Analysis for Design of a High Vacuum Turbomolecular Pump

WOO YOUNG LEE* AND KYOUNG BOG JIN**

*School of Mechanical Engineering, Korea University of Technology and Education,
Chonan 333-860, Korea
phone: +82-41-560-1134, fax: +82-41-560-1253
e-mail: wylee@kut.ac.kr

**Dept. of Control Systems Engineering, Korea University of Technology and Education,
Chonan 333-860, Korea
phone: +82-41-560-1144, fax: +82-41-560-1253
e-mail: kbjin@kut.ac.kr

1. Introduction

In modern manufacturing, new applications and technologies demand smaller, and functional devices to replace large systems. As miniaturization becomes a necessity, many companies are interisted in small pumps for use in creating ultra high vacuum, but past efforts to develop such systems have failed due to problems with vibration, stress, heat and power consumption. This paper shows analysis-based design techniques for high vacuum turbomolecular pump by finite element analysis. The ultra high turbomolecular pumps are spreadly used in semiconductor industries and the application areas now grow up rapidly.

2. Analysis Technologies for TMP structural Design

2.1 Brief Description of Analysis Technology

Now a days, according to the processing capabilities of computer systems and the mechanical analysis tools became high, the efforts to design the complicated TMP systems using finite element analysis is very active and widely used . It is need to analyze several areas for proper design of high revolution of TMP from 100,000 up to 250,000 rpm. These areas are (1) static analysis for magnetic bearing, (2) modal analysis for rotor blades, (3) madal and harmonic analysis for full rotational system, (4) full modal analysis for blade rotor, (5) stress analysis for blade rotor, (6) thermal analysis for TMP system.

2.2 Circumferential Stress Analysis a High Rotatioal Speed

In this research, the structural analysis for multi-step blades when the rotational speed changes from 20,000 rpm to 40,000 rpm is performed. The analysis tool for this research is ANSYS finite analysis commercial tool. Fig. 1 shows the three dimensional model of the rotor of TMP and Fig. 2 shows the 1/8 sectional model for computation. Fig. 3 shows the stress distribution of a analysis results at 40,000 rpm. By using this result we can justify the safeness of the design specification of the rotor system.

2.3 Vibration Analysis of Rotor

The dynamic stability of a rotor at high rotational speed is very important factor to characterize the system performance and life of the TMP system. There are three considerations for the analysis of dynamic stability analysis.

(1) Blade Vibrations

The most common vibration issue in turbo-machinary. This is where a single blade exited in its natural frequency. It can lead to tip rubbing, as well as to high cycle fatigue.

(2) Rotor Dynamic Vibrations

The entire rotating system, including the rotor and bearings, can vibrate under many different modes. The stiffness of the bearings and housing that holds them is critical in this type of dynamic behavior.

between the rotor and housing, and high cycle fatigue failures.

(3) Blade Rotor Vibrations

Under certain circumstances, groups of blades and the rotor structure can interact together to produce higher modes in the rotor. This can also cause tip rubbing or high-cycle fatigue failures.

Fig. 4 shows the mesh generation model for the blade-rotor part for modal analysis, and Fig. 5 shows the example of the first mode shape..

2.4 Thermal Analysis of the Rotor

According to the high rotational speed of the rotor, the temperature of the rotor also rises up to certain degree . It also causes thermal stress and deformation of the rotor. It should be checked out the clearences between rotor and housing due to thermal deformation.

2.5 Impact Analysis of the Stator

A small fragment of the rotor blade can cause impact loading to the stator at operation of the TMP. In this case the stator and housing can be severely damaged. Fig. 6 shows the mesh generation model for the stator(half model) and Fig. 7 shows a example of stress distribution of the stator in this impact loading case.

3. Conclusions

There are several important considerations for the design of turbomolecular pump used in semiconductor industries. In this paper it is surveyed the analysis techniques for the TMP by finite element analysis. Analysis-based design for the TMP can help us to decide the trade offs between vibratory, thermal, stress, and weight isusses in complicated system.

