Numerical simulation of posture in 3-DOF parallel mechanism based on VB

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Abstract. In this paper, a forward displacement solution of 3 degree of freedom (3-DOF) parallel mechanism is primarily resolved. The close loop equation is adopted for the positional posture analysis of the output displacement of spatial 3-RPS parallel mechanism, the forward displacement of the mechanism is educed, and the positional posture of output displacement is acquired. Finally, numerical examples are performed for the positional posture analysis of the mechanism.

Introduction

3-DOF parallel mechanism has been widely used in the independent mechanism、joint mechanism、

machine tool worktable、positioning workpiece and so on[1] because of their valuable advantages

which embrace high stiffness、high precision、simple structure、easy manufacturing and convenient

access to other mechanisms. Inverse displacement solution of parallel mechanism is easier to get while forward displacement solution is extremely complicated, therefore the focus on forward displacement solution is far less than inverse displacement solution. As for forward solution, there are mainly two ways to acquire, one is numerical method and the other is analytical method[1]. It is easy to get mathematical model and suit most parallel mechanisms in numerical method but not all the solutions will be acquired. All the solutions will be acquired in analytical method and the error between import and export will be expressed quantitatively but it is hard to deduce[2-4].

In this paper, the method of getting forward displacement solution of 3-DOF parallel mechanism has been primarily discussed. The positional posture of the output piece of spatial 3-RPS parallel mechanism is analyzed by use of close loop equation to get the kinematics forward solution, which means the positional posture of output piece is confirmed. Finally, numerical simulation examples are performed for the positional posture analysis of the mechanism.

Description of mechanism

Structural parameters of spatial 3-RPS parallel mechanism[5] are shown in Fig.1. This parallel

mechanism is composed of base platform、mobile platform and three branches. Mobile platform and

branches are connected by spherical pairs, base platform and branches are connected by rotational pairs, and translational pairs on the branches serve as driving pairs. Changing length of the three branches will inevitably lead to the changes of position and posture of mobile platform.

Coordinate system of spatial 3-RPS parallel mechanism are shown in Fig.2. Base platform is triangle $A_1A_2A_3$, mobile platform is triangle $B_1B_2B_3$, and three branches are A_1B_1、A_2B_2 and A_3B_3 and A_i（x_{Ai}

, y_{Ai} , 0）and B_i（x_{Bi} , y_{Bi} , z_{Bi}）(i=1,2,3) respectively represent the center of rotational pairs and spherical pairs. Base coordinate system A_1-xyz is set up, origin lies in the position A_1, axis x goes along A_1A_2 , axis z goes upwards and is vertical to base platform, and axis z is confirmed by the right hand rule. $\vec{i}$ 、 $\vec{j}$ 、 $\vec{k}$ respectively stand for direction unit vectors of the three axes. Side length of the base

platform is expressed by a_i, and its direction unit vector is expressed by $\overset{\vee}{a}_i$; Side length of the mobile platform is expressed by b_i, and its direction unit vector is expressed by $\overset{\vee}{b}_i$; length of three branches is expressed by p_i, and its direction unit vector is expressed by $\overset{\vee}{p}_i$.
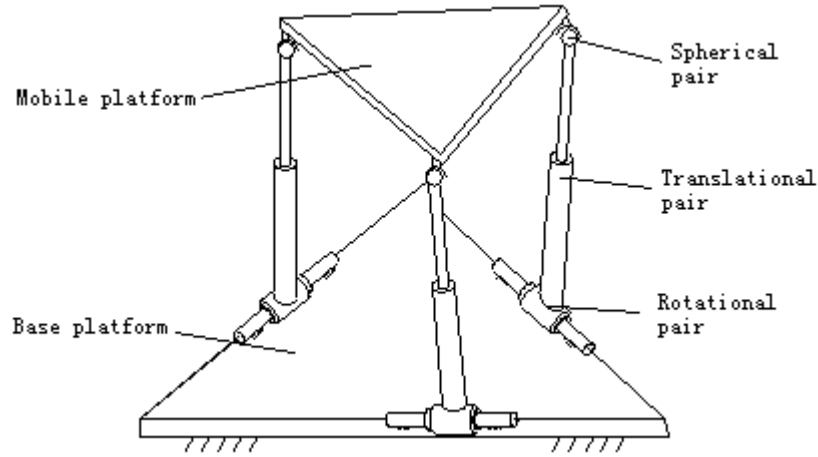

