

Research on designing method of manipulator's controller

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Abstract. In this research, a three-dimensional model consisting of two-joint welding manipulator is built using Solidworks. Then the model that imported into MSC Adams execute both kinematics and dynamics simulation through the interface module between MSC Adams and Matlab. The control system of manipulator implemented the interactive simulation at the end. The two-joint welding manipulator's path control is based on PD controller that combined with robust and adaptive terms. Result shows that the manipulator system has a convincing performance in both dynamic response characteristics and trajectory tracking capability.

Introduction

We discussed one kind of two-joint manipulator system in this paper, it's used for welding operation in industry, end effector mounted on the manipulator is the welding torch, whose task is to move according to a present trajectory, using PD control law which combined with robust items and gravity compensation items, we can control the trajectory of the manipulator system [6].

This manipulator system includes mechanical parts and control system, Adams simulation software can facilitate the realization of the kinematics and dynamics simulation of mechanical parts, Matlab software has powerful computing capabilities, and can easily construct mathematical control system model. Using these two software to build an interactive simulation system of manipulator, either simulation analysis of the kinematics and dynamics of manipulators, they can frame a manipulator control system, through an interactive simulation, can effectively improve the manipulator's designing efficiency and effective solution to the problem in control systems, to provide reliable technical basis for the development of the physical prototype.

Modeling and simulation analysis of virtual prototype

2.1 Three-dimensional model of welding manipulator

In this paper, we did researches on the two-joint welding manipulator which have two revolute joint, the end effector is mounted on the end of manipulator.

Taking into account the low accuracy of the Adams software to established complex three-dimensional solid model, and the operation is more complex, so we choose the three-dimensional modeling software modeling the two-joint welding manipulator and the end effector. The important parameters of the manipulator as the table 1 shows:

Table 1: parameters of the manipulator

	ARM 1	ARM 2
LENGTH	R1=1m	R2=0.8m
MASS	M1=0.5kg	M2=0.5kg

Complete the establishment of two-joint welding three-dimensional model, the manipulator as shown in Figure 1



Fig. 1 three - dimensional model

The controller design

2.1 Control Law

In this paper, the dynamic characteristics of the welding manipulator can use the following two-order nonlinear differential equation to be described [2]:

$$\tau = D(q)\ddot{q} + C(q, \dot{q})\dot{q} + G(q) + \omega \quad (1)$$

Where: $q \in R^2$ is Angular displacement of the joint entry, $D(q) \in R^{2 \times 2}$ is Manipulator inertia matrix entry, $C(q, \dot{q}) \in R^2$ is Centrifugal and Coriolis force term, $G(q) \in R^2$ is gravity entry, $\tau \in R^2$ is Control Moment items, $\omega \in R^2$ is Various errors and disturbance.

In gravity environment, PD control law has been unable to meet the control requirements of the mechanical arm, thus, adding gravity compensation items in PD control law [1]. Set constants:

$K \geq 0$, set variables: y, q_r , take the tracking error: $e = q_d - q$, set: $y = \dot{e} + Ke$, $\dot{q}_r = \dot{q}_d - Ke$, Then the following relationship holds:

$$y = \dot{q} - \dot{q}_r \quad (2)$$

$$\tau = D(q)\dot{y} + C(q, \dot{q})y + \Phi(q, \dot{q}, \dot{q}_r, \ddot{q}_r)P + \omega \quad (3)$$

2.2 Control system equation

The two joints welding manipulator we studied in this paper is tandem manipulator. Through controlling the rotation angle of the motor in the joint can realize controlling the actuator reaches a predetermined end position, the model diagram of the manipulator shown in Figure 3:

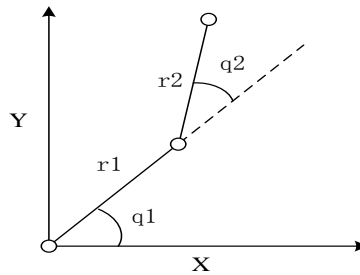


Fig. 3 diagram model of the manipulator

As shown: there is rotary between the base and arm 1, the same as arm 2 and arm 1, the end effector of the manipulator mounted on the end of arm 2. Manipulator's output vector are the rotational angle of arm 1 and arm 2 $q = [q_1, q_2]^T$, the input vector are the input torque of the joints

$\tau = [\tau_1, \tau_2]^T$, In the gravity disturbance conditions, the system equation:

$$\begin{bmatrix} D_{11}(q_2) & D_{21}(q_2) \\ D_{12}(q_2) & D_{22}(q_2) \end{bmatrix} \begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \end{bmatrix} + \begin{bmatrix} -C_{12}(q_2)\dot{q}_2 & -C_{12}(q_2)(\dot{q}_1 + \dot{q}_2) \\ C_{12}(q_2)\dot{q}_1 & 0 \end{bmatrix} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \end{bmatrix} + \begin{bmatrix} G_1(q_1, q_2)g \\ G_2(q_1, q_2)g \end{bmatrix} = \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix} \quad (4)$$

Where: $D_{11}(q_2) = (m_1 + m_2)r_1^2 + m_2r_2^2 + 2m_2r_1r_2 \cos q_2$, $D_{12}(q_2) = m_2r_2^2 + m_2r_1r_2 \cos q_2$, $D_{22}(q_2) = m_2r_2^2$,

$C_{12}(q_2) = m_2r_1r_2 \sin q_2$, $G_1(q_1, q_2) = (m_1 + m_2)r_1 \cos q_2 + m_2r_2 \cos(q_1 + q_2)$,

$$G_2(q_1, q_2) = m_2 r_2 \cos(q_1 + q_2)$$

Interactive Simulation System Design

In the Adams and Matlab interactive simulation system, using PD control law which added robust item and adaptive item, then, input reference signal, and controlled the manipulator tracking the reference signal.

