Dynamic Analysis of Three Dimensional Numerical Control Laser Cutting

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Abstract. The finite element software is used to analyze the dynamics of the three dimensional numerical control laser cutting machine. Method for analysis of dynamic structure using the modal analysis of the main moving parts, driving beam and on this basis, from the angles of kinematics and dynamics of the whole equipment stress, strain and displacement and stiffness of the system analysis and research, for cutting machine design and provide a theoretical basis for structural optimization.

Introduction

Laser cutting machine is the use of laser beam energy to achieve mechanical cutting equipment, is mainly used to cut into the required shape and size. Since 1979, Italy Prima industry company to produce the world's first laser cutting machine, laser cutting technology has been widely used in automotive, aerospace and aviation[1].

Laser cutting machine is the use of laser beam radiation to the workpiece surface when the release of the energy to melt and evaporate the workpiece, in order to achieve the purpose of cutting equipment, mainly used for sheet metal cutting. With high precision, fast cutting speed, not restricted by cutting patterns, smooth incision, low processing costs, will gradually replace the traditional cutting technology. With the development of science and technology, has been widely used in aerospace, shipbuilding, automotive and power equipment manufacturing industry such as CNC laser cutting machine, and cutting thickness increases toward the cutting speed, the rapid and precise cutting direction. Three dimensional numerical control laser cutting machine represents the highest level of laser processing technology.

Dynamic analysis is different from the static analysis, the stress, strain and displacement of the cutting machine are changed with the change of time. Because of the requirements of the process, the start and stop time of the cutting machine is very short (t=0.2s). The dynamic loads produced by this time have great influence on the strength and stiffness of the structure of the cutting machine, which is also the key point of this project. And modal analysis is the most basic content of all dynamic analysis. Mode is the inherent property of the structure, only with the material properties and mechanical structure, and the length of time is not related to the load. The main parameters of the modal parameters are: eigenvalue (Eigenvalue), natural frequency (Frequency), generalized mass (mass Generalized), and compound modal damping (modal damping Composite).

The beam and the drive beam is the core of the moving parts of 3D CNC laser cutting machine, its quality is large, accounting for about 2/3 of the quality of laser cutting machine, laser cutting machine in the work process, due to the rapid movement, fast cutting, laser head acceleration starting and accelerating stop great impact strength, the inertial force caused by the action of the moving parts of the stiffness of the life and work efficiency are, especially the effect of periodic vibration level of the moving direction of the equipment even more. This paper uses the finite element software, the wide and heavy plate track CNC laser cutting machine and 3D CNC laser cutting machine for dynamic analysis. Method for analysis of dynamic structure using the modal
analysis of the main moving parts, driving beam and on this basis, from the angles of kinematics and dynamics of the whole equipment stress, strain and displacement and stiffness of the system analysis and research, for cutting machine design and optimization provide a theoretical basis, has theoretical guidance for the design and reconstruction of 3D CNC laser cutting machine.

Research Program Flow Chart
The program flow chart is shown in Figure 1.

![Research Program Flow Chart](image)

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Establish the Solid Model of 3D Numerical Control Laser Cutting Machine. SolidWork software is used to model the 3D NC laser cutting machine, and then the finite element analysis is carried out in the software. Before the contact analysis is carried out, we should first establish the three-dimensional model to simplify the process. The main components of the whole model are: cross beam, Z shaft drive, base, etc. These parts need to do some simplified in structure, remove the bolt, nut, washer, gasket, cushion, protective cover, a pin, a spring, chamfer, fillet, the bolt holes and pin holes and holes filled, attention is needed to ensure the overall quality. One of the purposes of these simplified processing is to get the size and type of the grid, and to improve the quality of the grid, so that the concept of the calculation is more accurate. There are some parts of the deformation is very small, such as motor, it is simplified as a discrete rigid body, and the abolition of the gear shaft and the key link between the gear. The whole model is not symmetrical model, so it is necessary to analyze the whole model. The final simplified model is shown in Figure 2.

![Solid Model of Three Dimensional Numerical Control Laser Cutting Machine](image)
Material Properties and Selection of Analysis Step of Cutting Machine. The simplified cutting machine materials are mainly Q235A, 45 and QT, the analysis step time is 0.2S.

Strength and stiffness of cutting machine welding material for ordinary carbon steel (Q235A), allowable stress:

\[
[\sigma] = \frac{\sigma_s}{n_s} = \frac{240}{1.5} = 160 \text{MPa}
\]

Type $[\sigma]$—The allowable stress of materials (MPa);
Type $\sigma_s$—Material yield limit (MPa); Type $n_s$—Material yield limit (MPa)

The maximum machining diameter of the same common metal cutting machine tool is generally 19-80N/μm [2], and the requirement of the laser numerical control machine tool is higher than that of the ordinary machine tool 50%. Its stiffness is 28.5-120N/μm [3]

The stiffness formula is: \( K = \frac{P}{\delta} \)

Type $K$ — Stiffness of object(N/μm);
Type $P$ — Applied external load(N); Type $\delta$ — Object deformation (μm).

Define Contact and Constraints. The whole 3D CNC laser cutting machine contact between the parts will be near, mainly in: between the rack and gear surface of various types of motor and the guide seat of the gear and shaft and slide the model and the bottom surface of the slide surface. Most of the remaining parts of the constraints are binding constraints. In order to reduce the number of binding, need to merge a part of parts, such as a beam and a base frame are welded, no relative motion, can be regarded as an integral component, so it will be merged into one part, which saves the time of analysis, but also reduce a lot of unnecessary modeling errors.

The Result and Analysis of the Settlement of three Dimensional Numerical Control Laser Cutting Machine

Analysis of Beam Components. Fig. 3 shows the equivalent stress cloud at the end of the beam analysis step.

Figure 3. Equivalent Stress Cloud at the End of the Beam Analysis Step.

Figure 4 shows the displacement of the beam at the end of the analysis step.

Figure 4. The Displacement of the Beam at the End of the Analysis Step.
Figure 5 is the light path compensation equivalent stress nephogram.

![Figure 5: Equivalent Light Path Compensation Stress Nephogram.](image)

Figure 5. Equivalent Light Path Compensation Stress Nephogram.

Figure 6 is the light path compensation displacement.

![Figure 6: Displacement Light Path Compensation.](image)

Figure 6. Displacement Light Path Compensation.

Figure 7 is the system kinetic energy curve.

![Figure 7: System Kinetic Energy Curve.](image)

Figure 7. System Kinetic Energy Curve.
Summary

With no penetration contact constraint conditions and tangential contact conditions based on the theory of finite element for 3D CNC laser cutting machine model, the dynamic contact problem by simulating the accelerated start time, analysis of the influence of dynamic acceleration on the whole body; in the dynamic analysis, the structural response is not only related with the boundary condition of load, and is related to the initial state of the structure. For the problem of space, by using the theory of material mechanics and other basic formula cannot be solved, so this paper adopts the theory of finite element solution in time domain at any point on the stress, strain and displacement, and then using the numerical integral technique response of each point on the time domain, and check the stiffness condition of the equipment strength. Cutting machine in the accelerated process, the main moving parts and beam deflection compensation in the light path along the direction of movement of the value of small stiffness index were 35.42N/ m, 34.01N/ m, the whole stiffness to meet the design requirements.

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