Research on Three Kinds of Swing-plate Manipulators Based on Hydraulic Reclaimer and Non-standard Machine

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Abstract. Aiming at the problems of low efficiency of hydraulic press reclaiming and the difficulty of realizing the diversification of reclaiming methods in our country. In this paper, three non-standard manipulators of hydraulic reclaimer are designed, and the modes of three non-standard manipulators are analyzed and studied. Using ANSYS workbench to simulate the modal parameters of one of the manipulators, the modal parameters and the actual performance of the manipulator are analyzed. The results show that the first order modal value is 2.0542 e-003Hz according to the modal value. At the same time, combined with the actual working conditions of the hydraulic press, the mode satisfies and is far greater than the fixed frequency value.

1. Introduction

The New York Times, based on Made in China 2025, reported that the New York Times, based on Made in China 2025, reported that the New York Times, based on Made in China 2025, reported that the New York Times, based on Made in China 2025, reported that the New York Times, based on Made in China 2025. Industrial robots in the United States have become a norm, and is a wholly owned industrial robots, is a necessary equipment. In the mechanical processing manufacturing enterprises, gradually increased to a very large number of non-standard machine beds and general assembly line equipment automation. There is no formal tradition of genuine research in this study [2]. The answers to these two questions are: First, the coordination between the two plans is not strong enough; is an under-standard design from "0" to "1" [3]. On this basis, this chapter also specifies the standards of non-standard equipment, the main content is: design standards, manufacturing standards and technical objectives. At the same time, our national research institutes have also carried out in-depth research, especially in technology and equipment. As the implementation of Shanxi Province is rising, so in the production process, the demand for non-standard mechanical equipment is also increasing, therefore, the demand in the market is also increasing, so that non-standard mechanical equipment and non-standard mechanical equipment design can be achieved. In a manufacturing process, The following needs to be taken into account: First, the safety of non-standard mechanical equipment should be taken into account, Secondly, it is necessary to consider the controllability, controllability, controllability and user's production demand that can be accurately grasped, and then to consider the maximum production means of non-standard products, at
the same time, it is necessary to consider the marketability and controllability, so as to improve the efficiency and efficiency, and at the same time, it is necessary to consider the extended design of other non-standard mechanical products. At the same time, at the time of design, green materials and green energy are used in the manufacturing and processing of machinery to protect the environment and reduce pollution, thus improving the combined effect of equipment [4]. On this basis, this paper mainly studies the morphological performance analysis of three kinds of decorative machinery of asphalt felt machinery.

2. Modal Theory

Modal analysis mainly uses Lagrange method to establish the system motion equation, and its expression is [5]:

\[
\frac{d}{dt} \left( \frac{\partial T}{\partial \dot{q}_i} \right) - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} + \frac{\partial D}{\partial q_i} = Q_i, \quad (i = 1, 2, \ldots, n)
\]  

(1)

Where \( q_i \) and \( \dot{q}_i \) are generalized coordinates and generalized velocities, respectively; \( T \) and \( U \) are the total kinetic energy and potential energy of the system respectively. \( D \) is the energy dissipation function; \( Q_i \) is the generalized disturbance force.

At that same time, suppose that there are six component in a mechanical system, and the kinetic energy function of the system is:

\[
T = \frac{1}{2} \left( m_1 \dot{x}_1^2 + m_2 \dot{x}_2^2 + m_3 \dot{x}_3^2 + m_4 \dot{x}_4^2 + m_5 \dot{x}_5^2 + m_6 \dot{x}_6^2 \right)
\]  

(2)

The potential energy function is:

\[
U = \frac{1}{2} \left[ k_1 x_1^2 + k_3 (x_2 - x_1)^2 + k_4 (x_3 - x_2)^2 + k_5 (x_4 - x_3)^2 + k_6 (x_5 - x_4)^2 + k_7 (x_6 - x_5)^2 \right]
\]  

(3)

The energy dissipation function of the system is:

\[
D = \frac{1}{2} \left[ c_1 \dot{x}_1^2 + c_3 (\ddot{x}_2 - \ddot{x}_1)^2 + c_4 (\ddot{x}_3 - \ddot{x}_2)^2 + c_5 (\ddot{x}_4 - \ddot{x}_3)^2 + c_6 (\ddot{x}_5 - \ddot{x}_4)^2 + c_7 (\ddot{x}_6 - \ddot{x}_5)^2 \right]
\]  

(4)

