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A New Type Reconfigurable Mobile Manufacturing Robot

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ABSTRACT: The solving method of positions and attitudes of discrete solder joints in a curved weld and the method for constructing a weld coordinate system based on Frenet-Serret's vector were put forward and the position and orientation vectors relative to time series of discrete welding points were obtained. Thus the relative position and orientation between welding point and welding torch will be derived more easily. Based on the coupling constraint relationship between the ends of the active poistioner kinematic chain and the driven robot kinematic chain, the coordinated welding kinematic model and the corresponding parameter solving process were presented for the optimum ship-welding position. Morever the joint angles, angular velocities and angular accelerations of robot's and positioner's were obtained according to the parameter solving process.

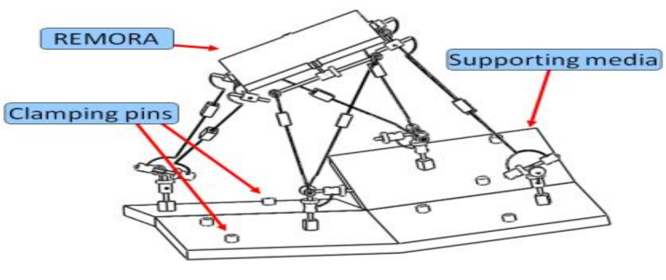
Index Terms: cooperative welding; position changing machine; master slave kinematic chain; ship type welding

I. Introduction

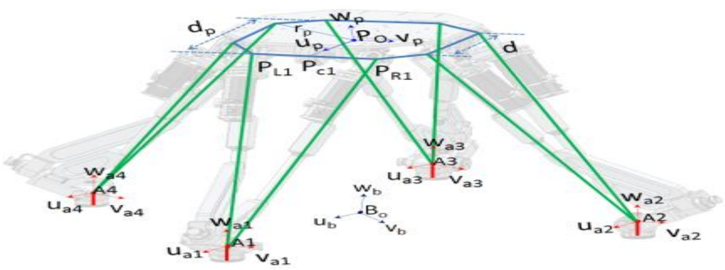
Welding is the most important factor that affects the quality of products in modern industrial production. Increasingly accelerated process of welding automation, as well as the production efficiency, quality indicators, such as the increasingly stringent requirements.Single welding robot has been difficult to achieve welding torch and solder joint between the whole welding process in the relative position and attitude in the best welding position, thereby affecting the weld quality. The robot with variable combination of a machine (can be regarded as another robot) or multirobot collaborative welding, welding system of higher degree of flexibility, work space bigger, faster in speed and welding process more stable, more easy to avoid singularity configurations which can adapt to more complex welding seam curve and obtain better welding position and welding quality[1], so in the flexible manufacturing system and intelligent equipment R&D multirobot coordinated motion and control technology is to be solved the core problem and key technology.

In existing on multirobot collaborative welding motion planning literature, robot pose transformation matrix elements mostly is represented as combinations of system D-H parameters[11] (each coordinate axis angle or distance), which is difficult to be directly used to determine the weld pose and solve welding industry and trade attitude and system obtained by the positive / reverse kinematics parameter is also a function of the structural parameters rather than a function of time and physical significance is not clear and intuitive.

welding robot system configuration



(a) Configuration of variable position welding system



(b) System coordinate system

{W}:World coordinate system,{RB}Robot base coordinate system,{1-CS}: robot 1 axis coordinate system, {2-CS}: robot 2 axis coordinate system, {3-CS}: robot 3 axis coordinate system, {4-CS}: robot 4 axis coordinate system, {5-CS}: robot 5 axis coordinate system, {6-CS}: robot 6 axis coordinate system, {7-CS}: variable bit machine 7 axis coordinate system, {8-CS}: variable bit machine 8 axis coordinate system, {h}: torch at the end of the coordinate system, {PB}: variable bit machine base frame, {TB}: variable bit machine coordinate system, {WP}: workpiece coordinate system, {M}: to be solder joint coordinate system

FIG 1 configuration and coordinate system of variable position welding system

Presented in this paper collaborative welding system is composed of a 6 DOF serial robot and a 2 degree of freedom can be rotary tilting positioner constitute the main body, 1 to 6 axis robot six joint rotating shafts, 7 and 8 of shaft for variable bit machine rotation, tilt axis. The coordinate system of the system is set up in Figure 1 (b), the position machine eighth axis coordinate system {8-CS} and the workpiececoordinate system {WP} and the work table coordinate system (TB) coordinate origin coincidence. The origin of the world coordinate system {W} and the robot base coordinate system is coincident. According to the right-hand rule Z axis.

based on the joint FrenetSerret vector pose solution

In this paper, the valve sealing surface of the weld for the space elliptic curve, the parameters of the equation (time t units for the s, the displacement of the unit for the mm, the following with) for:

$$\begin{cases} x = 430 - 1.2 * \cos(0.5t) \\ y = 4.6 * \sin(0.5t) + 132 \\ z = 0.4 * \cos(0.5t) - 5 * \sin(0.5t) - 466 \end{cases} \tag{1}$$

