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Dynamics Simulation of 6-DOF Assemblying Manipulator Based on ADAMS

Lei WANG[1,2,a,*], Xin ZOU[1,2,b], Peng-Xiong LIN[3,c]

[1]Anhui Key Laboratory of Advanced Numerical Control and Servo Technology, Anhui Polytechnic University, Wuhu 241000, China

[2]School of Mechanical and Automotive Engineering, Anhui Polytechnic University, Wuhu 241000, China

[3]Makita China Co., Ltd, Kunshan 215300, China

[a]wangdalei2000@126.com, [b]2597412593@qq.com, [c]1076432457@qq.com

[*]Corresponding author

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Abstract. Considering the application of automatic assembly line, the required functions of manipulator are selected and the overall structure is designed including modeling and virtual assemblying. Meanwhile, the strength of some key parts is also checked. Finally, a simplified six degree of freedom (6-DOF) manipulator's 3D model is established in order to be imported in ADAMS to do kinematics simulation. The displacement, velocity, acceleration curves were obtained, and the simulation results were analyzed.

Introduction

Nowadays, industrial robots or manipulators have been widely used in the tasks which require high control precision with relatively high payload and high speed [1]. The major characteristic of a robot or manipulator is to be able to carry out various tasks by changing its program.Therefore, manipulator design until now has been focused on general purpose manipulators that can adapt to more tasks [2]. A manipulator must be having the specifications required for the tasks in order to accomplish given tasks successfully, for example, workspace, degrees of freedom (DOF), velocity, accuracy, and so on. For example, several approaches have been proposed to design manipulators with maximum workspace [3], isotropic behaviors, maximum dexterity, optimal inertia, and desired stiffness characteristics [4-6] by minimizing/maximizing given performance indices. Snyman [7] proposed a task based kinematic design in order to determine the link lengths and the base position required for execution of a tool moving task in a serial drive planar manipulator. Tsai [8] carried out task based kinematic design to determine the link length, the joint angle limit and the base position of a serial drive manipulator from its workspace with advance information on some kinematic parameters.

Recently, the application area of a robot or manipulator is widely being expanded to some nonindustrial fields such as undersea, space, medical service, and nuclear power plant as well as some industrial fields such as welding, loading/unloading, or assembly. And thus, the necessity of special purpose manipulators for a specific task is increasing. In designing a special purpose manipulator, it is necessary to endow the manipulator with the functions and performances optimal to a given task, namely, to determine the appropriate values of workspace, accuracy, velocity, payload, and so on [2]. For example, a kind of task based kinematic design of parallel manipulators is carried out by Huang [9] and Muller [10].

However, because the technologies and theories for these devices are not developed sufficiently, most of the existing industrial manipulators are less accurate than conventional ones and more expensive today. Therefore, further research work is needed to make manipulators more suited to the industrial requirements.

This paper examines the feasibility of a 6-DOF industrial manipulator used for nut assemblying production line. In the following sections, the overall structure design and model of the 6-DOF manipulator is introduced. Afterwards, dynamic simulation is carried out in ADAMS software, and the simulation result is analyzed to validate our designed result.

The Overall Structure Design and Model of the Assemblying Manipulator

Application Background

According to the actual needs of the enterprise, our designed manipulator's task is to assembly six nuts on a body surface, and the distribution of the six nuts is shown in Fig.1.

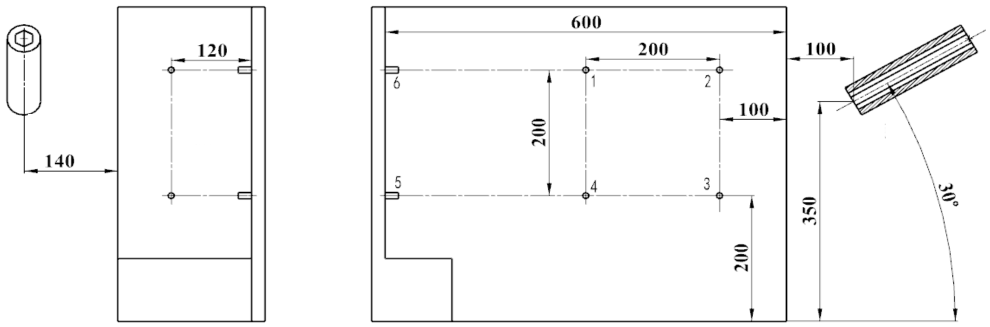

Fig.1. The distribution of the six nuts

The work process is as follows: Firstly, the manipulator takes six nuts from the nut source and then assemblies each nut according to 1-2-3-4-5-6 sequence, and finally it returns to at the source and then takes six nuts for the next assembly sequence, and so on.

