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Design and Analysis of a New Parallel Glass Handling Manipulator

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Abstract: Glass handling manipulator plays an important role in the field of advanced manufacturing. It can replace human beings to carry out glass handling work and can realize the mechanization and automation of production. In the current glass production line, most glass handling manipulators have problems such as low speed, small range of movement, and low efficiency. Therefore, a glass handling manipulator with nine axes and six degrees of freedom closed-loop structure is designed. The motor drive is used to make it complete the efficient grasping and placing work in a large range. The three-dimensional model of the mechanism is established in SolidWorks, and its dynamic simulation analysis is carried out. Stress analysis on the crossbar under the maximum stress is conducted, and the rationality of the mechanism model is verified through simulation. The structure changes the current situation of low flexibility of traditional manipulator and greatly facilitates the glass handling.

1. Introduction

Scientific progress drives the development process of industrial automation and promotes industrial automation to a new level, making fully automated production equipment become the mainstream and gradually replacing manual operation [1]. With the development of science and technology, robots are widely used. Among all kinds of robots, industrial robots are the most successful in practical applications, mainly used in automobile, electronics, mechanical processing and other fields [2]. Modern robots refer to industrial robots, also known as serial robots [3]. Compared with the series robot, the parallel robot has the advantages of large stiffness, stable and compact structure, strong bearing capacity, small accumulated error, high accuracy and good dynamic performance [4].

The earliest high-speed parallel manipulator was invented by a French doctor named R. Clavel in 1985. The parallel mechanism is called Delta parallel mechanism [5]. British scholar Gough designed a tire testing machine in 1947, which is very close to the 6-6 parallel robot now recognized, and is the earliest known six-legged parallel robot [6]. ABB UK developed IRB series parallel robots in 1999, and introduced computer vision into parallel robots [7]. An intelligent sorting robot developed by Japan’s Yaskawa Electronics Co., Ltd. is widely used in automobile parts assembly and household appliance industry, and uses binocular vision to achieve accurate positioning and grasping of parts [8].

China needs to improve the automation and informatization level of industry and manufacturing industry. Robots are an important part of industry and manufacturing, and an important link to improve the level of industrial automation [9]. At present, China is the world’s largest industrial robot market, with the largest installation volume in the world [10]. However, the proportion of domestic industrial robots is not high, and the global sales volume is lower than that of Japan, Germany, the United States and other developed countries [11]. Therefore, it is of great significance to develop China’s independent industrial robot technology and design high-performance and low-cost industrial robots [12]. Compared with European and American countries, China's parallel robot research started late. Professor Huang Zhen of Yanshan University is one of the founders of China’s parallel robot research [13]. In the context of the reduction of the dividend of the domestic population, Delta parallel robot has been rapidly developed with its unique advantages, and is widely used in high-precision fields [14]. In the research of glass handling robot, series robot is the main. Liu Zhengyong summarized three common series configurations of glass substrate handling robots in the FPD industry at present: vertical multi-joint type, plane multi-joint type, and cylindrical coordinate type [15].

A new type of parallel glass handling manipulator studied in this paper can complete the grasping and handling of glass. The suction cup can quickly absorb the glass and can adjust itself to adapt the glass to different placement methods from multiple angles and transport it to the designated place. It greatly improves the handling efficiency and reduces the labor cost.

2. Overall Layout

According to the working requirements of the parallel glass handling manipulator, the overall layout is shown in Figure 1. Its executive mechanism is mainly composed of three parts: grabbing mechanism, translation mechanism, and integral frame. The work flow of the handling manipulator is as follows: driven by the motor, the grabbing mechanism grabs the glass to be processed through the suction cup vacuum. Then put the glass to be processed into the designated position through translation, to complete the task of glass grabbing and placing.