In view of the complicated space curve welding seam, this paper based on Frenet - Snow row vector[9] to define and seam curve discrete solder joint pose calculation. According to vrenna snow column vector theory, by formula (2) in the weld curve parameter equation can be obtained to be solder joint coordinates relative to the workpiece coordinate system pose transformation matrix:

$$ {}^{WP}_{M}T = \begin{bmatrix} e_{xx} & e_{yx} & e_{zx} & p_x \\ e_{xy} & e_{yy} & e_{zy} & p_y \\ e_{xz} & e_{yz} & e_{zz} & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

Which ex, ey, ez, for {M} solder joint coordinates x, y, and Z axis respectively in the workpiece coordinate system {WP} the axis direction of the component, namely the curvilinear - weld - line in a joint unit tangent vector, unit time vector method and unit normal vector, P to the solder joint relative to the workpiece position vector, can express as a function of time t [9], to weld a, for example, the transformation matrix is as follows:

$$e_x = [e_{xx}, e_{xy}, e_{xz}]^T = [-\sin 0.83t, \cos 0.83t, 0]^T \tag{3}$$

$$\begin{aligned} e_y &= e_z \times e_x = [e_{yx}, e_{yy}, e_{yz}]^T \\ &= [e_{xz}e_{zy} - e_{xy}e_{zz}, e_{xx}e_{zz} \\ &\quad - e_{xz}e_{zx}, e_{xy}e_{zx} - e_{xx}e_{zy}]^{\mathrm{T}} \end{aligned} \tag{4}$$

$$e_z = [e_{zx}, e_{zy}, e_{zz}]^T = [-\cos 0.83t, \sin 0.83t, 1]^T \tag{5}$$

$$
\begin{aligned}
p &= [p_x, p_y, p_z]^T \\
&= [430 - 1.2 * \cos 0.5t, 4.6 * \sin 0.5t \\
&+ 132, 0.4 * \cos 0.5t - 5 * \sin 0.5t - 466]^T
\end{aligned}
\qquad \text{Ⅳ} \qquad (6)
$$

Kinematic Modeling Of 3 Position Changing Robot Manipulator 1 Robot Cooperative Motion Constraint Equation

In this paper, we propose a cooperative welding robot system to satisfy the motion constraints as follows:

The co main movement in welding process chain driven welding, weld solder joints should make the pose is always in the best welding position, welding or welding or ship pose: vector cut solder joints and the horizontal direction of gravity vector and molten metal are parallel and reverse, so that it can improve the welding quality and welding speed; welding torch pose the welding process unchanged: welding process from kinematic chain (robot kinematic chain) at the end of the main chain to always follow the motion pose of welding torch (a positioner movement chain) coordinates of discrete points at the end of the weld, ensure smooth weld torch track positioner to change the solder joint; a machine, robot kinematic chain coupling: the welding process, and from the kinematic chain should be coupled to a closed kinematic chain by coincidence end coordinates, namely the target position at the end of the torch should be discrete and weld Position and orientation of solder joint[7][8].

In this paper, the coupling relationship between the robot and the robot is presented as follows:

$$ {}^{W}_{PB}T \cdot {}^{PB}_{TB}T \cdot {}^{TB}_{WP}T \cdot {}^{WP}_{M}T \cdot {}^{M}_{H}T = {}^{W}_{RB}T \cdot {}^{RB}_{6}T \cdot {}^{6}_{H}T \quad (7) $$

Including: from the world coordinate system to the robot base coordinate transformation matrix from the robot base coordinate system to the robot the 6 axis coordinate transformation matrix from the six axis coordinate system to the torch end coordinates transformation matrix from the world coordinate system to the variable bit machine based coordinate transformation matrix from a machine base coordinate system to variable bit machine worktable coordinate transformation matrix from variable bit machine worktable coordinate system to the workpiece coordinate system transformation matrix from the workpiece coordinate system to be the spot coordinates transformation matrix from the solder joints coordinate system to the torch end coordinates transformation matrix[10].

The left for variable bit machine movement on the main chain motion transformation from the world coordinate system to the torch at the end of the coordinate system, the right for the robot from the kinematic chain from the world coordinate system to the torch at the end of the coordinate system of motion transformation between. In order to achieve the coordination welding, the robot motion chain must be coupled to a closed loop kinematic chain.

The formula (7) can be rewritten as the following formula (8), (9), in order to obtain the kinematics and inverse kinematics of the robot and the robot:

$$ ({}^{W}_{RB}T)^{-1} \cdot {}^{W}_{M}T \cdot {}^{M}_{H}T \cdot ({}^{6}_{H}T)^{-1} = {}^{RB}_{6}T \qquad (8) $$

$$ {}^{W}_{M}T = {}^{W}_{PB}T \cdot {}^{PB}_{TB}T \cdot {}^{TB}_{WP}T \cdot {}^{WP}_{M}T \qquad (9) $$

The formula (8) is the robot kinematics equation to solving the robot the 6 axis with respect to the pose of the robot base coordinate system; (9) variable bit machine, the kinematics equations for solving the variable bit machine solder joints with respect to the world coordinate system of the pose.

