Design and Simulation Analysis of Stone Carving Robot

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Abstract. The stone carving robot is a fully automatic computer-controlled equipment for carving on natural stone, ceramics, and glass. The space position movement and processing range of the traditional bridge-type stone carving are movement and processing range are restricted. Therefore, this paper is based on SolidWorks software to design the three-dimensional model of the stone carving robot, thereby shortening the design time of the stone carving robot, increasing the diversity of spatial displacement, and analyze its movement trajectory to realize the intelligence and modernization of stone processing equipment.

1. Introduction

With the continuous development of computer technology, stone processing is moving towards digitization and intelligence[1]. Stone processing equipment has also made great progress. At present, stone products are developing in the direction of diversification and quality. In order to improve the stone processing environment and processing quality, stone robots have also been continuously used in the stone processing industry[2]. Currently, the most widely used stone carving robots on the market are bridge-type[3], suitable for plane processing, with limited spatial angle and displacement, low efficiency, high processing cost, not conducive to dust processing in stone processing, and short machine life. In order to realize high-precision, high-efficiency, multi-angle, multi-displacement stone carving[4], this article is based on SolidWorks software to design a stone carving robot.

Start from the mechanism design of the whole machine[5]. Then 3D modeling, assembly and simulation analysis are carried out through SolidWorks. Determine the feasibility of the whole machine movement, carry out linear analysis[6], and whether there is interference during operation. Finally, 3D model printing is carried out to verify the overall assembly of the equipment and the motion relationship between various components.

At this stage, the mechanical design work has been completed. In the later stage, the research on automation and control can be carried out according to the corresponding functions[7], and the stone cutting and processing of the whole machine can be realized with the help of virtual simulation[8]. And this research and design can be applied not only in real processing work, but also in simulation teaching.

2. The main mechanism design of stone carving robot

The stone robot discussed in this article is mainly used for stone carving, and can process Roman columns, railings, feng shui balls, figures and animal statues, plant and flower statues, etc. The engraving robot is mainly composed of the base, the big arm, the forearm, and the end gripper. The
stone carving robot is an articulated robot with 6 degrees of freedom. Through the variability of 6-axis linkage, it can move the space position to realize the high efficiency of stone processing and the diversity of products. This article uses SolidWorks to carry on the overall design and the movement simulation to the stone carving robot.

The material of the robot arm is made of aluminum alloy, with a square structure, and the arm thickness is about 34mm. The internal structure design is shown in Figure 1.

![Figure 1. Stone carving robot](image)

Both the big and small arms of the stone carving robot use single-piston rod hydraulic cylinders to achieve reciprocating motion. The diameter of the boom hydraulic cylinder is 40mm, the stroke is 400mm, and the working pressure is 5MPa. The diameter of the small boom hydraulic cylinder is 30mm, the stroke is 100mm, and the working pressure is 3MPa. The hydraulic pump motor for the boom is 0.65KW, and the motor for the forearm hydraulic pump is 0.45KW.

The base and waist are made of No. 45 steel, with a square structure and a wall thickness of about 40mm. The waist rotation is driven by the stepping motor to drive the small gear, and the small gear drives the large gear to rotate. The big gear drives the waist rotation axis. The rotating shaft is supported by a pair of tapered roller bearings. The waist rotation drive motor adopts a stepping motor, and the stepping motor selects 8.5NM torque.

3. Overall assembly of stone carving robot

In order to test the overall structure of the stone carving robot, the overall assembly design of the stone carving robot is carried out. At the same time, in order to better verify whether there is interference in the assembly relationship between the various components, a rapid prototyping method was used to create a three-dimensional printing model of a stone carving robot, as shown in Figure 2.

![Figure 2. Stone carving robot 3D printing physical objects](image)

3.1. Movement distance limit of hydraulic device of stone carving robot

In order to ensure the smooth movement of the stone carving robot in actual work, and to consider the movement of each joint without interference and conflict, [Advanced Coordination] is carried out in the assembly, and the movement distance of the hydraulic device that mainly affects the robot's movement is restricted.