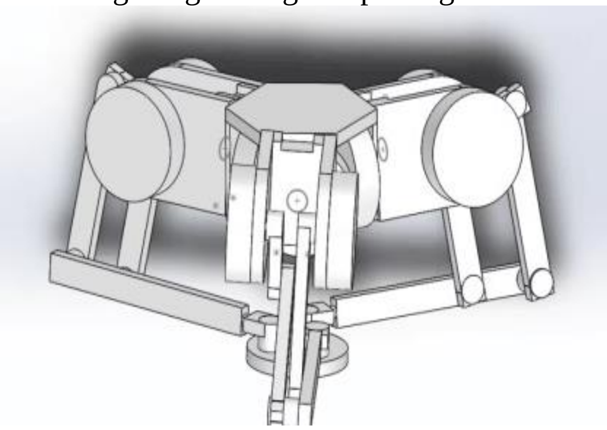
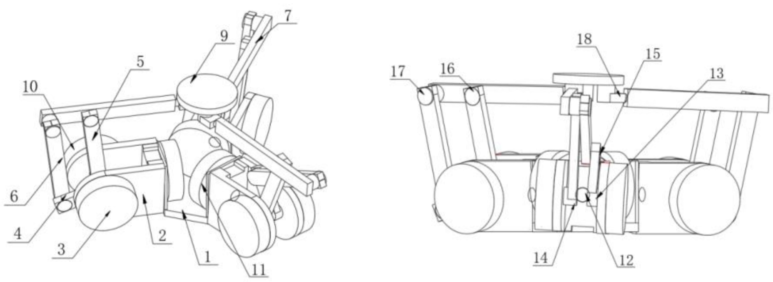


Figure 1: Overall layout diagram.

3. Structural Design

The structure of the handling manipulator is shown in Figure 2, which is composed of the base, baffle, motor, driving rod, driven rod, connecting piece, suction cup and moving pair. The suction cup 9 in the initial state is at a certain height before the handling manipulator starts to move. After the movement starts, motors 3, 10, and 11 drive the driving rods 4, 5, and baffle 2 to rotate, respectively. The driving rod 4 drives the driven rod 6 to rotate. The driving rod 5 and the driven rod 6 jointly drive the driven rod 7 to move. The driven rod 7 drives the suction cup 9 to move in a wide range through the connecting piece to complete the glass adsorption and handling work.



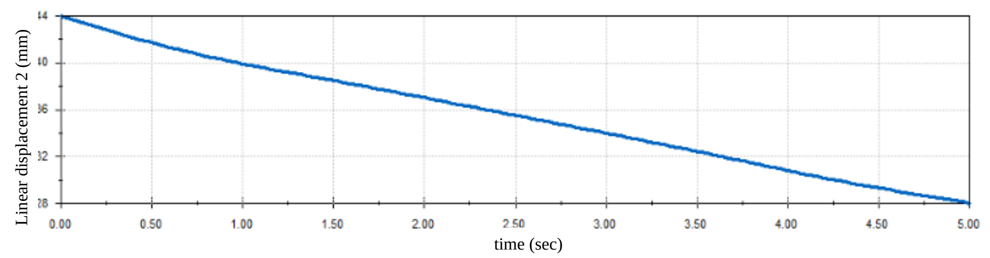
(2a) (2b)

1-base, 2-baffle, 3-motor I, 4-driving rod I, 5-driving rod II, 6-driven rod I, 7-driven rod II, 8-connecting piece, 9-suction cup, 10-motor II, 11-motor III, 12-rotating pair I, 13-rotating pair II, 14-rotating pair III, 15-rotating pair IV, 16-rotating pair V, 17-rotating pair VI, 18-prismatic pair

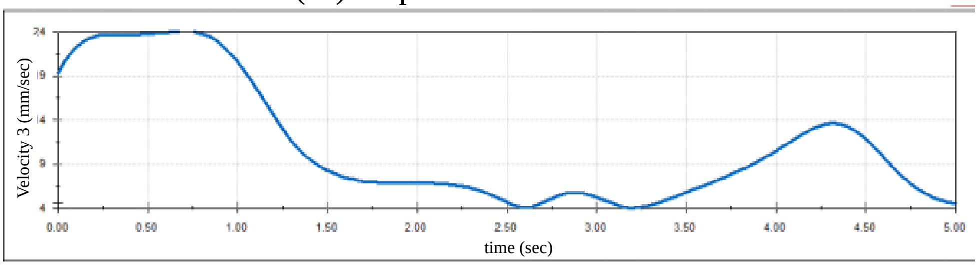
Figure 2: Schematic diagram of manipulator structure design.

