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Dynamic balance design and simulation verification of reed system of loom beating up mechanism

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Abstract. In order to reduce the vibration caused by the eccentricity of the reed system in the beating up mechanism of the loom, the centrifugal force generated by the eccentric reed system is decomposed into two parallel base planes, and a dynamic balance design scheme based on the principle of counterweight is established. Based on structural analysis and theoretical calculation, the reasonable balance weight mass, structure and assembly position are determined, and the reed system simulation model based on Adams/view platform is constructed. The correctness of the dynamic balance design scheme is verified by rigid body dynamics simulation and error analysis. The analysis results show that the centrifugal force simulation value F=347.008N, the design value F1=347.222N, and the error is 0.06%, which meets the requirements of mechanical accuracy design. It provides an important technical reference for dynamic balance design, vibration reduction and noise reduction of fixed axis rotation system.

1. Introduction

The high-speed running mechanism must be accompanied by greater inertial force and moment of inertia, which leads to greater vibration and noise of the machine. This problem has become a restrictive factor to ensure the stable operation of looms and improve product quality.
Kuchar and Maciej studied the influence of reed system vibration on fabric [1] and the simulation experiment is also done [2]. Chung Feng Jeffrey Kuo,Studied and analyzed the dynamic model of beating up mechanism [3]. Celik, H. I discussed the kinematic law of beating up mechanism [4]. Katunskis.J respectively carried out theoretical analysis and experimental verification on the beating up stage [5].
This paper takes the reed system as the research object, and carries out a series of research on it, such as structural analysis, theoretical calculation, CAD modeling, dynamic simulation and error analysis, so as to provide theoretical basis and technical reference for the vibration and noise reduction and high-speed research and development of loom beating up mechanism.

2. Reed system structure and its kinematic law

2.1 Reed system structure

The reed system is the core component of the loom, as shown in figure 1. Its components include: reed, reed base, reed base foot and rotating shaft. The reed is supported in the reed base. The reed, reed base, reed base foot and rotating shaft are fixedly connected in turn. The whole reed system can be regarded as a rigid body. The rotating shaft is installed on the box through the bearing, and the transmission mechanism drives its operation, so as to realize the weft beating operation process.

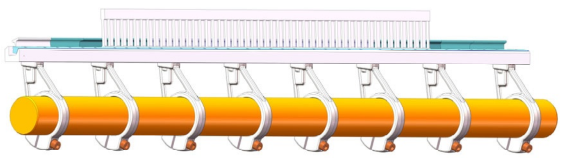

Figure 1. Structural diagram of reed system.

2.2 Kinematic law

In this paper, the four-bar linkage is used as the transmission mechanism, and its schematic diagram is shown in figure 2. The rectangular coordinate system is established with the crank rotation center O_1 as the origin, the limit position of the front dead center of the beating up mechanism $O_1A_1B_1C_1$ as the initial position, the crank rotates counterclockwise, O_2 is the rotating shaft of the reed system, L_1 is the crank, L_2 is the connecting rod, L_3 is the rocker and the swing angle of the rocker is ψ.In this paper, the complex vector method is used to solve the motion law of reed system with MATLAB, and the crank speed is set to 1000 r/min.

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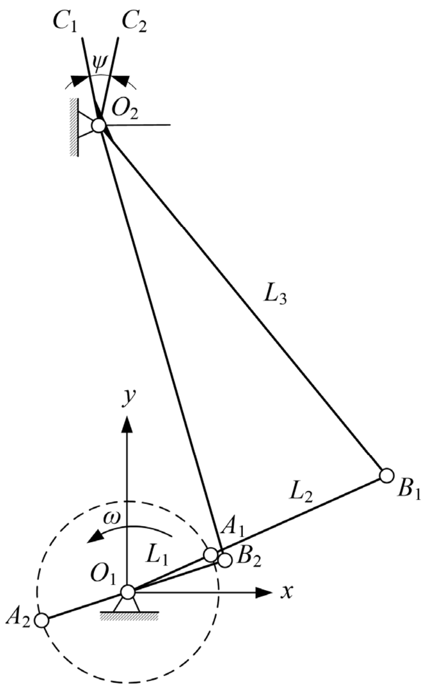

Figure 2. Four link beating up mechanism.