The partial derivatives of the functions (2), (3) and (4) in the Lagrange equation and the differential equations of motion of the mechanical system can be obtained by introducing \( m_1 m_2 m_3 m_4 m_5 m_6 \) into the six parts. The equations are expressed by matrices as follows:

\[
[m] \{ \ddot{x} \} + [c] \{ \dot{x} \} + [k] \{ x \} = \{ P \}
\]  

(5)

Where \( \{ x \} \), \( \{ \dot{x} \} \), \( \{ \ddot{x} \} \), \( \{ P \} \), \( [m] \), \( [c] \) and \( [k] \) denote displacement array, velocity array, acceleration array, interference force array, mass matrix, damping matrix and stiffness matrix, respectively.

When there is no damping, its function (5) is expressed as:
Let the solution of function (5) be:

\[ \{x\} = \{A\} e^{iw_x} \]  

(7)

Of which, \( \{A\} = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{bmatrix} \), \( \{x\} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \);

The first derivative and the second derivative of the equation (7) are obtained respectively, and the equation of the main vibration mode obtained by introducing the equation (6) into the equation is as follows:

\[ \left( [k] - \omega_n^2 [m] \right) \{A\} = \{0\} \]  

(8)

Obviously, for \( \{A\} \) to have a non-zero solution, the coefficient determinant in Equation (8) must be zero, i.e., the frequency equation:

\[
\begin{vmatrix}
  k_{11} - m_{11} \omega_n^2 & k_{12} - m_{12} \omega_n^2 & \cdots & k_{1n} - m_{1n} \omega_n^2 \\
  k_{21} - m_{21} \omega_n^2 & k_{22} - m_{22} \omega_n^2 & \cdots & k_{2n} - m_{2n} \omega_n^2 \\
  \vdots & \vdots & \ddots & \vdots \\
  k_{n1} - m_{n1} \omega_n^2 & k_{n2} - m_{n2} \omega_n^2 & \cdots & k_{nn} - m_{nn} \omega_n^2 
\end{vmatrix} = 0
\]  

(9)

The n-th order algebraic equation of \( \omega_n^2 \) is obtained by expanding it:

\[
\omega_n^{2n} + a_1 \omega_n^{2(n-1)} + a_2 \omega_n^{2(n-2)} + \cdots + a_{n-1} \omega_n^2 + a_n = 0
\]  

(10)

Where \( a_1, a_2, \ldots, a_n \) is a combination of \( k_{ij} \) and \( m_{ij} \).
A mechanical system accord to 6 parts, for which \([m]\) and \([k]\) are

\[
\begin{bmatrix}
m_1 & 0 & 0 & 0 & 0 & 0 \\
0 & m_2 & 0 & 0 & 0 & 0 \\
0 & 0 & m_3 & 0 & 0 & 0 \\
0 & 0 & 0 & m_4 & 0 & 0 \\
0 & 0 & 0 & 0 & m_5 & 0 \\
0 & 0 & 0 & 0 & 0 & m_6
\end{bmatrix}
\]

and

\[
\begin{bmatrix}
k_{1}+k_{2} & -k_{2} & 0 & 0 & 0 & 0 \\
-k_{2} & k_{2}+k_{3} & -k_{3} & 0 & 0 & 0 \\
0 & -k_{3} & k_{3}+k_{4} & -k_{4} & 0 & 0 \\
0 & 0 & -k_{4} & k_{4}+k_{5} & -k_{5} & 0 \\
0 & 0 & 0 & -k_{5} & k_{5}+k_{6} & -k_{6} \\
0 & 0 & 0 & 0 & -k_{6} & k_{6}
\end{bmatrix}
\]

are brought into the formula (8) to obtain:

\[
\begin{bmatrix}
k_{1}+k_{2} & -k_{2} & 0 & 0 & 0 & 0 \\
-k_{2} & k_{2}+k_{3} & -k_{3} & 0 & 0 & 0 \\
0 & -k_{3} & k_{3}+k_{4} & -k_{4} & 0 & 0 \\
0 & 0 & -k_{4} & k_{4}+k_{5} & -k_{5} & 0 \\
0 & 0 & 0 & -k_{5} & k_{5}+k_{6} & -k_{6} \\
0 & 0 & 0 & 0 & -k_{6} & k_{6}
\end{bmatrix}
\begin{bmatrix}
m_1 & 0 & 0 & 0 & 0 & 0 \\
0 & m_2 & 0 & 0 & 0 & 0 \\
0 & 0 & m_3 & 0 & 0 & 0 \\
0 & 0 & 0 & m_4 & 0 & 0 \\
0 & 0 & 0 & 0 & m_5 & 0 \\
0 & 0 & 0 & 0 & 0 & m_6
\end{bmatrix} = \begin{bmatrix} A_1 \\
A_2 \\
A_3 \\
A_4 \\
A_5 \\
A_6 \end{bmatrix} \tag{11}
\]

Finally, the 6-order dominant modes of the 6-part mechanical system are obtained: \(\{A^{(1)}\}, \{A^{(2)}\}, \{A^{(3)}\}, \{A^{(4)}\}, \{A^{(5)}\}, \{A^{(6)}\}\).

