The Flexitank Valve Body Assembly with 6-Dofs Robot Trajectory Planning

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Abstract

In order to realize the automatic assembling and tightening of the valve on the flexitank, the 6-DOFs robot is used to assemble the valve automatically, and then accomplish reasonably trajectory planning to determine the pose. The assembly robot , the special assembly tool arranged at the end of the assembly robot-arm, achieves the acquisition of the valve and automatic tightening. According to the requirements of assembling , design the pose for the assembly tool at the each working stage. And then the joint angles of the assembly robot-arm corresponding to those poses above mentioned were computed according to the robotic inverse kinematics. Ultimately, the trajectories, angle speeds and angle accelerations were obtained from starting joint angles to ending joint angles of each of trajectories according to the trajectory algorithm. The research realizes the complete assembly trajectory planning.

Keywords

Flexitank, Assembly Robot, Inverse Kinematics Algorithm, Trajectory Planning.

1. Introduction

The flexitank is a novel transport container which integrates the functions of storage and packaging, and is suitable for bulk non-hazardous liquid or chemical products [1, 2]. Because of its compliance with environmental and food packaging requirements, and comparing with the traditional way of transport packaging, there has significant economic advantages, so it is widely used in various types. Generally, there are valves on the flexitank to facilitate feeding and discharging. The valve seat is arranged inside the flexitank, and the valve body is positioned outside the flexitank, and which are screwed by 8 bolts. Between the valve seat and valve body is the material of flexitank and sealing gasket. Whether bolt is tightened to the specified value, it plays a very critical role for the sealing of the valve connection. Nowadays, the valve of the flexitank is assembled by hand, and it is difficult to effectively guarantee the tightening torque of the blot to reach the specified value relying on manual operation. Therefore, this paper uses 6-DOFs industrial robot for automatic assembling of valve.

In this paper, the D-H parameter method is used to build the robot object. According to the requirements of the spatial position of grasping the valve body, the pose of the special tool each stage are designed at each stage. Based on the special tool pose, the joint angle of the robot is obtained by using the inverse kinematics of the robot and the trajectory of joint space is calculated and the trajectory planning is completed. This paper uses the Robotics Toolbox of MATLAB to realize the motion simulation of the forward and inverse kinematics [3, 4, 5].

2. Work Environment Description

The valve installed on the flexitank is composed of a valve body, a valve base and a handle, and the valve body and valve seat are fastened with 8 M10 blots. Fig. 1 shows the composition of the valve. Before installing the valve body, cylindrical thin materials of flexitank (length 8m, width 4m) have been set in the frame type core (for supporting flexible flexitank), and the valve base has been placed in the inner side of the flexitank, and the central hole of the valve base is exposed by laser cutting. Using Pro/E to create three-dimensional model, the overall layout is as shown in Fig. 2. In order to

realize the automatic acquisition and installation of the valve body, a special assembly tool is designed to be installed at the end of the 6-DOFs robot.
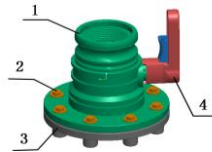
1-valve body, 2-M10 screw with gasket, 3-the valve base, 4-handle
Fig.1 Valve components
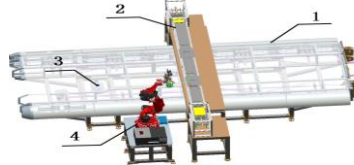
1-the frame type core, 2-Valve body conveying device, 3-Valve installation position, 4-6DOFs robot
Fig. 2 The layout of valve installation position

3. The Pose Design of Assembly Tools

The special assembly tooling of the valve body installed in the end of the 6-DOFs robot-arm, can grab the valve body from the conveyor belt and place the valve body on the valve base. At the same time, the assembly tool with two electric screwdriver, accomplishes automatic fastening of blots. The basic action sequence of the assembly tool is as follows: start from zero, and move to the specified location of the valve body in the conveyor belt, and grab the valve body; deliver the valve body and make the valve body accurately placed on the valve base and align the mounting hole; using diagonal assembly method, multiple tools and multiple tightening achieve tightening of 8 screws; lift the assembly tool vertically and return to zero position, to complete a work cycle.

The pose of the assembly tool is the beginning and end of each phase, and assembly tool coordinates relative to the position and direction of the coordinate frame, can use a 4x4 homogeneous transformation matrix to describe. In this paper, T_0 represents the pose of the zero position of assembly tools, and T_{11} and T_{12} can show the pose of grasping the valve body, and T_{21} and T_{22} are the pose to fix the valve body, and T_{31} and T_{32} and T_{33} and T_{43} express 4 poses of fastening bolts. In order to realize the accurate installation of valve, some positions are artificially set corresponding to the work site in the joint variable space trajectory planning [6], such as A, B,..., F. The layout of each working site is shown in Fig. 3.