The eccentric reed system will inevitably produce centrifugal force during operation, which acts on the frame through the bearing, resulting in severe vibration and noise of the machine. It can be seen from figure 4 that this motion is variable speed fixed axis swing, the maximum angular velocity of return is 25.459 rad/s, the angular velocity is the largest, and the centrifugal force is also the largest.

3. Principle and method of dynamic balance

3.1 Principle analysis

In the dynamic balance design of the rotor, firstly, the eccentric mass in each rotation plane shall be determined through structural analysis, and then the number, size and position of counterweight required to make the rotor achieve dynamic balance shall be calculated according to the distribution of eccentric mass.

The reed system is approximately equivalent to a particle m, and figure 3 shows the design principle of dynamic balance.

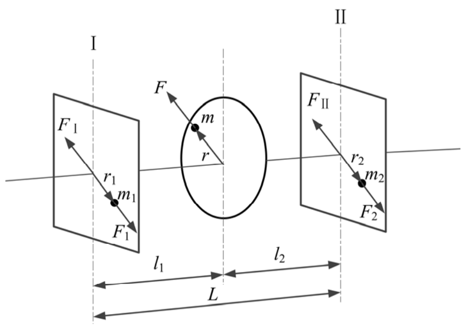

Figure 3. Design principle of dynamic balance.

According to theoretical mechanics, the force can be decomposed into two components parallel to it. According to the dynamic balance design principle shown in figure 3, two balance base planes I and II are selected as the installation position of counterweight, and the centrifugal force F is decomposed into planes I and II. Obviously, in order to make the reed system reach the dynamic balance state, it is only necessary to apply an appropriate balance mass m_1 and m_2 in planes I and II respectively, so as to generate two centrifugal inertial forces F_1 and F_2 in the opposite direction, and finally make the sum of the centrifugal inertial forces in the two planes equal to zero. In figure 3, F is the centrifugal force generated by the eccentric mass m, where L_1=204mm, L_2=204mm, r=26.509mm, r_1=40.56mm, r_2=40.56mm.

3.2 Counterweight calculation

According to the static equilibrium conditions, the following equilibrium equations exist in the equilibrium bases I and II:

$$F_1 + F_{\mathrm{I}} = 0 \tag{1}$$

$$F_1 + F_{\mathrm{II}} = 0 \tag{2}$$

Where: F_1 and F_2 are the centrifugal forces generated by the balance weights m_1 and m_2.

According to the rotor dynamics theory and figure 3, F_1 and F_2 can be expressed as:

$$F_1 = F\frac{l_1}{L} = mr\omega^2\frac{l_1}{L} \tag{3}$$

$$F_2 = F\frac{l_2}{L} = mr\omega^2\frac{l_2}{L} \tag{4}$$

Replace equation (3) into static equilibrium equation (2) and eliminate it ω^2 available:

$$mr\frac{l_1}{L} + m_1 r_1 = 0 \tag{5}$$

The mass of the reed system measured in the CAD environment is 40.416kg, and the counterweights m_1 and m_2 in the balance base surfaces I and II are 13.2 kg calculated by equation (5).

3.3 Balance weight structure design

According to the center of mass position and counterweight mass, a sector balance weight is designed in the balance base plane to offset the decomposition forces F_{I} and F_{II}. The design parameters in the two balance base planes are the same, so the structure of the balance weight is also the same. The section of the sector balance weight designed in this paper is shown in figure 6， R_0=60mm， R_1=40mm， R=152mm， α=120°。 The balance weight is made of steel with mass density ρ=8000 kg/m^3, the thickness of the balance weight h=80.8mm is calculated from formula (5). According to the geometric parameters of the balance weight, its three-dimensional solid model is established in Solidworks environment.

