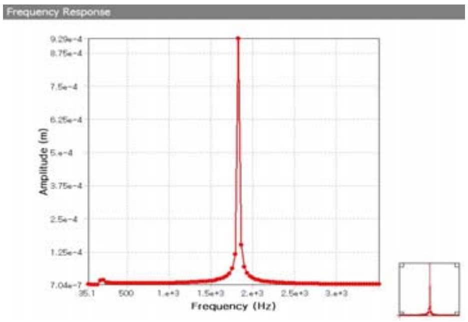

Fig. 6 Frequency response function (y-direction)

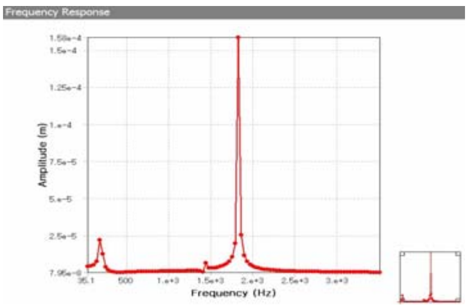

Fig. 7 Frequency response function (z-direction)

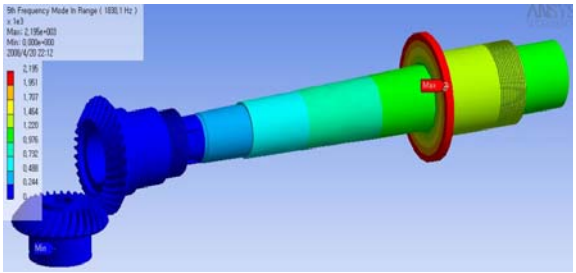

Fig. 8 Mode shape at 1830.10 Hz

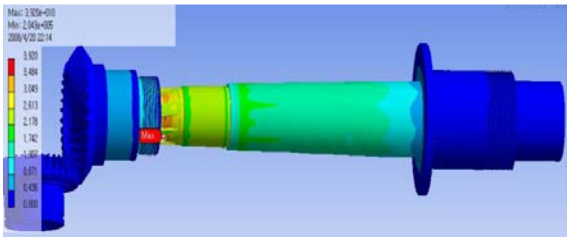

Fig. 9 Equivalent (von-Mises) stress at 1830.10Hz

3. Optimum design

In this study, optimum design of driving ASS'Y is conducted by using DesignXplorer in ANSYS/Workbench. The longest dimension on driving shaft (DS_1) is defined as design variable. Table 3 lists the properties of DS_1. Totally 5 different lengths of driving shaft are designed for getting the lowest maximum Equivalent (von-Mises) stress when resonance is happened at 1830.10Hz and the lowest total deformation on meshed gears simultaneously. Table 4 lists the design results in detail and Fig. 10 shows the response between DS_1 and maximum Equivalent (von-Mises) stress when resonance is happened at 1830.10Hz. It can be seen that changing the length of driving shaft do not have influence on the result of total deformation on meshed gear. When the length of driving shaft is 117.33mm, the stress is highest, which should be avoided and when the length of driving shaft is 138.85mm, the stress is minimum, which is preferable.

Table 3 Analysis conditions

Name	Initial value	Upper bound	Lower bound
DS_1	123.5	135.85	111.15

Table 4 Design results

No	Factor	Result	
	DS_1	Total deformation(mm)	Stress in resonant frequency(Pa)
1	123.5	2.6411e-006	7.1944e-0010
2	111.15	2.6415e-006	1.1404e-0011
3	135.85	2.6415e-006	2.9445e-0010
4	117.33	2.6415e-006	3.4757e-0010
5	129.68	2.6415e-006	3.9199e-0010

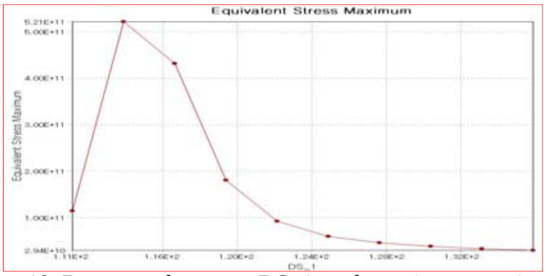

Fig. 10 Response between DS_1 and maximum equivalent (von-Mises) stress at 1830.10Hz

4. Conclusion

In this study, ANSYS/Workbench is used to simulate statics and modal analysis of the driving ASS'Y in BMT turret. The conclusions can be obtained as follows.

1. Maximum value of von-Mises stress and total deformation on contacted gears are 76.8MPa and 0.00264mm, respectively. Both of them occur on the root of contacted gear teeth.
2. Fatigue calculations of the driving ASS'Y give minimum safety factor at 1.8899 under 10^6 cycles.
3. When driving ASS'Y is at 1830.10HZ, the 5th frequency mode contributes most significantly to the system response.
4. In optimum design, changing the length of driving shaft do not have influence on the reslut of total deformation. When the length of driving shaft is 138.85mm, the stress is minimum, which is preferable.

Acknowledgment

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