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Improving Absolute Position Accuracy Method Analysis of Machining Robots by Optimizing the Posture

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***Abstract*—Industrial robots can be applied in the machining work instead of CNC machine tools, which can be called machining robots. In the fields of aerospace, shipbuilding, high-speed rail train, machining robots can complete the cutting task with the advantages of large operating range, small installation space, high integration, good economic benefits and flexibility good economic benefits and flexibility. However, the stiffness of the machining robot is weaker than the CNC machine tools. Therefore, the absolute position accuracy of machining robots is lower than CNC machine tool, too. The key technology of the application of the machining robot is to improve the stiffness and the absolute position accuracy in the cutting process. The methods of improving the kinematic errors of the machining robot by optimizing the gesture were analyzed in this paper. This analysis can support a foundation and reference for improving the accuracy of the machining robot by optimizing the posture.**

Keywords—Absolute Position Accuracy, Machining Robots, Posture

I. INTRODUCTION

Intelligent manufacturing technology has become an objective trend in the development of the m-anufacturing industry. Industrial robots are an important part of intelligent manufacturing technology. In “China manufacturing 2025”,Chinese Council has explicitly industrial robots as one of the key areas that have pushed for breakthrough development. According to statistics from the International Federation of Robotics, in 2014, China has become the world’s largest demanding country for industrial robots. According to the data released by the National Bureau of Statistics on January 22, 2018, in 2017, the cumulative production of Chinese industrial robots exceeded 130,000 units, having an increase of 68.1% year-on-year. It is expected that Chinese industrial robot market will maintain a high speed growth in the future.

In recent years, the development of off-line programming technology has promoted the application of industrial robots in the fields such as cutting, grinding, deburring, and laser cutting[1]. And, in the fields of aerospace, shipbuilding, high-speed rail train, etc., many works, such as making holes, grinding and milling, and other cutting operations, are required at the assembly site. The parts that need to be assembled are usually large in size, and the structure is complex. Traditional multi-axis NC machining center, with a large area and low flexibility, is often unable to adapt to the on-site machining requirements of such large-scale complex structures [2]. In these occasions, it has the advantages of large operating range, small installation space, high integration, good economic benefits and flexibility to use industrial robots instead of CNC machine tools to complete multi-axis cutting machining [3].

II. ANALYSIS OF THE POSITIONING ERROR OF MACHINING ROBOT

Early industrial robots were widely used in the stacking, handling, and welding industries because of the good repeatability of positioning precision. In these areas, because the task trajectory is relatively simple, the robot can be programmed with a “teach” method, and its repeated positioning accuracy can satisfy the requirement.

In the machining work, the machining trajectory may be more complex, and the high work efficiency and safety requirements are required. The machining trajectory is too complex, and the industrial robot should be able to work by off-line programming. Off-line programming is a programming method to establish a geometric model of the robot and its environment by using computer graphics, and apply some planning algorithms to control and operate the model to complete a trajectory planning based on this model in the off-line situation. Relative to “teach” programming, off-line programming puts higher requirements on the absolute positioning accuracy of the robot. However, the stiffness of the robot is weaker than the CNC machine tool. It results in that the absolute positioning precision of the machining robot is much lower than CNC machine tool, too. It needs to improve the absolute positioning precision by some technical means for the application of machining robots.

III. INFLUENCE FACTORS ANALYSIS OF THE MACHINING ERRORS OF THE ROBOT

The machining robot is usually with an articulated structure. The stiffness of the joint reducer is weak, resulting in a weak overall stiffness of the machining robot [4]. In the machining process of the machining robot, the robot arm is in a cantilever state, resulting in a poor rigidity of the robot itself[5]. There is a gear gap inside the reducer that affects the stiffness of the robot[6]. These factors cause the robot to be less rigid relative to the CNC machine tool. In general, the stiffness of large industrial

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machinery is usually less than 1N/μm. The stiffness of CNC machine tools is usually greater than 50N/μm[7-8]. The low stiffness of the robot results in lower absolute positioning accuracy during cutting. For robots that are not calibrated, the absolute positioning accuracy is lower than repeat positioning with one order of magnitude[9].

IV. THE METHOD OF IMPROVING MACHINING ACCURACY BY OPTIMIZING THE POSTURE OF THE ROBOT

The study found that the stiffness of the machining robot and its posture are closely related. By optimizing the posture of the machining robot, its stiffness can be increased. Chen and Kao's series of studies revealed the relationship between the terminal stiffness matrix of the machining robot and the joint stiffness matrix with robot posture. It also shows that the stiffness of the terminal of the machining robot changes with the posture of the machining robot [10]. Ang Jr et al. studied a tandem robot, describing the end stiffness of the robot as a function of posture, and selecting a suitable posture that satisfies the stiffness requirement to accomplish a specific task [11]. Pashkevich et al. studied the stiffness performance and stability of planar three-bar linkage robots in three different attitudes, and proposed a method to enhance the rigidity of the robot [12]. Zargarbashi et al. [13] pointed out that there must be a stiffness-optimized posture in many postures for redundant degrees of freedom robots. Bu et al. [14] of Nanjing University of Aeronautics and Astronautics in China defined the quantitative evaluation index of robot machining performance based on the flexible model of industrial robot in robotic drilling system. The drilling operation is performed by selecting the tool posture for optimizing the performance index to ensure the machining depth of the hole and the axial precision of the hole. Palpacelli [15] proposed a redundant drive with a rope drive to improve the static and stiffness characteristics of the robot.

V. DISCUSSION

As can be seen from the methods above, the relationship of the absolute position accuracy of the machining robots and its posture can be deduced according to some mathematical models. By studying the mathematical relationship of the absolute position accuracy and the posture, the machining accuracy of the robots can be improved by optimizing the posture. However, the range of the improving value of the absolute position accuracy is limited by optimizing the posture. It is usually applied in a specific task, such as drilling a hole. In the complex machining tasks, how to improve the absolute positioning accuracy by optimizing the attitude is worthy of further study.

According to the models, the sensitivity of the kinematic errors to the machining error of the robot is different in different posture. Therefore, different postures can be designed to identify the kinematic errors of the robot. The sensitivity of the kinematic errors to the machining error of the robot should be analyzed to help design the posture. The kinematic errors should be identified and compensated. And then, the absolute position accuracy should be improved furtherly both by optimizing the posture and compensating the kinematic errors which can be identified from the designed postures.

In the other hand, in off-line programming machining task, the best posture of the machining robot will be changed by the trajectory of the machining task. Therefore, the trajectory of the machining task and the machining parameters should be designed according to mathematical relationship of the posture and the absolute position precision.

VI. CONCLUSION

The absolute position accuracy is crucial in the application of the robot in the cutting task by off-line program. By analyzing the mathematical relationship of the absolute position accuracy and the posture, the machining accuracy of the robots can be improved by optimizing the posture. This is because that the stiffness of the robot should be improved while the robot is working by a better posture. And, further study should be carried out in the future, including: design some different postures to identify the kinematic errors of the machining robot and compensate the kinematic errors; design the trajectory of the machining task and the machining parameters according to mathematical relationship of the posture and the absolute position precision of the machining robot.

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