Design and Model of the Assemblying Manipulator

The designed assemblying manipulator has six degrees of freedom, and it consists of the base body, waist, arm, forearm, wrist and gun nut.According to the length required for each link and joint layout scheme, the overall 3D outline design and model of the assemblying manipulator is shown in Fig.2.

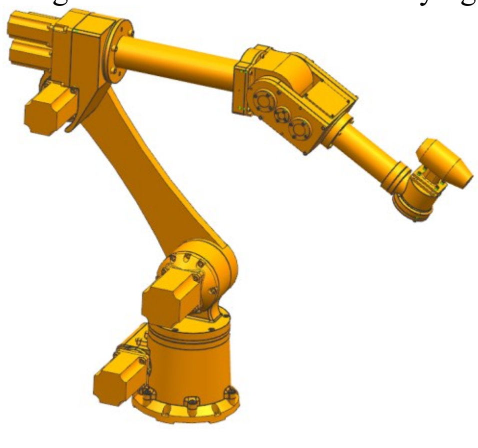

Fig.2. Virtual assemblying model

In addition, some key components, which include straight-tooth and bevel gear contact fatigue strength, tooth root bending fatigue strength, and so on, were checked and the results are satisfied with the strength or stiffness requirements.

Dynamic Simulation for Assemblying Manipulator Based on ADAMS

To reduce the complexity of the model in ADAMS, only the mechanical parts of our manipulator are included in the UG drawing. This structure is sufficient to reflect the physical properties of the assemblying manipulator (Fig.3). After modeling, we save this 3D model as *.x_t document so that it can be imported into ADAMS software directly.

MSC.ADAMS is one of many computer programs for modeling and simulating multibody systems. In ADAMS a virtual prototype of a mechanism can be built and then be simulated. And it also allows users to import part geometry from CAD programs. The most popular file format to import into ADAMS is Parasolid (*.x_t) which increases the chances of receiving solids when importing geometry. Using parasolid is convenient because one file contains all the geometry and ADAMS/Exchange creates a separate part for each solid. After the parts of the mechanical system are developed by using UG, we import this solid model which has already been saved as *.x_t document. All the constructional and technological features specified at the designing stage have found reflection in the mechanical virtual model. Fig.4 shows the virtual prototyping model in ADAMS.

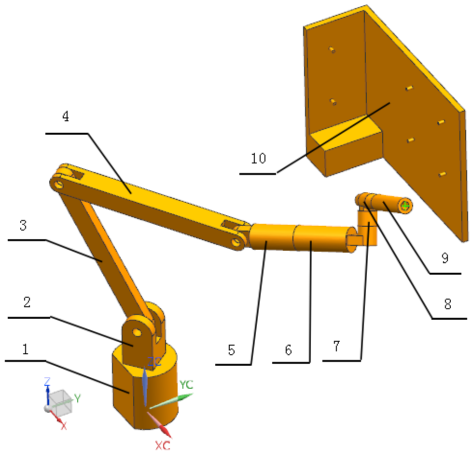

Fig.3. UG drawing of assemblying manipulator

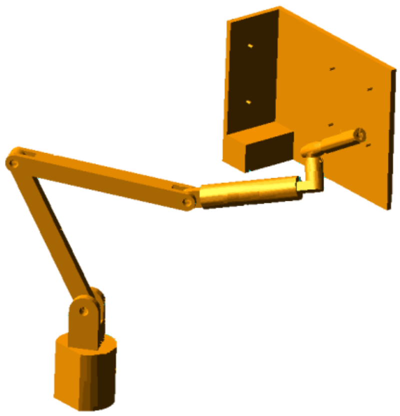

Fig.4. Virtual prototyping model in MSC.ADAMS

The elaborated ADAMS model must takes several aspects into account, such as mass, joint constraints, contact constraints, friction, actuation forces, inertial properties and reference markers, which enable good approximation of the real manipulator behavior. First, each joint of the mechanism is specified as a revolute joint (Fig.5, Fig.6). Secondly, according to the design parameters of the manipulator, material, mass and moment of inertia tensor should be defined in ADAMS. ADAMS calculates the mass and inertia of each rigid body based on its solid geometry and its material type. The default properties for the part can be modified by entering the properties we need. For each part a body-fixed reference frame with its origin at the center of mass is defined in ADAMS as a marker. Additionally other reference markers could be created if needed.

