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Dynamic and static analysis of the key vertical parts of a large scale ultra-precision optical aspherical machine Tool

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Abstract

In this paper, a finite element model is built up to investigate the static and dynamic characteristics of the key vertical parts of a large scale ultra-precision optical aspherical machine. The spring-damper units of moving joint surfaces are applied in the finite element analysis. The analysis of static characteristics shows that the stiffness of grinding point is much smaller in other directions than that in vertical direction. When the ram is in the highest and lowest positions, the first-order natural frequencies of the vertical parts are 85.6Hz and 84.6Hz, respectively, more than twice times of the maximum spindle speed.

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Keywords: grinding machine; aspherfic surface; characteristics.

1. Introduction

Large scale ultra-precision optical aspherical mirrors are applied to laser fusion device, large diameter telescope and lithography machine etc [1], so the large ultra-precision grinding machine is very important for the fabrication of the large ultra-precision aspherical optics. It restricts processing efficiency and precision.

An ultra-precision optical aspherical machine tool has been developed. The maximum diameter of the workpiece could reach 1500mm. The vertical components move on a stepped beam. This article discusses the static and dynamic analysis of the key vertical parts of the large scale ultra-precision optical aspherical machine tool. It is inevitable to set up accurate dynamic models. Machined joints exist extensively in machines and mechanical. The moving joint surfaces are applied in the finite element analysis.

Interfacial parameters including contact stiffness and contact damping are of great importance to contact dynamics and interface modeling[2]. The contact stiffness and damping of the joint surface has a great influence in the characteristics of the overall mechanical structure. Numerous studies show that the contact stiffness of the joint surface account for 60% ~ 80% of the overall stiffness of the machine, and more than 90% of the total damping of the machine comes from the joint surface [3] [4] [5]. Therefore, the impact of joint parameters should be considered in the finite element analysis. Machine joint surface can be classified as fixed joints, and sliding or moving joints [6]. Fixed joint surface is the contact surface connected by bolts or screw. Moving joint surface is the contact surface of the moving parts such as sliding contact and hydrostatic contact. Physical phenomena in the joint are quite complex and therefore too impractical to model at the micro-scale. The primary impediments to modeling mechanical joints are their nonlinear nature and variability [7]. Because the joint surface has dual characteristics of storage and expending energy, joint surface are characterized by contact stiffness and contact damping. The dynamic model of joints was often simplified into a group of equivalent spring-damper model. Spring-damper can be used as a token of the normal or tangential dynamic characteristics of the joints [8]. The spring-damper units have been used to simulate the contact between the joint surface in this paper.

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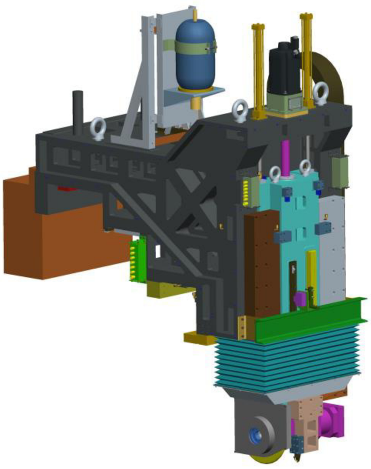
2. Method

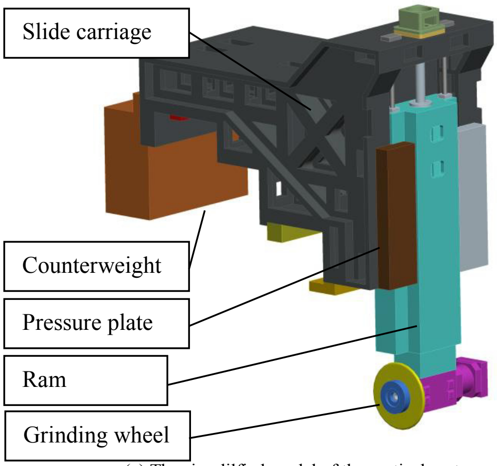
2.1. model

The models of the vertical axis component are shown in Fig.1. Fig.a shows the Slide carriage mounted in the stepped beam. The finite element model is set up as shown in Fig.2. In this model, vertical axis is meshed by hexahedron elements. The vertical axis slide, ram and guide plates are meshed by 20mm grid. For bearing seat and the motor blocks, they are meshed by 10mm grid. Other smaller structures are meshed by 5mm grid. The mesh model of the vertical parts is showed in Fig. 2. The mesh model has 259,212 units, 1,063,236 nodes, the average mass of the grid is 0.75.

(a) Slide carriage mounted in the stepped beam



(b)



(c) The simplilfied model of the vertical parts

Fig. 1.The models of the vertical axis component

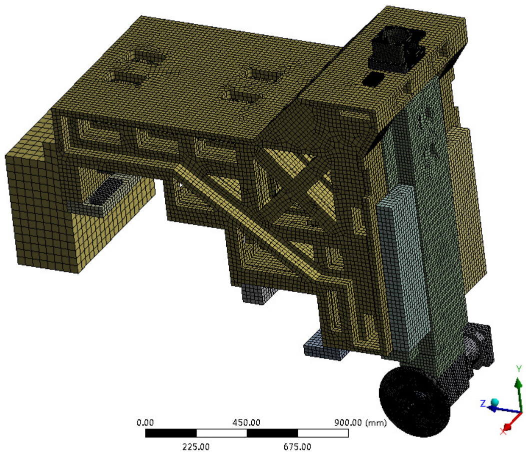


Fig. 2.The mesh model of the vertical part

2.2. Material

The material parameters of the model need to be set before finite element calculation. According to the design of materials used, material type and parameters of each component are shown in Table 1 below.

Table 1 Material

Objective	Material	Yong modulus （Pa）	Poisson's ratio	Density （kg/m^3）
Slide carriage	HT350	1.45E+11	0.27	7300
Ram	HT350	1.45E+11	0.27	7300
Pressure plate	HT350	1.45E+11	0.27	7300
Motor seat	HT350	1.45E+11	0.27	7300
Balance weight	HT250	1.38E+11	0.256	7280
Oil pad	QSn4-3	1.10E+11	0.33	8800
Ball screw	40Cr	2.11E+11	0.277	7870
Ball screw bearing	40Cr	2.11E+11	0.277	7870
Main shaft flange	45	2.09E+11	0.269	7810
Grinding wheel base	45	2.09E+11	0.269	7810