Dynamic Performance Simulation and Analysis of Longmen Frame of Heavy Duty Machine Tool

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Abstract. The modal analysis is an important part of the dynamic performance analysis tool. The 3D numerical models of a heavy duty machine tool is established by CAD sofeware. Then, the natural frequency and the modal shape of the machine tool modal analysis is obtained, which can provide the support for the improvement of structure design and fault diagnosis of machine tool.

1.Introduction

With the continuous development of science and technology, all fields of industrial products continue to innovate, and machinery manufacturing industry as the foundation of our country, but also for the military, aerospace and other fields to create a high standard of mechanical parts [1]. These parts require very high precision, the traditional machine cannot complete the task of processing, coupled with the fierce market competition at home and abroad, it is needed to establish a new era of CNC machine tools to meet these requirements [2]. Under the guidance of the strategy of revitalizing the equipment manufacturing industry, the development of the machine tool industry began to enter the golden period of development, ushered in an unprecedented development opportunity. However, the overall transformation and upgrading of China's machine tool industry is slow, but also need to accelerate the pace of product innovation, cross country door to the world of CNC machine tool market. Based on the finite element method, the model of the milling machine is established [3, 4], and the modal analysis is carried out to obtain the natural frequency. On this basis, several optimization schemes are compared. Finally, the structure of the model is reasonable.

2.The establishment of finite element model

Finite element model pre process. Due to the Longmen box structure of heavy duty machine tool is very complex, before carrying out finite element analysis, The entity model (as shown in Figure 1)of the Longmen box of machine tools need to be necessary modified. A small model of the hole, and some small size chamfering should be removed, ignoring the tiny details in assembly. As the machine tool Longmen box and the work platform is an independent component, and the dynamic characteristics of the Longmen box is the main research content, so work platform was removed in this paper. In this way, not only can reduce the resource occupancy rate, but also can improve the efficiency of the finite element calculation, analysis and solution, and prevent the occurrence of singular and stress concentration.

This machine tool model has five joining point, respectively, the left and right column - beam, beam - apron and apron - Ram, and the joining point are treated as bonded type in the ANSYS. According to the actual working conditions of the machine tool, the whole surface of the left and right columns of the machine tool is fully restrained.

According to the actual working conditions of the machine tool, the whole surface of the left and right columns of the machine tool is fully restrained as shown in figure 2.

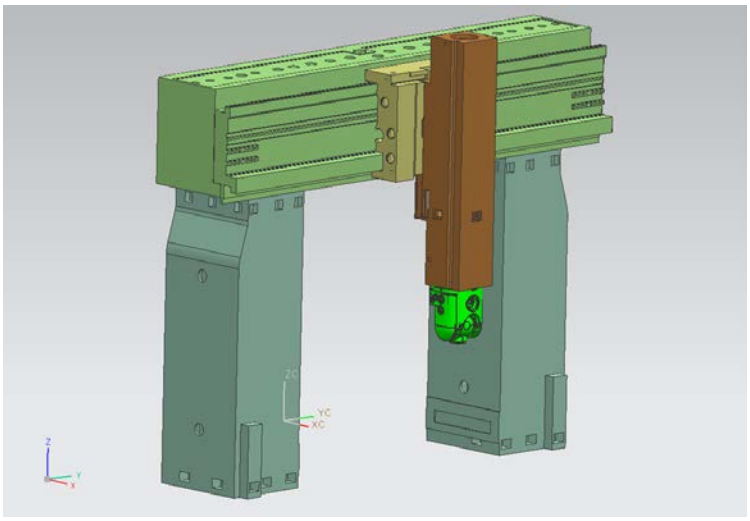

Fig. 1 Model of machine tool

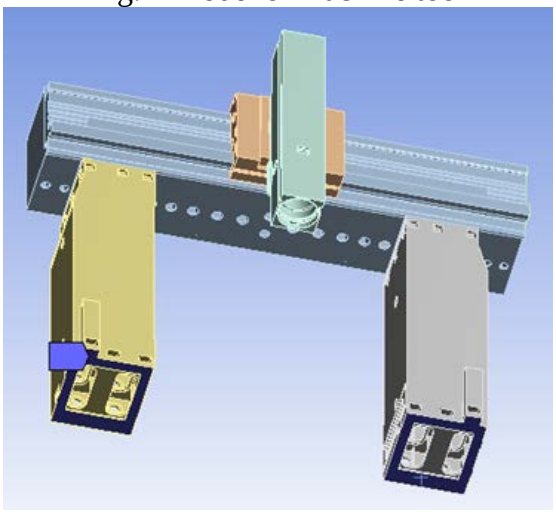

Fig. 2 Constraint conditions of machine tool

Each part of the machine tool is a casting, and its material parameters are as follows:

Table 1 Material properties of each component

Component	Material	Density (kg/m3)	Modulus of elasticity (Gpa)	Poisson ratio
Beam	QT600	7200	174	0.275
Column	HT250	7100	110	0.25
Apron	QT600	7200	174	0.275
Ram	QT600	7200	174	0.275
Milling head	-	-	-	-

Grid division is one of the key elements in the finite element analysis, and the mesh quality is good or bad for the correct and reasonable establishment of the finite element model is very important [5]. The basic principles of Grid: grid number, mesh density, element order, mesh quality, grid interface and boundary point, grid layout, node and unit number, which has a great influence on the subsequent calculation [6]. The number of grid will affect the calculation time and precision analysis. Under normal circumstances, the parts division is fine, the total number of grid is more, so the results of the analysis accuracy is more close to the truth. However, the calculation of negative factors arising from the need is very large. If the grid number is too small, there may be the mesh distortion and the accuracy will be reduced accordingly, so to consider two factors to determine the number of grid [7-8].

SOLID187 unit is used for grid division. SOLID187 unit is a high order 3 dimensional 10 node solid tetrahedral element, and SOLID187 has two displacement modes can better simulate the irregular model, as shown in figure 3. The model unit of machine tool is divided into 3 parts: 60mm, the total number of nodes: 639874, the total number of cells: 338568.

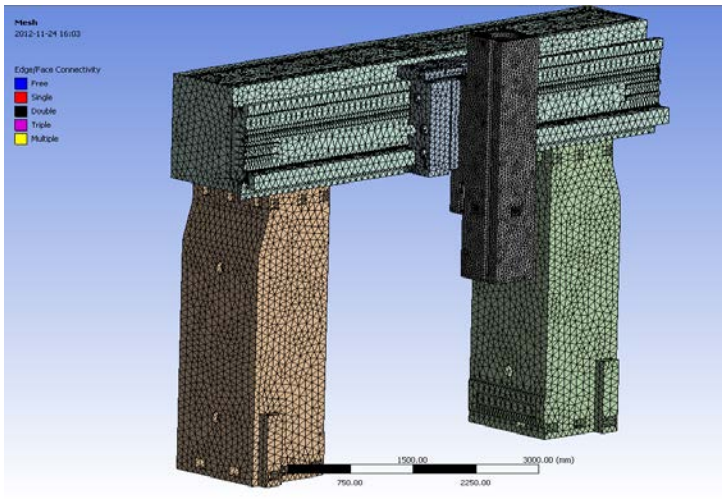

Fig. 3 Finite element model of machine tool

3.Modal analysis results of Longmen frame

The natural frequency of the Longmen box is shown in Table 2.

Table 2 Natural frequencies of each order

Modality	Frequency [Hz]
1	21.18
2	25.437
3	38.194
4	55.424
5	69.882
6	97.18
7	101.78
8	127.57
9	141.67
10	145.1
11	145.65
12	148.29

The vibration type of the Longmen box is shown in figure 4 to figure 9.