As can be seen from Fig. 3, the values of each working site in the frame coordinate O-XYZ are as follows: A (1646,0, 1462.5), B (1277.75, -1243.49, 1009.5), C(1277.75, -1243.49, 901.46), D (1900, 1000, 616.5), E(1900,1000,516.5), F(1900,1000,800).
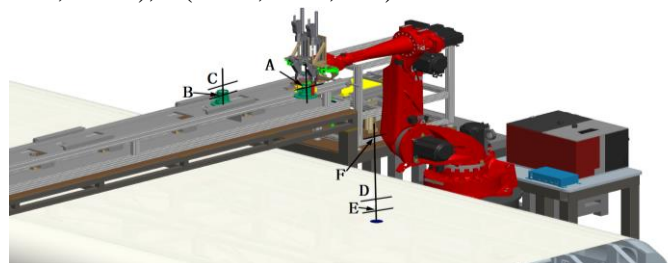

Fig. 3 The layout of each working site

4. Kinematic Analysis and Calculation

The kinematics analysis of robot can research mainly movement law of the end of the robot on displacement, velocity and acceleration, and usually establish the mathematical equations according to certain rules, and be called the position equation of the robot, which is the basis of robot trajectory planning research and control [7].

4.1 The Establishment of D-H Parameters of the Robot Arm.

This paper chooses 6-DOFs Comau robot named SMART-5-NJ-60-2.2 to complete the valve body assembling, and effective load of the SMART-5-NJ-60-2.2 robot is 60kg, the repetition precision is ±1mm. The D-H coordinates of the SMART-5-NJ-60-2.2 robot are as shown in Fig. 4. Using standard D-H parameter method [8, 9], according to figure 6, the D-H parameters of the SMART-5-NJ-60-2.2 robot are expressed in Table 1. Among them, $d_1=0.55$, $d_4=0.9755$, $d_6=0.175$, $a_1=0.4$, $a_2=0.86$, $a_3=0.21$, i is the rod number, d_i represents rob offset, a_i shows the length of the connecting rod, α_i expresses torsion angle between connecting rod, β_i indicates the joint offset angle.
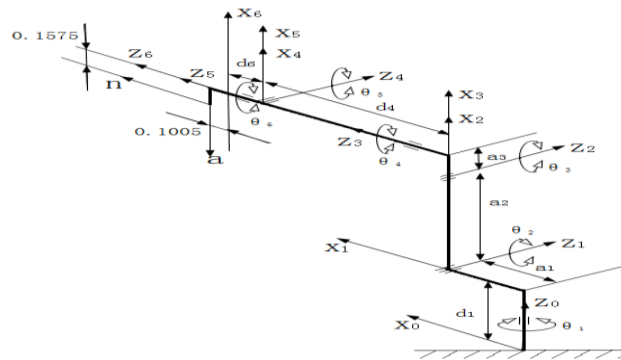

Fig. 4 SMART-5-NJ-60-2.2 robot D-H coordinates

Table 1. The list of D-H parameters

Numble	q_i	d_i	a_i	α_i	β_i
1	θ_1	d_1	a_1	$\pi/2$	0
2	θ_2	0	a_2	0	$\pi/2$
3	θ_3	0	a_3	$\pi/2$	0
4	θ_4	d_4	0	$\pi/2$	0
5	θ_5	0	0	$\pi/2$	0
6	θ_6	d_6	0	0	0

4.2 The establishment of robot object.

In MATLAB, the use of Robotics Toolbox is to establish the object of the 6-DOFs robot. Depending on table 1, the Link () function is used to construct the linkage object as follows:

L(i)=Link('revolute','d', d_i ,'a', a_i ,'alpha', α_i , 'offset', β_i);

Use SerialLink () function to create 6-DOFs robot object as follows:

RB_6=Serialink (L,'name','Robot6');

Now, the joint angle is defined as zero:

Qz= [0 0 0 0 0 0];

At this point, the end flange of the 6-DOFs robot is used as the end effector. If making special tooling as the end effector of the 6-DOFs robot, it is supposed to do translation and rotation transform for the established model of 6-DOFs robot, and the transform is below.

R_0=roty(-pi/2);

Tr_0= [-0.1 575 0 0.1005]';

T_0=rt2tr (R_0, tr_0);

RB_6.tool=T_0

At the same time, using the plot () method of the SerialLink can draw the pose of the 6-DOFs robot in space.