4. Dynamic Analysis Based on Solidworks/Motion

4.1. Simulation Model Establishment



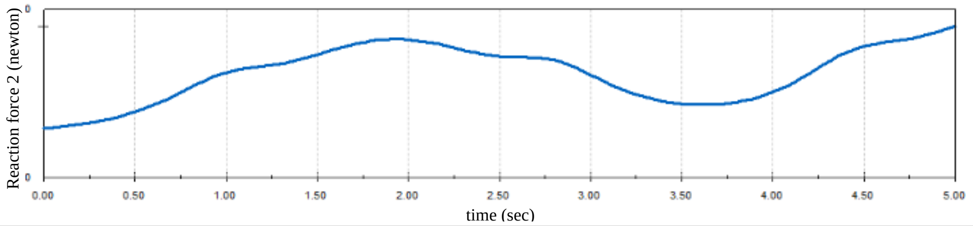
(3a) Displacement versus time



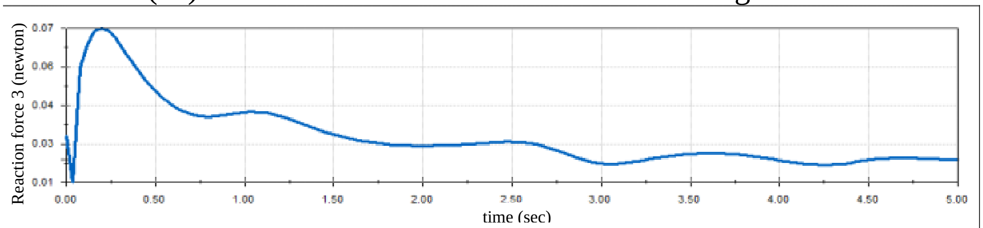
(3b) Linear velocity versus time

Figure 3: Displacement and velocity versus time.

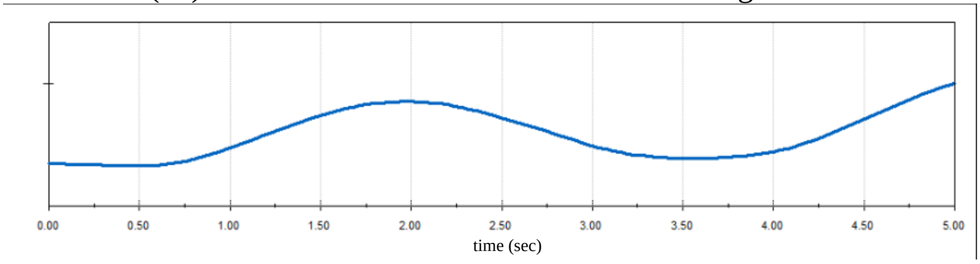
A model mechanism is created through 3D modeling, the material of each part is specified, and a linear motor of the suction cup is added. Define the motor data points to achieve the purpose of up and down movement of suction cups. Then add a vertical downward force and a vertical downward force of 100N to the suction cup, evenly distributed on the surface of the suction cup. Set the movement time to 5 seconds, the suction cup absorbs the glass in the 0th second, and the suction cup moves up 10mm in the 0th second to the 5th second. Solve the whole process of glass handling from absorbing glass to placing glass. Analyze the linear displacement and linear velocity of the suction cup in the process of movement, and obtain the change curve image of the linear displacement, linear velocity, and time relationship, as shown in Figure 3. The curve of reaction force of each pivot of the actuator with time is obtained, as shown in Figure 4.



