Design and Simulation of Punching and Discharging Manipulator

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***Abstract*—In this paper, according to the requirement of the feeding and unloading manipulator of punching machine, a set of stamping scheme is designed. The cylindrical coordinate structure and three degrees of freedom of the robot are selected by using the manipulator and punching machine. Then the mechanism is designed as a loading and unloading manipulator .Including the use of UG software to build a three-dimensional model of the manipulator, choose DC servo motor to drive each manipulator, mainly using synchronous gear transmission. The main body of the manipulator is designed and constructed for selecting types of motor and screw parts. Then, the three-dimensional graph of the upper and lower material manipulator is refined, the coordinate system of the manipulator is established according to the improved DH method, and the kinematics and dynamics of the manipulator are calculated and analyzed. The forward and inverse solutions of the kinematics equation of each component are checked and simulated with MATLAB. From the displacement curve, velocity curve and acceleration curve, the manipulator moves smoothly.**

Keywords—stamping machine tool; manipulator; loading and unloading; kinematics simulation

I. Introduction

With the progress of science and technology, stamping technology has entered the stage of automation, high speed, flexibility and precision. At present, thanks to the rapid development of press manufacturing technology, the speed of some large press can reach dozens of journeys per minute, and even a small mechanical press can complete thousands of journeys in one minute[1].

At present, the highest efficiency in industrial production is stamping production, but stamping production is also more manual participation, especially in the production mode of more loading and unloading operations. Therefore, the burden of enterprises increases with the increase of the cost of employing people, and the production cost of enterprises increases accordingly. In addition, accidents often occur when workers' fingers are broken off by press on the production line. The health of workers can not be guaranteed, which is not allowed by the new labor law. Therefore, finding a production method that can reduce the number of operators in stamping production line has become an urgent problem for some enterprises engaged in stamping parts production, especially for some small and medium-sized private enterprises, and the mechanical arm which can complete automatic loading and unloading has become the first choice for these enterprises[2].

In the specific process of stamping production, the transportation of materials between various presses is usually done by the operator by hand. Because of the huge stamping force of the press and the weight of the material sheet to be processed, this kind of work has become one of the most dangerous types of work, and accidents often occur when workers are injured. Therefore, since the early 1990s, some famous European automation engineering equipment companies have begun to research and develop stamping automation technology, hoping to replace manual labor by industrial robots or robotic arms in stamping production line[3-4].

II. Materials and Method

A. General Design

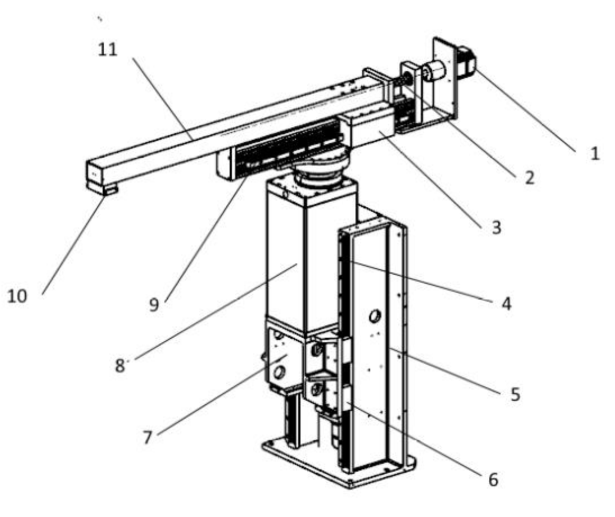


FIGURE I. GENERAL DESIGN FIGURE: 1. SMALL ARM MOTOR; 2. ARM SCREW; 3. SMALL ARM; 4. BOOM GUIDE; 5. BASE; 6. BIG ARM SLIDER; 7. ROTARY SUPPORT PLATE; 8. REVOLVING SHELL; 9. ARM GUIDE; 10. END EFF ECTOR; 11. ARM SHELL.

We can see from FIGURE I that we choose a cylindrical coordinate three-degree-of-freedom manipulator, which is mainly controlled by the rotating part, the lifting part and the telescopic part. These three parts mainly realize the movement of the manipulator in space. The overall height of the base of the manipulator is 1 meter, mainly because the corresponding working table of the punch press is close to 1 meter high and the working space of the punch press itself increases by 400 mm through the manipulator arm, so there is no problem for the upper and lower materials of the punch press.