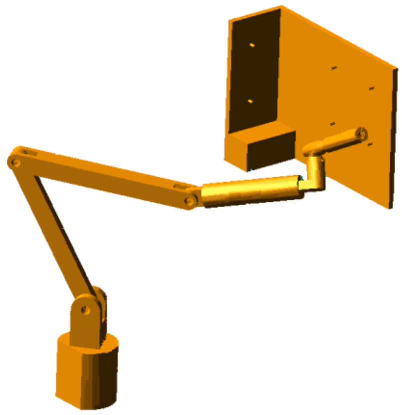

Fig.5. Adding motion pair constraints for manipulator

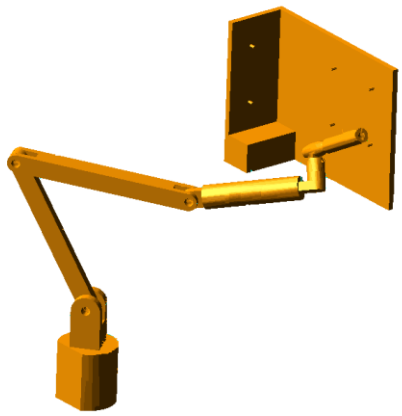

Fig.6. Adding driving constraints for manipulator

After defining the motion equations of each rotational pair and the dynamics simulation results can be obtained, as shown from Fig.7 to Fig.9.

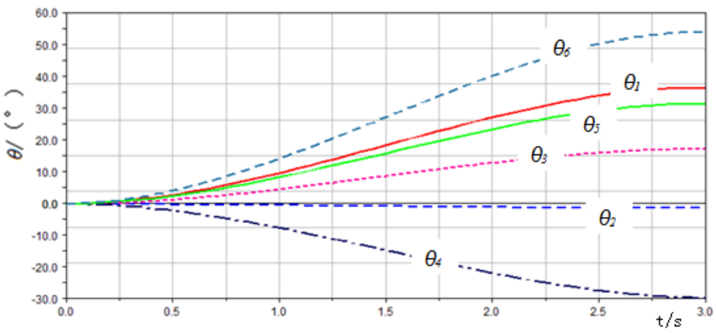

Fig.7. Angular displacement curve of each joint

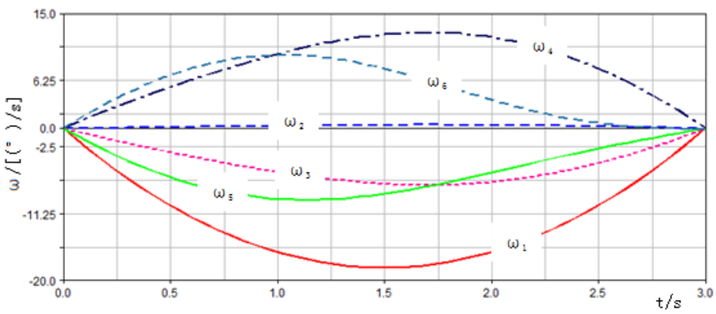

Fig.8. Angular velocity curve of each joint

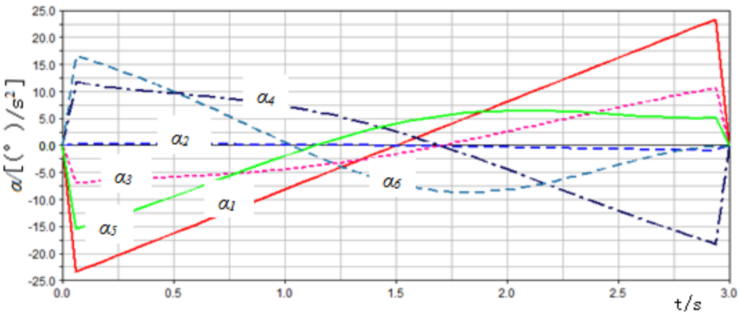

Fig.9. Angular acceleration curve of each joint

By observing the angular displacement, angular velocity and angular acceleration curve of each joint, it can be seen that these curves are very smooth. The simulation results indicate that our designed 6-DOF assemblying manipulator is reasonable.

Conclusions

The overall design and model of the assembly manipulator is given according to the requirements for automatic assemblying line. Meanwhile, the strength of some key parts is also checked. Finally, a simplified 6-DOF manipulator's 3D model is established in order to be imported in ADAMS to do Dynamics simulation. The displacement, velocity, acceleration curves were obtained, and the simulation is analyzed and the result indicates that our designed scheme is reasonable.

Acknowledgments

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