3. Modeling

According to the common working conditions of hydraulic press and the working principle of hydraulic press, the hydraulic press and three kinds of different platen-arranging robot hands are designed. The three kinds of integral assembly drawings of hydraulic press are shown in Fig. 1. At that same time, the overall parameter for the robot hand for the design stand are shown in Table 1.

**Figure 1.** Three kinds of integral assembling drawings of hydraulic press and manipulator.
### Table 1. General parameters of manipulator.

| Operating conditions      | Parameter                     |
|---------------------------|-------------------------------|
| Ambient temperature       | -5 ~ 45°C                     |
| Relative humidity         | 20%~80%                       |
| Power supply              | AC380V±10%                    |
| Voltage fluctuation range | ±10%                          |
| Power frequency           | 50HZ                          |
| Air source                | 0.4-0.6Mpa                    |
| Ground resistance         | ≤ 4 Ω Factory owned by user   |
| Foundation requirements   | The ground is flat without loosening |

As shown in FIG. 1, different swing plate manipulators are designed for different mounting positions of the conveyor belt and different positions of the clamping parts, 2, 3, and 4, respectively.

**Figure 2.** Scheme 1 swing plate non-standard manipulator.  
**Figure 3.** Option 2 swing plate non-standard manipulator.  
**Figure 4.** Option 3 swing plate non-standard manipulator.

This paper focuses on the modal analysis of three kinds of swing-plate manipulators under simulated working conditions. Next, the modal simulation analysis will be carried out.

### 4. Modal analysis model

Modal analysis is a modern method to study the dynamic characteristics of structures. The method of system identification is applied in engineering vibration field. With the inherent vibration characteristics of the mechanical structure frame, each mode has a specific frame natural frequency, damping ratio and mode shape. These modal parameters can be obtained by calculation or experimental analysis. These sub-calculation or experimental analysis process is called modal analysis. These analysis processes are
called computational modal analysis if they are obtained by finite element method. If the input and output signals of the acquisition rack system are identified to obtain modal parameters through experiments, it is called experimental modal analysis. Generally, modal analysis is also referred to as experimental modal analysis [6-7]. Therefore, for three kinds of swing-plate robot hand, one will be extracted for analysis. Because all three are alike. The most important thing in the modal analysis of a swing-plate-loaded manipulator is to analyze its base. Because the vibration frequency of the base frame will directly affect the machining accuracy. Therefore, the shelf base in Figure 2 is extracted and meshed by ANSYS/Workbench. The final result of mesh generation is shown in Figure 5.

And then set its boundary conditions. In this study, the boundary condition is mainly to set the fixed surface. According to FIG. 5, the bottom surfaces of the four fixing screws of the base are set as fixing surfaces to limit their displacement. Finally, the modal analysis is carried out, and the first six order modal cloud diagrams are taken, as shown in Figure 6 (a), (b), (c), (d), (e), (f).

Figure 5. Mesh diagram.

Figure 6. First six mode cloud.
As shown in FIG. 6, that first-order mode value, which is the most important and primary observation, is 2.0542 e-003 Hz. According to the actual working condition of the hydraulic press, the structure of modal simulation is far greater than the actual fixed frequency, so it meets the actual requirements.

5. Conclusion
Firstly, three kinds of non-standard swing-plate manipulators are designed according to the different working mode and belt conveying position of the hydraulic press. Secondly, the modal simulation analysis of one of the manipulators is presented. But before the analysis, the modal theory is pushed forward. After that, the boundary conditions are set, the mesh is divided and the modal simulation analysis is carried out. Finally, the first order modal value is obtained and analyzed, which is 2.0542 e-003Hz. Combined with the actual working conditions of the hydraulic press, the frequency value is far greater than its natural frequency, so the design is reasonable. At the same time, it provides a basis for similar research in the future.

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