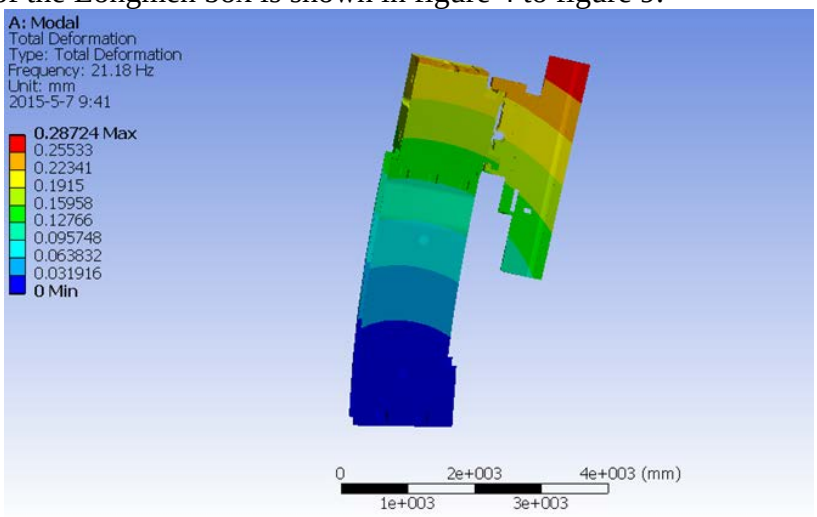

Fig 4 First order mode (first order flexural vibration of Longmen frame)

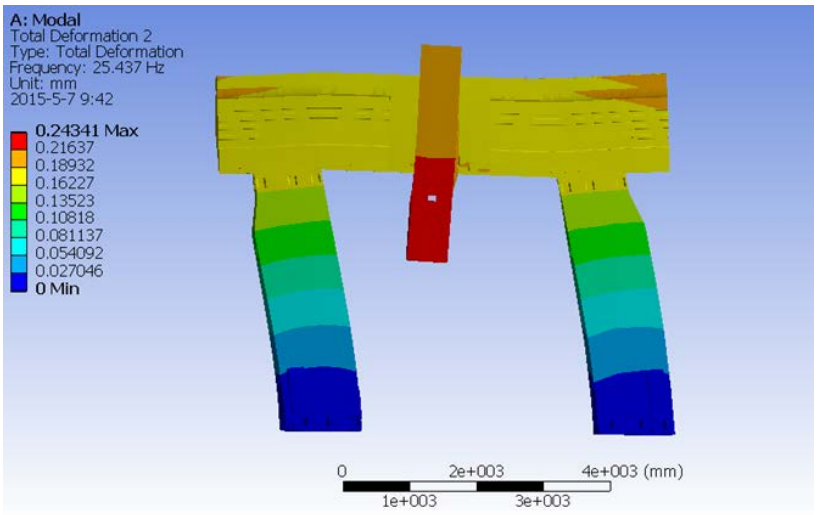

Fig 5 Second order mode (First order flexural vibration of Longmen frame in Y-direction)

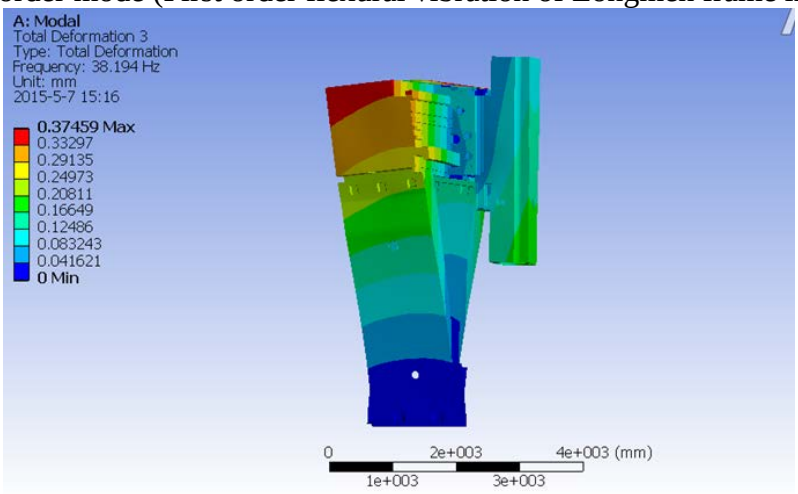

Fig 6 Third order modes (Backward first order flexural vibration of column)