B. Concrete design

1) Terminal Design of Manipulator: This manipulator is mainly aimed at punching and discharging materials, the main materials are generally sheet metal, so here I choose the magnetic suction end-effector.

2) Design of Rotary Shaft of Manipulator: The main role of the rotating shaft is a steering role of the manipulator. The design of the rotating shaft is not very complicated. So the rotating motion of the manipulator is formed by gear transmission.

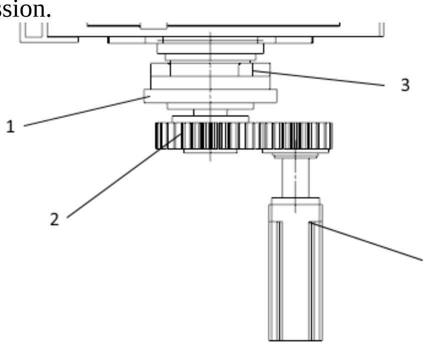


FIGURE II. DESIGN FIGURE OF ROTARY SHAFT OF MANIPULATOR: 1. RETARDER; 2. GEAR; 3. BALANCE BLOCK; 4. ELECTRIC MACHINERY.

3) Design of Manipulator Arm: In order to achieve smooth operation, it is necessary to combine motor accelerator, reducer and screw to drive the robot. The power modules of robots of all kinds in the world are usually used. The low power servo motor is used in conjunction with the high precision reducer. The whole platform relies on slider guides in the vertical direction. As shown in FIGURE II. The spindle is driven by a servo motor. The motor is connected with the reducer, which drives the screw to rotate and makes the main shaft move up and down. The two ends of the lead screw are positioned by two tapered roller bearings, which can withstand both axial and radial loads to meet the design requirements of the small loading arm. The operators need to meet the requirements of high rigidity and high resistance. At the same time, this layout helps to shorten the transmission chain of the structure and simplify the design of the machine structure. The spindle relies on the slider guide in the vertical direction, which plays a supporting and guiding role.

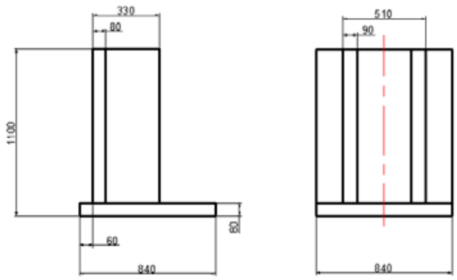


FIGURE III. FIGURE OF BASIC DIMENSIONS OF MECHANICAL BASE.

From FIGURE III above, we can know that the size of the base of the manipulator is mainly designed according to the height of the corresponding punch. Under the condition of ensuring the normal operation of the manipulator, the height of the manipulator is reduced as far as possible. The two rectangular plates in the middle are mainly assembled with the lifting guide rail of the manipulator and the rotating motion of the motor and the lead screw.

III. MODEL SIMULATION BASED ON MATLAB

Robotics Toolbox toolbox in MATLAB software chooses the three-dimensional model of the driving robot to construct the model of each joint of the manipulator 1:1. Finally, each joint is combined to complete the state of the model. Then, the Link function of Robotics Toolbox is called to realize the simulation of the manipulator. As shown in FIGURE Ⅳ, the robot is simulated under joint variables.

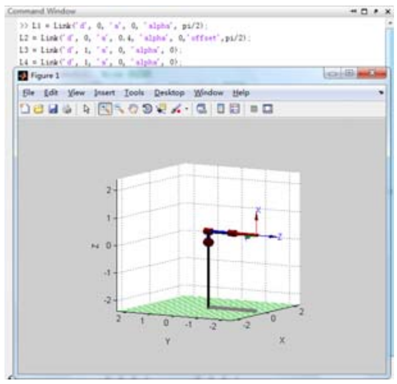


FIGURE IV. MATLTB MANIPULATOR SIMULATION MODEL DIAGRAM

Trajectory Planning and Simulation of Manipulator

For trajectory simulation, jtraj function in Robotics Toolbox is used to establish simple trajectory simulation. The trajectory of the end of the manipulator is shown in FIGURE Ⅴ when the initial position of the manipulator is arbitrarily set.:

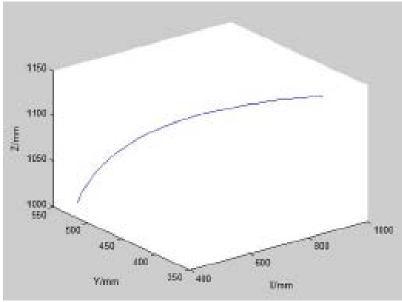
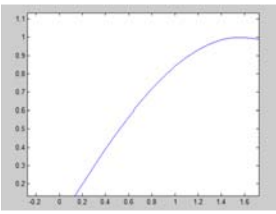
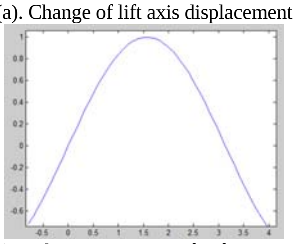


FIGURE V. SPATIAL TRAJECTORY OF TERMINAL PICKER

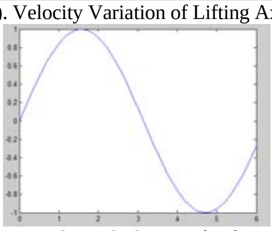
According to the above figure, we can see the position change of the material on the manipulator, and complete the trajectory planning between the two points of the end effector. The space motion trajectory of the end point of the actuator of the loading and unloading manipulator is obtained, and the displacement, velocity and motion trajectory of the three-degree-of-freedom articulated loading and unloading manipulator are obtained by using MATLAB software.



(a). Change of lift axis displacement

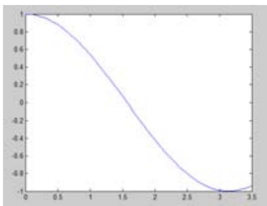


(b). Velocity Variation of Lifting Axis

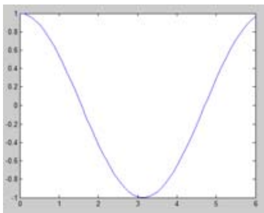


(c). Accelerated Change of Lift Axis

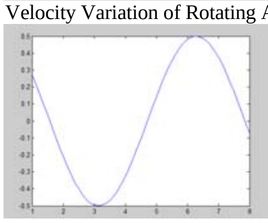
FIGURE VI. CHANGE CURVE OF LIFTING AXIS



(a). Displacement change of rotating axis

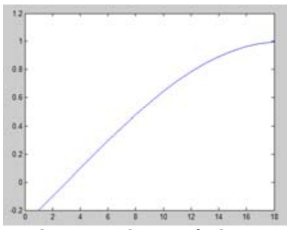


(b). Velocity Variation of Rotating Axis

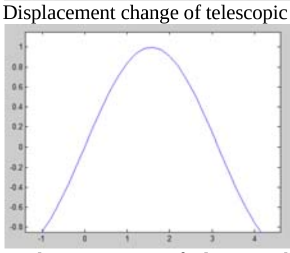


(c). Accelerated Change of Rotating Axis

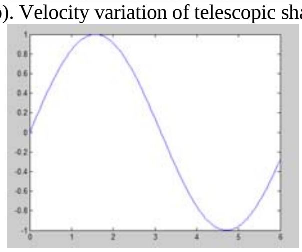
FIGURE VII. CHANGE ROTATING AXIS CHANGE CURVE



(a). Displacement change of telescopic axis



(b). Velocity variation of telescopic shaft



(c). Accelerated change of telescopic axis

FIGURE VIII. ROTATING AXIS CHANGE CURVE

From the motion trajectory shown above, it can be seen that the designed manipulator can reach the predetermined position, and the speed and acceleration of the starting and stopping positions are balanced, and there is no impact phenomenon. This shows that if the manipulator works properly, the trajectory planning is smooth.

IV. CONCLUSION

In this paper, based on the working environment of punch press, the finger structure, driving type and driving device structure of the manipulator are considered synthetically. The parameters of the components used to cooperate with each part of the structure are established, and the virtual model of the manipulator is established. Combining with the software simulation, the working conditions of the manipulator under the actual working conditions of punch press are restored one by one. The experimental data show that the operating route of the manipulator is smooth and there are no singularities, which indicates that the design of the manipulator is reasonable and fully adapts to the working environment of the punch.

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