Analysis and Research of High Speed Laser Cutting Machine Based on FVM

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Abstract. The structure of high speed CNC laser cutting machine is described, the deformation of the high speed laser cutting machine flying beam mechanism in the course of the campaign, FVM was used to analyze the deformation of the flying beam generated in different situations, according to the analysis results, put forward the method of NC system dynamics based on the inhibition of deformation to reduce flight. The deformation of the beam when high speed cutting purposes.

Introduction

In recent years, with the continuous improvement of the domestic economic situation, China's laser industry has been rapid development, the government has always attached great importance to the development of the industry. Laser cutting machine is an indispensable tool in the metal processing industry and the key industry field in China. Laser cutting machine is widely used in the automotive industry, shipbuilding industry, power generation equipment, aerospace, military equipment and other fields. With the development of laser cutting machine, laser cutting machine is towards high speed and high precision, to carry out research on cutting technology and equipment of high speed CNC laser system to solve some key problems of laser cutting, the domestic high-speed CNC laser cutting machine has reached the international advanced level in the speed, accuracy index. And through the control system of high-speed laser cutting equipment, we can break through the dependence of laser cutting equipment on foreign control system, and promote the development of high speed laser cutting equipment design and manufacturing level. And finally realize industrialization to improve the technical level of domestic cutting industry, and create a good social and economic benefits.

The finite volume method (FVM), also known as the control volume method (CVM), is a very rapid development in recent years. Its basic idea is: the calculation area is divided into grids, and each grid point is surrounded by a non repetitive control volume[1].

Finite Volume Method (FVM) Analysis of the Flying Beam

The flying beam adopts special design, which has the advantages of light weight, good rigidity, high speed and stable operation. At the same time the dust enclosed structure, the structure of the cutting machine in the process of movement, when setting the cutting speed is high, slow flying beam mechanism at the moment, the most distal will produce large deformation. Because the deformation is not controlled by the human, and the deformation is different with the acceleration of the flying beam, so it is bound to have an impact on the quality of the final cutting workpiece.

Therefore, it is necessary to analyze the causes of the deformation of the flight beam, in order to reduce the error caused by the deformation in the structure design and control methods of the machine tool.

Finite Element Modal Analysis of Flight Beam

Modal analysis is a part of the dynamic analysis, which provides the most basic analysis data for the transient dynamic analysis, harmonic response analysis and spectral analysis.

The main content of the modal analysis of flight beams is to determine the vibration characteristics (natural frequencies and vibration modes), which are the important parameters in the
design of the dynamic load structure. By modal analysis can design the flying beam is reasonable to determine that the flying beam structure has no weakness, and according to this data to optimize the design of the flying beam, which can best structure design of the flying beam, then avoid the inherent frequency.

**Inherent Characteristics of Flying Beams**

The 3D model structure of the high speed laser cutting machine is shown in Figure 1, which mainly consists of the following parts: the flying beam structure, the base of the machine tool, the servo motor, the driving lead screw and the laser head. In fact, we are mainly concerned with the flight deformation of the beam structure in high-speed motion process, so in line with the actual problem, the whole machine model was reasonably simplified, in order to facilitate the analysis.

![Figure 1. High speed laser cutting machine.](image)

![Figure 2. Flight beam structure.](image)

**Establishment of Flight Beam Model**

The machine base inertia, therefore the simplified earth connection; mainly by guideway and ball screw to achieve between the machine base and the flying beam structure, so in ADMAS, this can be simplified into sliding connection constraint \[\{\}^2\], friction coefficient \(\text{Ud} = 0.02\); due to deformation caused by only considering the horizontal direction, so it can be in the vertical direction of the laser head caused by the static deformation of neglect; transfer relationship between X axis screw and the flying beam force is simplified as horizontal directions at two points of contact force \(F\). The flight beam structure is shown in Figure 2:

**Modal Analysis Results of Flight Beam**

The first order modal results are shown in Figure 3. The second modal results are shown in Figure 4

![Figure 3. The first order modal results.](image)

![Figure 4. The second modal results.](image)
The third order modal results are shown in Figure 5. The Fourth modal results are shown in Figure 6.

The flying beam modal analysis results can be seen in reaching the first frequency, machine flying beam deformation in X direction; at 2 frequencies, the flying beam generated in the Y direction of the large deformation; more than 3 frequencies above, the flying beam tends to be unstable.