First, set the [distance] limit for the small hydraulic device of the boom base, click [fit] to select the [distance] command of the [advanced fit] among them, and set the maximum distance to 120.00mm.
and the minimum distance to 1.00mm, as shown in Figure 3. Show. In the same way, set the [distance] limit setting for the large hydraulic device of the boom base, and set the maximum distance to 120.00mm and the minimum distance to 1.00mm, as shown in Figure 4.

![Figure 3. Distance setting of big arm small hydraulic device](image1)

![Figure 4. Distance setting of big boom hydraulic device](image2)

In the assembly process, consider the angle of the forearm joint connection and avoid interference between the big arm and the forearm, set the [distance] limit setting for the small hydraulic device at the forearm joint connection, and click [fit] to select one of them. [Distance] command of [Advanced Coordination], set the maximum distance to 80.00mm and the minimum distance to 1.00mm, as shown in Figure 5. In the same way, set the [distance] limit setting for the large hydraulic device at the joint of the forearm joint, and set the maximum distance to 131.72mm and the minimum distance to 92.61mm. Click OK to complete the assembly, as shown in Figure 6.
4. Motion simulation of stone carving robot

First, open SolidWorks, click [File] to open the assembly of the stone carving robot, and then click the SolidWorks plug-in SolidWorks motion. Click New Motion Study to enter the simulation interface, select the simulation mode, click the small arrow in the upper left corner of the motion study, and select motion to start the simulation. Click the [Motor] command, select the motor to select [Rotate Motor], select the arm base for the parts, rotate clockwise, select the base for the relative moving parts, and click OK to complete the simulation, as shown in Figure 7.

Click the [Motor] command again, select [Linear Motor] for the motor, select the pump column of the large hydraulic device of the boom base for the parts, and select the pump housing of the large hydraulic device of the boom base for the relative moving parts, the time is 0S to 5S And click OK to
complete the simulation. Click [Results and Diagrams] at the same time to perform the linear analysis of the robot movement, as shown in Figure 8.

**Figure 8.** Movement Analysis of the Big Arm of the Stone Carving Robot

Click the [Motor] command, select [Linear Motor] for the motor, select the pump column of the large hydraulic device at the joint of the forearm, the direction is lower right, and select the pump housing of the large hydraulic device for the forearm for the relative moving part, and the time is from 0S to 5S, click OK to complete the simulation. Click [Results and Diagrams] at the same time to perform the linear analysis of the robot's forearm movement, as shown in Figure 9.

**Figure 9.** Movement analysis of the forearm of the stone axis carving robot

Analyze angular displacement and angular velocity. Click the [Results and Graphic] command, select [Select Category] as Displacement/Velocity/Acceleration, [Select Subcategory] as Angular Displacement and Angular Velocity to analyze the angular displacement and angular velocity of the stone carving robot movement, the results are shown in Figures 10 and 11.

**Figure 10.** Angular displacement of stone carving robot

**Figure 11.** Angular velocity of stone carving robot

Through the analysis and summary of the simulation movement of the stone carving robot, it is finally concluded that the whole machine has no interference phenomenon during the movement, and the overall movement has no errors. It can complete the movement of the whole machine and realize the normal processing of the stone.
5. Conclusion
This paper designs the stone carving robot through SolidWorks software. The plug-in SolidWorks motion is used for simulation motion analysis, and 3D printing is carried out after the overall design analysis is completed. This not only saves the design time, but also reduces the cost. The feasibility of robot motion and the range of spatial position angle are intuitively displayed to realize efficient modular design. Finally, the 3D printing model is used to better test the overall assembly of the equipment and the motion relationship between various components.

This design can increase the research on control, which can not only be applied to stone cutting and carving. At the same time, teaching research can be carried out for virtual simulation, or simulation rehearsal can be carried out for the factory to prevent accidents.

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