According to the requirements of the adaptive robust PD control law, we need to set 6 state variables: ARM_T1, ARM_T2, ARM_q1, ARM_q2, ARM_dq1, ARM_dq2. After the setup is complete [3], Adams modeling process is finished, and the interface program with Matlab generates.

Put the simulation of ADAMS and Matlab files into the same working directory, run simulink module, open interface model adams_sys.mdl, for simulation. Where: interactive simulation of simulik model shown in Figure 5:

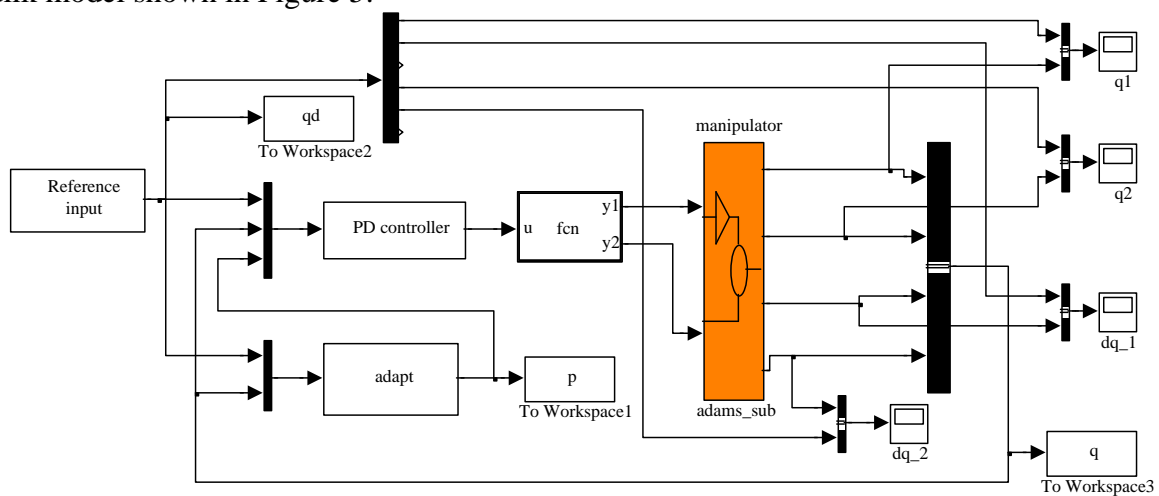


Fig. 5 interactive simulation interface

Manipulator tracking curve analysis

As shown in Figure 6: the actual rotation angle of the first joint in comparison with a reference signal, wherein the blue color of the curve is the actual angle, red color curve for the reference signal. The actual output curve of rotational angular displacement of joint 1 is smoothing, Description of smooth manipulator motion, reflecting the robustness of the control algorithm; and comparative description of the reference signal, during movement, the manipulator first joint has good tracking results, the actual output angle basically consistent with the reference signal, reflecting an adaptive control algorithm. As shown in Figure 7: the actual rotation angle of the second joint in comparison with a reference signal, wherein the blue color of the curve is the actual angle, red color curve for the reference signal. Compared with first joint movement the second joint of the manipulator to track the effect of general, movement are volatile.

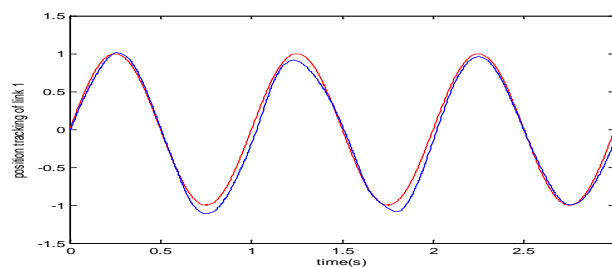


Fig. 6 actual rotation angle and the reference signal of joint 1

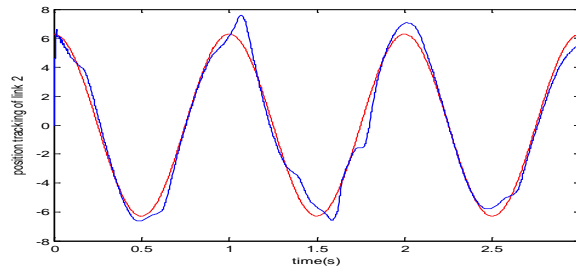


Fig. 7 actual rotation angle and the reference signal of joint 2

Conclusion

Establish an interactive simulation system based on MSC Adams software and Matlab software. That is, in the design of the mechanical systems with control system, using the virtual prototype model in Adams, debugging control system with virtual prototype in Matlab. In modern mechanical engineering, mechatronics product design issues are generally considered the two major components of the mechanical and control. For a complex mechanical system with control devices, designing and modeling in Adams, Call for interactive simulation of virtual prototype in Matlab, dynamics simulation and control simulation of complex mechanical systems can be integrated one, then, the basic principles of general mechanics combined with modern control theory, More effectively address the problem of mechanical system controlling problem, provides the means of modern methods and advanced mechanical design system.

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