Acknowledgments

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References

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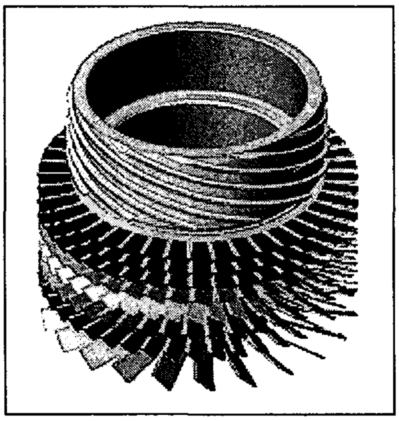

Fig1. Three Dimensional Model of the Rotor

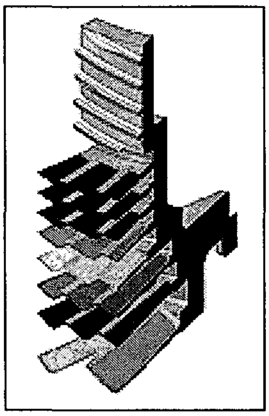

Fig.2 1/8 Sectional Model for Computation

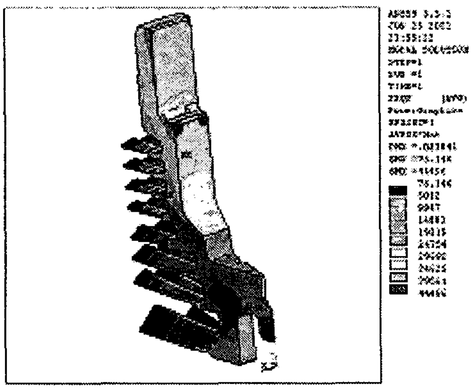

Fig.3 Stress Distribution of the Rotor

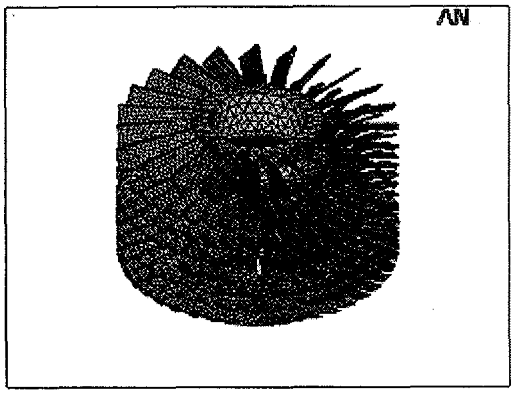

Fig.4 Mesh Generation of the Blade Rotor

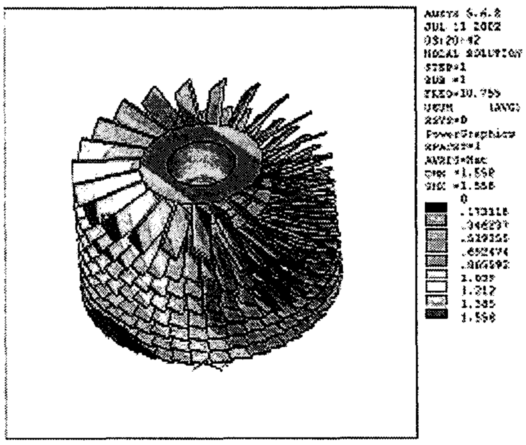

Fig.5 First Mode Shape

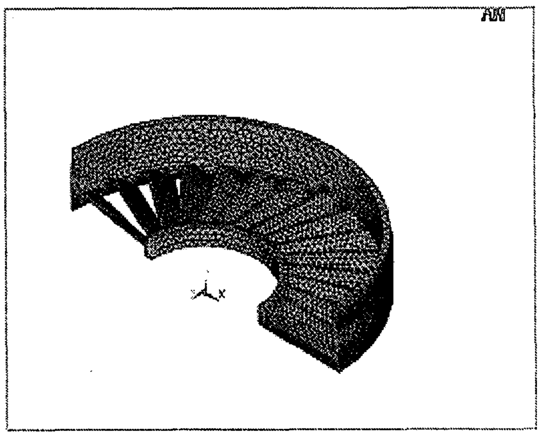

Fig.6 Mesh Generation for Stator, Half Model

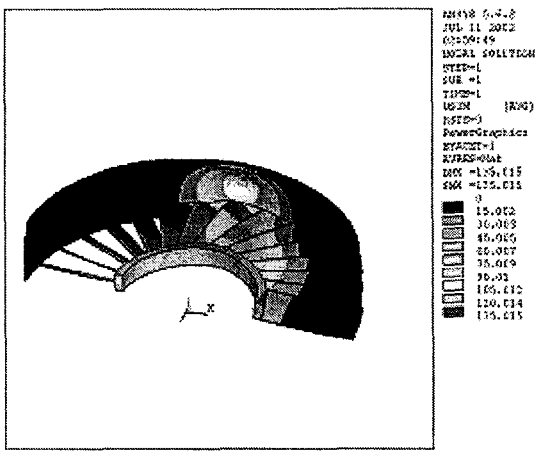

Fig.7 Stress Distribution for Stator