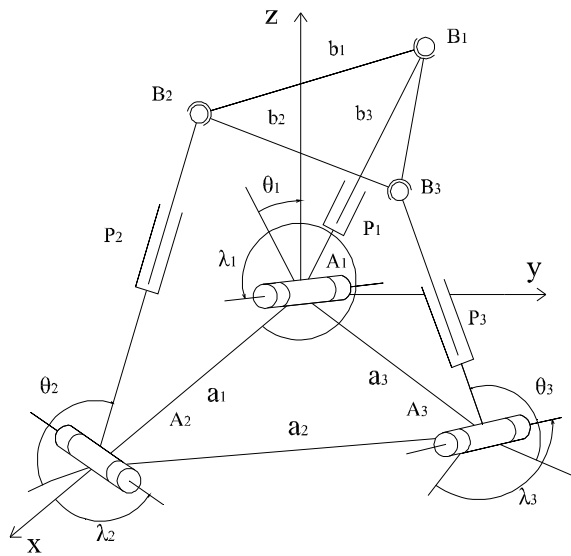Fig.1. Sketch of 3-RPS mechanism
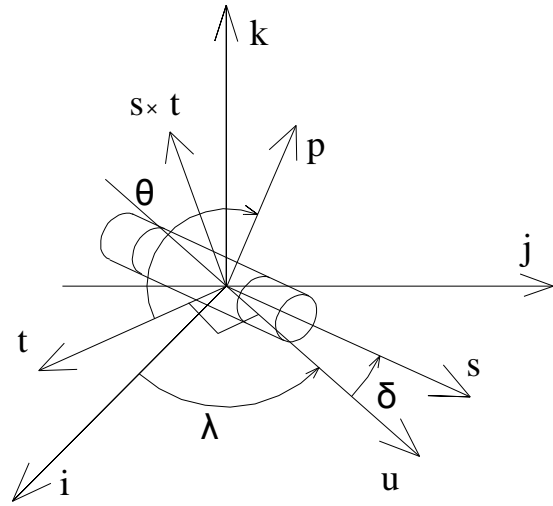

Fig.2. Coordinate system of 3-RPS mechanism   Fig.3. Direction unit vector of parallel mechanism

The connections among all direction unit vectors have been expressed in Fig.3. Direction unit vector along rotational pair axis is $\overset{\vee}{s}_i$, and $\overset{\vee}{s}_i$ is projected on the plane of xA_1y, then $\overset{\vee}{u}_i$ is the direction unit vector of projection. l_i is angle between $\overset{\vee}{u}_i$ and $\overset{\vee}{i}$, d_i is angle between $\overset{\vee}{u}_i$ and $\overset{\vee}{s}_i$, $\overset{\vee}{t}_i$ is direction unit vector which is vertical to both rotational pair axis and z axis. q_i is rotational angle among three branches, and a_i is angle between base platform sides and positive x axis. Therefore, the equations are following.

$$\overset{\vee}{a}_i = \cos a_i\, \overset{\vee}{i} + \sin a_i\, \overset{\vee}{j} \tag{1}$$

$$\overset{\vee}{u}_i = \cos l_i \overset{\vee}{i} + \sin l_i \overset{\vee}{j} \tag{2}$$

$$\overset{\vee}{t}_i = \sin l_i \overset{\vee}{i} - \cos l_i \overset{\vee}{j} \tag{3}$$

$$\overset{\mathbf{r}}{s}_i = \cos l_i \cos d_i \overset{\mathbf{r}}{i} + \sin l_i \cos d_i \overset{\mathbf{r}}{j} + \sin d_i \overset{\mathbf{r}}{k} \tag{4}$$

$$
\begin{aligned}
\overset{\vee}{p}_i &= \cos q_i \overset{\vee}{t}_i + \sin q_i (\overset{\vee}{t}_i \times \overset{\vee}{s}_i) \\
&= \cos q_i \left(\sin l_i \overset{\vee}{i} - \cos l_i \overset{\vee}{j}\right) + \sin q_i \left(-\cos l_i \sin d_i \overset{\vee}{i} - \sin d_i \sin l_i \overset{\vee}{j} + \cos d_i \overset{\vee}{k}\right) \\
&= \left(\cos q_i \sin l_i - \sin q_i \cos l_i \sin d_i\right) \overset{\vee}{i} - \left(\cos q_i \cos l_i + \sin q \sin d_i \sin l_i\right) \overset{\vee}{j} \\
&\quad + \cos d_i \sin q_i \overset{\vee}{k}
\end{aligned}
\tag{5}
$$