Modeling Of Forward And Inverse Kinematic Modeling And Parameter Solution Of Position Changing Machine

The valve body displacement welding robot system with two degree of freedom rotating tilting positioner, the variable bit machine 7 axis is tilted axis rotation angle theta 7 8 axis for the rotation axis (angle theta 8). By formula (9) the positive kinematics equation of the position machine can be obtained. The transformation matrix of the coordinate system of the solder joint to the world coordinate system is as follows:

Among them:

$$\begin{cases} a_{xx} = e_{xz}.\sin\theta_7 + e_{xy}.\cos\theta_7.\cos\theta_8 + e_{xx}.\cos\theta_7.\sin\theta_8 \\ a_{xy} = e_{xy}.\sin\theta_8 - e_{xx}.\cos\theta_8 \\ a_{xz} = e_{xz}.\cos\theta_7 - e_{xy}.\cos\theta_8.\sin\theta_7 - e_{xx}.\sin\theta_7.\sin\theta_8 \\ a_{yx} = e_{yz}.\sin\theta_7 z + e_{yy}.\cos\theta_7.\cos\theta_8 + e_{yx}.\cos\theta_7.\sin\theta_8 \\ a_{yy} = e_{yy}.\sin\theta_8 - e_{yx}.\cos\theta_8 \\ a_{yz} = e_{yz}.\cos\theta_7 - e_{yy}.\cos\theta_8.\sin\theta_7 - e_{yx}.\sin\theta_7.\sin\theta_8 \\ a_{zx} = e_{zz}.\sin\theta_7 + e_{zy}.\cos\theta_7.\cos\theta_8 + e_{zx}.\cos\theta_7.\sin\theta_8 \\ a_{zy} = e_{zy}.\sin\theta_8 - e_{zx}.\cos\theta_8 \\ a_{zz} = e_{zz}.\cos\theta_7 - e_{zy}.\cos\theta_8.\sin\theta_7 - e_{zx}.\sin\theta_7.\sin\theta_8 \\ P_x = A + C.\sin\theta_7 + p_z.\sin\theta_7 + p_y.\cos\theta_7.\cos\theta_8 + p_x.\cos\theta_7.\sin\theta_8 \\ P_y = p_y.\sin\theta_8 - p_x.\cos\theta_8 \\ P_z = B + C.\cos\theta_7 + p_z.\cos\theta_7 - p_y.\cos\theta_8.\sin\theta_7 - p_x.\sin\theta_7.\sin\theta_8 \end{cases} \qquad (10)$$

To be the best pose for spot welding or ship welding pose [10], the solder joints Z axis should be in the vertical direction is [6].

$$[a_{zx} \quad a_{zy} \quad a_{zz}] = [0 \quad 0 \quad \pm 1] \qquad (11)$$

The type (10) into equation (11) can be obtained in the best position to solder joint meet

$$\begin{cases} a_{zx} = e_{zz}.\sin\theta_7 + e_{zy}.\cos\theta_7\cos\theta_8 \\ \qquad + e_{zx}.\cos\theta_7.\sin\theta_8 = 0 \\ a_{zy} = e_{zy}.\sin\theta_8 - e_{zx}.\cos\theta_8 = 0 \\ a_{zz} = e_{zz}.\cos\theta_7 - e_{zy}.\cos\theta_8\sin\theta_7 \\ \qquad - e_{zx}.\sin\theta_7.\sin\theta_8 = \pm 1 \end{cases} \qquad (12)$$

This can be solved:

$$\theta_8^j = a\tan 2(e_{zx}, e_{zy}) + k \times 180^0 \quad (13)$$

Where k is an integer. Because the atan2 range ($-180^0 180^0$], according to the joint angle displacement theta 8 range determining theta 8 possible number of solutions[12].

$\theta_7^j = a\tan 2(e_{zy}\cos\theta_8 + e_{zx}\sin\theta_8, -e_{zz}) + k \times 180^0$ (14) In summary, there are many possible inverse kinematics solutions of the positioner. Which can be the most close to the zero position or the current displacement of the joint angle as a set of optimal solutions [6]

II. CONCLUSION

In this paper, based on fry the snow cur**v**e weld in the vector theory of discrete solder joint pose solution column, and time series corresponding to the discrete solder joint pose; collaborative welding robot system must satisfy the kinematic constraints based on the proposed variable bit machine robot, from the coupling equation between kinematic chain ends was educed, which to ship welding is the best welding position of collaborative welding kinematics model and parameter solving process.

The result confirms that the proposed method is correct and feasible, and it provides a necessary foundation for the research and development of automatic welding production line.

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