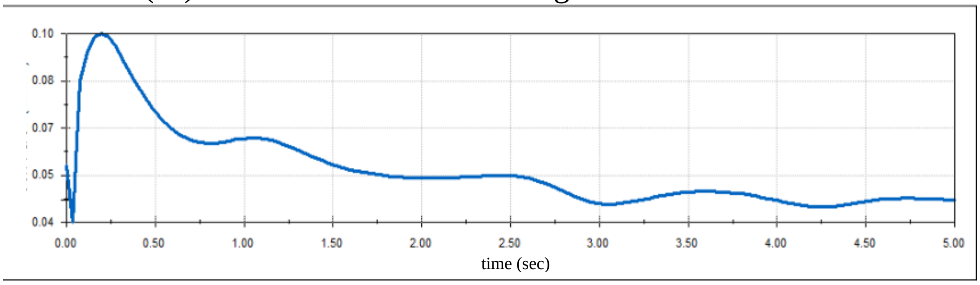
(4a) Reaction force between cross bar and long bar III



(4b) Reaction force between cross bar and long bar II



(4c) Reaction force between long rod III and short rod



(4d) Reaction force between long rod II and baffle

Figure 4: Curve of reaction force of each fulcrum of the actuator with time.

4.2. Stress Analysis of Cross Bar under Maximum Stress

It can be seen from the relationship curve between velocity and time that the parallel manipulator does not move at a uniform speed. The fastest speed is from the 0th second to the 1th second, and the slowest speed is from 1.5th second to the 3.25th second. It can be seen from the analysis that the overall force of the parallel manipulator is the largest during the period from 1.5 seconds to 3.25 seconds.

Through the analysis of the force of each fulcrum of the actuator and the structure of the parallel manipulator, it can be seen that the force of the mechanism is the largest at the 2th second, and the cross bar is the overall weak part. Analyze the stress of the crossbar during the movement from 1th second to 3.5th second, and the stress nephogram is shown in Figure. 5.

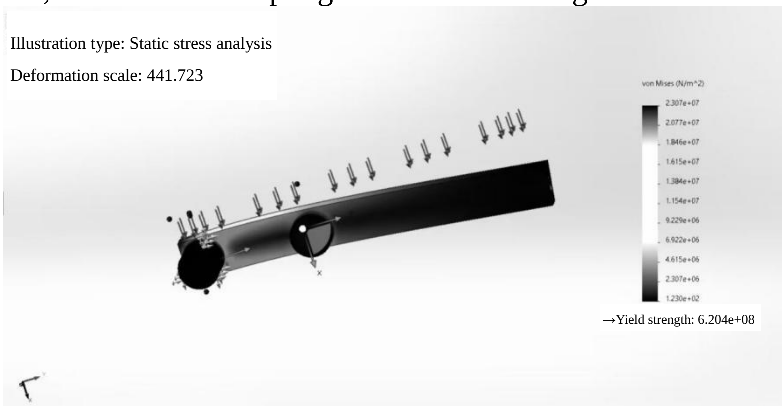


Figure 5: Stress nephograms of the cross bar.

4.3. Analysis of Simulation Results

At the 2th second, the parallel manipulator and the absorbed glass are parallel to the ground, and the force of the mechanism is the maximum. When analyzing this position, the stress nephogram at the cross bar can be obtained, and the maximum stress is distributed at the joint of the cross bar and the long bar II, which is 2.307×107N/m2. The material used is ordinary alloy steel with a maximum yield strength of 6.204×108N/m2, the structural strength design meets the requirements. So the design is reasonable.

5. Conclusion

The structure of a new type of parallel manipulator is designed and the dynamic analysis of its actuator is carried out. The results show that the designed manipulator actuator action meets the requirements. Through simulation analysis, when the actuator is in the 2th second, the stress of its components is the largest, of which the cross bar is the largest, and the stress nephogram of the cross bar is obtained. The data shows that the structure meets the design requirements.

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