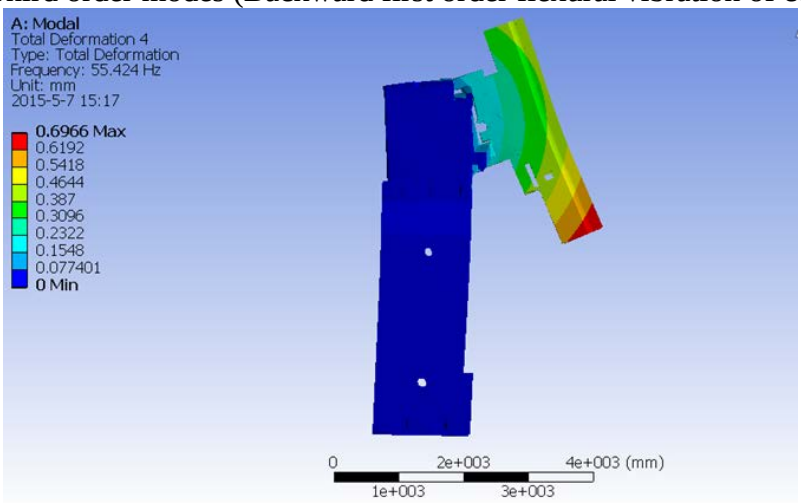

Fig 7 Fourth order modes (First order flexural vibration of Ram in X-direction)

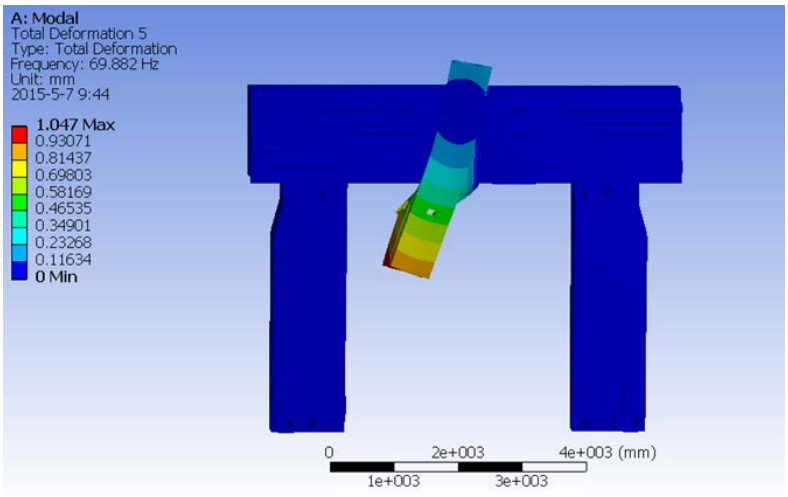

Fig 8 Fourth order modes (First order flexural vibration of Ram in Y-direction)

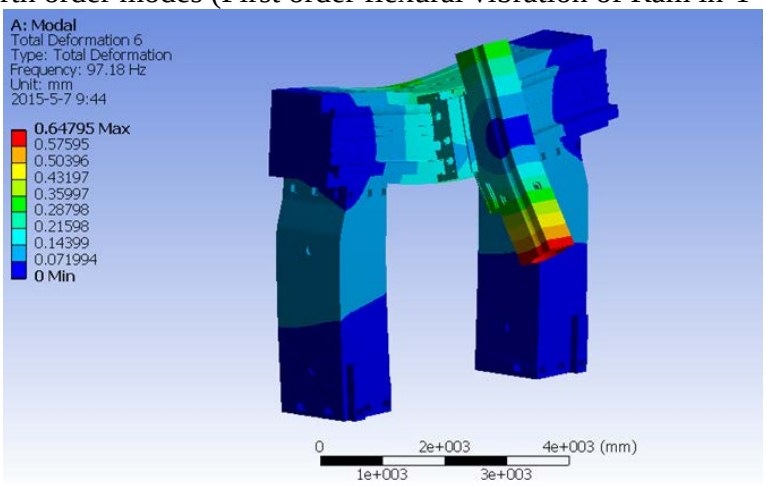

Fig 9 sixth order mode（First order flexural vibration of beam and torsion of the column）

4.Summary

From the analysis results of the Longmen box, the first seven order modes are mainly based on the whole bending and torsion deformation of the transverse beam, the ram, the column, and the local torsion of the column and the local concave and convex of the beam from the eighth stage. The analysis results show that the overall rigidity of Longmen box is better. From the eighth order to the twelfth order, some local mode shapes can be known, the local stiffness of the Longmen box is relatively low. The design can be further optimized by all parts of the material distribution, optimize the design of the various parts of the wall thickness and rib arrangement, so that the local stiffness is improved, so that each part stiffness tends to close, the local vibration mode into overall vibration.

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