So, when the flying beam design, can change the flying beam section shape or increases the flying beam stiffness to improve the first order frequency, thereby reducing the inherent characteristics of the flying beam caused by the error during cutting.

**Analysis of the Deformation of Flying Beam in the Process of High Speed Cutting**

The calculation principle of flight beam deformation is shown in Figure 7.

**Analysis of Flight Cross Beam Deformation under Different Conditions**

Rational analysis and calculation process, to solve the problem of the whole play a crucial role. In this section, the maximum deformation of the flying beam in two cases is analyzed. Through the comparison and analysis of the deformation of the test point of the flying beam under different circumstances, the deformation law of the flight beam is found out. In this paper, the design of the two analysis process is as follows:

1. In the case of the same weight and acceleration, the impact of the acceleration of different sizes on the flight cross beam is compared.
2. In the case of the same acceleration and the size of the acceleration, the comparison of the different weight of the speed of the flying beam produced by the deformation.

The same acceleration mode and the acceleration of the size, different weight of the case, the flight of the beam deformation in the case, setting the maximum cutting speed of $V_{\text{max}} = 10 \text{m/min}$, acceleration is $a = 5 \text{m/s}^2$. Trapezoidal acceleration mode.

When the flying beam material is 45 steel or Aluminum Alloy, two kinds of materials in the process of deformation motion measurement points are shown in Table 1.

By comparing the calculation results of the above two conditions, we can get the following conclusions: the same acceleration mode and the same size acceleration, the greater the quality of the flight beam, the greater the amount of deformation generated.
Table 1. Same acceleration mode, the same acceleration of the size, different quality of the test point deformation.

<table>
<thead>
<tr>
<th>Deformation amount (mm)</th>
<th>a=5m/s²</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 #</td>
<td>Aluminum alloy</td>
</tr>
<tr>
<td>1.9</td>
<td>0.66</td>
</tr>
<tr>
<td>recovery time (s)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The Same Acceleration Mode and Weight, Different Accelerations, the Deformation of the Test Points

In this analysis, the flying beam material is selected for 45# steel, and the trapezoidal acceleration mode is adopted; The maximum cutting speed is Vmax = 10m/min. When the acceleration is large, the deformation of the flying beam can be analyzed in the case of different accelerations.

Table 2. Deformation for the Test Point on Different Acceleration, with Same Mass and Acceleration Mode.

<table>
<thead>
<tr>
<th>Maximum deformation (mm)</th>
<th>45 #</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4g</td>
<td>0.5g</td>
</tr>
<tr>
<td>0.35</td>
<td></td>
<td>1.9</td>
</tr>
<tr>
<td>Deformation recovery time (s)</td>
<td>2.4</td>
<td>2</td>
</tr>
</tbody>
</table>

Therefore, by comparing the results of different acceleration conditions, we can find that: for the same quality of the flying beam in the same way, accelerate the situation, as the acceleration increases, deformation of the flying beam produced in the instantaneous acceleration also increases. [5]

We can draw the following conclusions by analyzing the calculation results of the flying cross beams in the above two cases:

For the same machine tool, in the acceleration motion of the trapezoidal acceleration method, the deformation of the flight beam is increased with the acceleration of the same machine.

In the case of the same acceleration and acceleration, the deformation of the flying beam increases with the increase of the weight of the flying beam.

The deformation caused by the movement of the flying beam in different situations has been analyzed in detail. By analyzing the results, we can see: the flying beam in the acceleration and deceleration of the moment, resulting in the largest amount of deformation, such as trapezoidal acceleration mode, the acceleration of 5m/s², the test point of the deformation of up to 1.8mm. Such a large deformation in the workpiece cutting process, it is bound to have an impact on the quality of the final workpiece cutting. Therefore, it is necessary to find a suitable method to reduce the deformation caused by the flying beam during the movement. S-shaped acceleration and deceleration refers to the acceleration and deceleration process, the acceleration of the derivative J constant acceleration and deceleration process. By control acceleration derivatives to avoid the acceleration of abrupt change, and reduce the vibration caused by the acceleration of the mechanical system caused by the acceleration of the process. [4]

Summary

In this paper, the deformation of the high speed laser cutting machine in the course of motion, the flying beam mechanism is analyzed. Firstly, the modal analysis of the flying beam mechanism is carried out, which provides a theoretical basis for the design of the mechanical structure of the
flight beam mechanism. And analyze the deformation of the flying beam under various circumstances, and find out the law of the deformation. And the theoretical basis of the numerical control system is introduced in this paper.

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**References**