Numerical simulation

Numerical simulation has been done based on Visual Basic[6-7] to check out the actual pose of mechanism. Where the parameters of mechanism are $a_1 = a_2 = a_3 = 600(mm)$ 、 $b_1 = b_2 = b_3 = 300(mm)$ 、 $a_1 = 0^{\mathbf{o}}$, $a_2 = 120^{\mathbf{o}}$ 、 $a_3 = 240^{\mathbf{o}}$ 、 $l_1 = 300^{\mathbf{o}}$ 、 $l_2 = 60^{\mathbf{o}}$ 、 $l_3 = 180^{\mathbf{o}}$. According to equations from (14) to (16), input variable p_1 、 p_2 are taken as a fixed value, and p_3 continuously changes within a certain range, then curves will be obtained($p_3 - q_1$ curve 、 $p_3 - q_2$ curve and $p_3 - q_3$ curve)

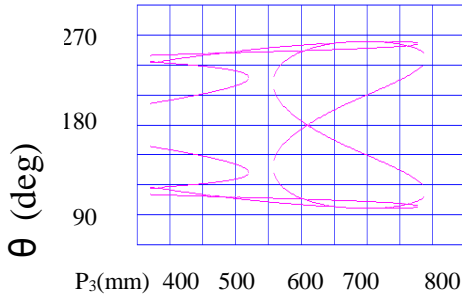Example 1 Input displacement $p_1 = 377$, $p_2 = 477$, $p_3 = 370 \sim 820$ (mm)
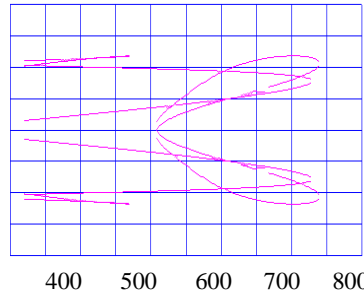

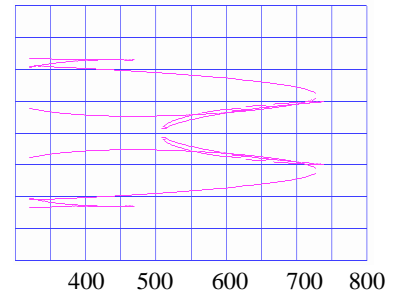Fig. 3.1 $p_3 - q_1$ curve   Fig. 3.2 $p_3 - q_2$ curve   Fig. 3.3 $p_3 - q_3$ curve

Example 2 Input displacement $p_1 = 377$, $p_2 = 527$, $p_3 = 370 \sim 820$ (mm)
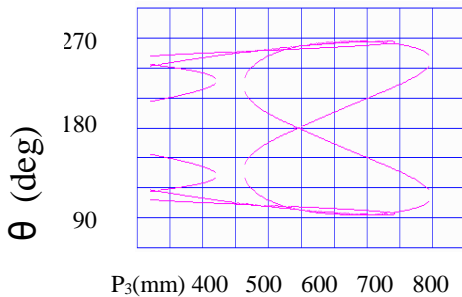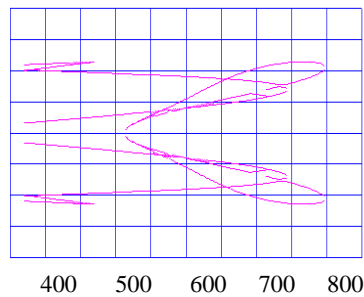

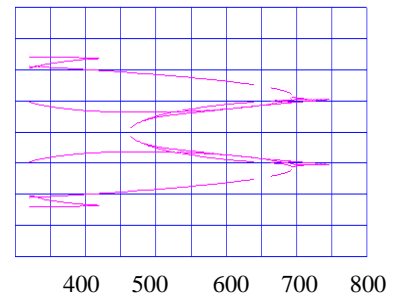Fig. 3.4 $p_3 - q_1$ curve   Fig. 3.5 $p_3 - q_2$ curve   Fig. 3.6 $p_3 - q_3$ curve

Seen from Fig.3.1 to Fig3.6, Input displacement p_1 、 p_2 are fixed values, $p_3 - q_1$ curve 、 $p_3 - q_2$ curve and $p_3 - q_3$ curve will be changing followed by the changes of variable p_3. All these curves are symmetrical about horizontal line because of geometrical symmetry of mechanism. Where there is discontinuity of curves, there is limiting position of mechanism, and the motion will be absent of regularity, therefore the limiting position should be especially considered when analyzing properties of mechanism.

Conclusion

3-RPS spatial three-DOF parallel mechanism is analyzed in this paper. Kinematic forward solution is solved by use of closed loop equations, connections between output variables and input variables are

expressed by curves, and the regularity of pose are also be obtained, which is useful for further analysis of mechanism properties[8-9] and also meaningful for other form of parallel mechanism.

Acknowledgements

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