4.3 The pose determination and the joint angle calculation of special tooling.

6-DOF robot, each joint angle has positive and negative rotation range, as ranges of joint angle θ_1 to θ_6 given below:(using units of radian)

q limits=[-180,180;-60,-125;-90,75;-2700,2700;-123,123;-2700,2700]$\times$3.1416/180

Assign ranges of joint angle θ_1 to θ_6 to robot objects:

RB_6.q lim=q limits

According to the trajectory planning of the valve body assembling, in MATLAB, given the rotational displacement parameters of the target position, the pose of the target position of each process is established and named as T. Using the inverse kinematics method of SerialLink calculates the joint angle which is q. The establishment of the pose and the calculation of joint angle are as follows in '11' position:
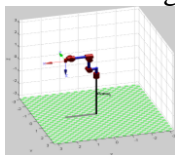
tr$_{11}$= [1.27775   -1.24349 1.0095]';

Rt=rotx (pi);
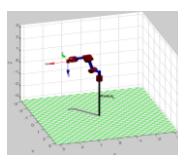
T$_{11}$=rt2tr (Rt, tr$_{11}$);

q$_{11}$=RB_6.ikcon (T$_{11}$, qz);

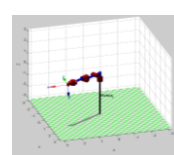Similarly, we can get the poses and angles of the other target.

Using plot () method in the SerialLink can draw the valve body assembly process of 6-DOF robot in space in each posture. Take some positions as an example, such as zero position and the position of getting valve and the fixing valve body position and the two tightening position. The poses of the 6-DOFs robot in space is shown in fig. 5, and, meanwhile, the simulation of 3D model motion in Pro/E is shown in fig. 6:
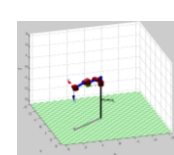

(a) zero position   (b) the position of getting   (c) the fixing valve body   (d) the two tightening
                                            valve   position   position

Fig. 5 the pose of 6-DOFs robot in each position

(a) zero position   (b) the position of getting   (c) the fixing valve body   (d) the two tightening
                                            valve   position   position

Fig. 6 The simulation of three dimensional model in each position

5. The analysis of trajectory and velocity and acceleration and the trajectory simulation.

According to the planning of the valve body assembly process, the point to point method is used to plan the trajectory, including the getting valve track (0-11-12), the path of placing valve (12-21-22), valve tightening trajectory (22-31-32-33-34), and returning to zero position (34-0).

When the joint angles of starting position and the ending position in a trajectory and the time parameters for this trajectory are known, which are represented by q$_1$, q$_2$ and t. In MATLAB, the basic statements are as follows:

[q, qd, qdd]=jtraj(q$_1$, q$_2$, t)';

Among them, t is the time vector, qd is the speed of the joint angle change, qdd is the acceleration of the joint angle change.

According to the trajectory planning of the valve body assembly process, calculate angular displacement, angular velocity and angular acceleration joint angle at each trajectory. From the '0' position to '11' position of waiting to obtain the valve body, the calculation of angular displacement, angular velocity and angular acceleration of joint angle is as follows:

$[q_{0\text{-}11}, qd_{0\text{-}11}, qdd_{0\text{-}11}]$=jtraj(qz, q_{11}, 0:0.1:2);

It can be done to use the plot () method in the SerialLink to simulate the operation process of each trajectory, and the track simulation from '0'position to '11' position is as shown:

RB_6.plot ($q_{0\text{-}11}$)

To simulate the whole process of valve body installation, use the following statements:

Qq=[$q_{0\text{-}11}$; $q_{11\text{-}12}$; $q_{12\text{-}21}$; $q_{21\text{-}22}$; $q_{22\text{-}31}$; $q_{31\text{-}32}$; $q_{32\text{-}33}$; $q_{33\text{-}34}$; $q_{34\text{-}0}$);

RB_6.plot (qq)

Due to 'RB_6.plot (qq)' statement to generate the simulation animation which can show the whole process of valve body installation , it cannot be displayed here , so that, the use of the plot () in MATLAB can directly draw graphics on changes of angular displacement, angular velocity and angular acceleration during the installation of the valve body.

6. Summary

For efficient automatic installation of valve in flexitanks, in this paper, using 6-DOFs robot can accomplish automatic assembling of valve body. Using the D-H parameter method establishes the kinematics model, and works out the forward and inverse kinematics analysis. Then, using MATLAB Robotics Toolbox creates a 6-DOFs robot model, meanwhile, the program is written in MATLAB, and simulating the forward and inverse kinematics analysis result is the next step. Through the movement simulation, it can show the relationship between the pose of the robot's end effector and each joint variable, and determine the rationality of parameters in trajectory planning. The design provides reference basis for using 6-DOFs robot safely and effectively to achieve automatic assembling of the valve body in flexitanks.

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