The installation position and initial phase of the balance weight are determined according to the dynamic balance design, and the balance weight is assembled on the rotating shaft. The reed system model is shown in figure 5. The mass center of the model is measured in

Solidworks. The overall mass center of the assembled model is basically consistent with the rotation center of the rotating shaft, which verifies the correctness of the structural design of the balance weight.

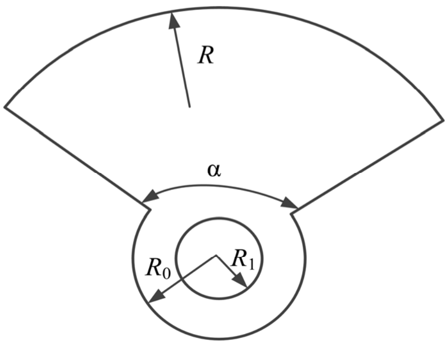

Figure 4. Schematic diagram of balance weight.

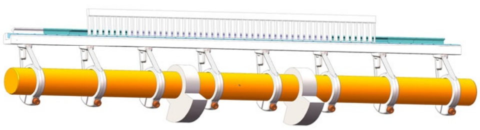

Figure 5. 3D CAD model of balance weight.

4. Simulation Verification

4.1 Model construction

The three-dimensional model is imported into Adams/view environment through the interface program, and the material properties, constraints and connecting pairs between components are defined. The simulation is set to two swing cycles. Because the cubic spline interpolation method is intuitive, accurate derivation and smooth curve, the cubic spline interpolation method is adopted.

4.2 Dynamic simulation

The mass center displacement curve of the balance weight is obtained through data post-processing, as shown in.

It can be seen from that when the reed system moves with the specified law, the displacement amplitude of the mass center of the balance weight is 40.5mm, which is consistent with the design parameters of the rotation radius of the mass center of the balance weight. The mass center displacement law changes periodically with time, and the curve is smooth without obvious fluctuation, which meets the requirements of rotor dynamics design and speed law.

shows the mass center velocity curve of the balance weight. It can be seen from the curve in figure 8 that the curve is the zero point, that is, the reed system reverses, the return speed amplitude is v=1.0326m/s. The expression of centrifugal force is:

$$F = m_1 \frac{v_1^2}{r_1} \tag{6}$$

Substitute the parameters to calculate the centrifugal force of the balance weight, and the simulation result is F=347.008N; Because the two balance weights are centrosymmetric, the centroid velocity and centrifugal force are the same.

4.3 Error analysis

According to the dynamic balance theory, the design parameters m, r,ω,l_1, and L are substituted into equations (3) and (4) respectively to calculate the design value of centrifugal inertia force of balance weight: F_1=347.222N. In order to verify the accuracy of dynamic balance design, the error between centrifugal force design value F_1 and simulation value F is analyzed.

$$\Delta_1 = \frac{F_1 - F}{F_1} \times 100\% \tag{7}$$

Calculate the balance weight design error Δ_1 as 0.06% according to equation (7). According to engineering design specifications and experience, mechanical design errors are unavoidable in practice, According to the error calculation results obtained in this paper, the error between the dynamic balance theoretical design value and the dynamic simulation value meets the design requirements, which verifies the correctness of the design of the rotating shaft reed system, and shows that the dynamic balance theoretical calculation result is accurate and the design scheme is reasonable and feasible.

5. Conclusion

In this paper, the shape, mass and assembly position of the balance weight are determined through the dynamic balance design and calculation of the reed system, so that the center of mass of the whole reed system is consistent with the rotation center, The centrifugal force simulation value of the balance weight is F=347.008N, the design value is F_1=347.222N, and the error is 0.06%, which meets the design requirements of mechanical accuracy, effectively offsets the centrifugal inertia force generated in the swing process, so as to reduce the vibration and noise of the machine, The dynamic simulation results verify the correctness of the dynamic balance design scheme.

It can be concluded that the dynamic balance method established in this paper is practical and effective, and is easy to realize in engineering. It provides an important technical reference in the dynamic balance design, vibration and noise reduction of fixed axis rotation system.

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