Research on the Design of Conjugate Cam Shedding Based on High-Speed Rapier Loom

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Abstract. Cam shedding is a kind of shedding form commonly used in modern high speed loom, which has the characteristics of high motion precision and good impact resistance. In this paper, conjugate cam is applied to the shedding mechanism design of rapier loom. By analyzing the principle of cam mechanism, studying the motion characteristics of the follower, calculating the key parameters such as pressure Angle and curvature radius, the conjugate cam shedding mechanism of high-speed rapier loom is designed. In the Matlab environment, the main cam theoretical contour design program was written, the reasonable cam pressure Angle and roller radius were determined, the three-dimensional model of conjugate cam mechanism was established by using SolidWorks, and the Motion law of pendulum rod, two-arm rod and heald frame was verified by the simulation of motion module. At the same time, the conjugate cam and heald frame were analyzed by finite element statics. The simulation results show that the angular displacement, angular velocity and angular acceleration of the swinging rod and the two-arm rod are consistent with the theoretical profile expectation of Matlab, and conform to the motion law of the rapier loom heald frame. In the process of motion of the heald frame, the conjugate cam and the roller can keep continuous contact with each other, which has good motion stability and mechanism performance. It provides strong support for the design innovation and practical application of rapier loom shedding mechanism.

Keywords: rapier loom, conjugate cam, shedding mechanism, simulation, frame

1 Introduction

Currently, Rongyi Zhentao, Zhao Shihai and Yuan Ruwang investigated the influence of fabric organisation laws on the high-speed conjugate cam opening process. By analysing the motion law of the follower and the resting time of the heald frame, the role of these factors on the performance of the cam opening process was explored. The results show that the best cam performance is achieved in the opening process with the opening rest angle removed when the follower follows the simple harmonic motion law. In addition, this paper devised a matching relationship between the fabric organisation laws and the cam contour lines within and between groups of fabric loops, which enabled significant optimisation of the cam performance in practical machining[1]. Wei Z, Wang Z, LiD study deals with the rigid-flex coupled dynamics modelling and dynamic accuracy analysis of planar cam four-link mechanism with multiple gap joints. The research of Wei Zhe, Wang Zhe and Li De is aimed at the rigid-flexible coupling dynamic modeling and dynamic accuracy analysis of the multi-clearance sub-planar cam four-bar linkage mechanism. By integrating the gap collision model, finite element model and rigid-flexure coupled dynamics model, it is applied to the cam-link combined multibody mechanism. Within the speed range of 600-800 rpm, it is found that the dynamic performance of the system is less affected by the speed. Meanwhile, through the comparative analysis of various materials, the results show that the selection of carbon fibre composite material has the least influence on the motion accuracy of the system[2]. Haifei Qiu, Chunfeng Li, and Ming Chen of Xijing College conducted a research on the design of conjugate cam opening for external high-speed weaving machine. In order to reduce the wear and contact stresses between the cam and the rotor, a new external conjugate cam opening system based on biaxial structure was constructed on the basis of the mechanistic equivalence transformation. The programming design and dynamic calculation of the theoretical cam profile and its key performance parameters (α, R, ρ) are realised in MATLAB environment. Meanwhile, a functional prototype simulation model of the single-page heald frame was established in ADAMS/View, and the dynamics of the mechanism was analysed. These works provide a reference basis for the design and performance improvement of high-speed cam opening system[3].

2 Structural Modelling and Assembly Design of Main and Secondary Cams

2.1 Structural Modelling of Primary and Secondary Cams

The theoretical profile of the main cam is inverted by MATLAB, and the theoretical profile of the main cam minus the roller radius is the actual profile of the main cam. And then the actual contour of the main cam into SolidWorks to generate a conjugate cam main cam three-dimensional model, the main cam as shown in Fig 1; Known conjugate cam cam axis and pendulum axis distance of 180mm, the establishment of a simple base model, the base is 430mm long, 340mm wide, 5mm thick, in the base to play a hole, the diameter of 50mm, the camshaft is fixed in the base, and the diameter of 50mm hole to impose the hinge with; Establishment of the roller connector three-dimensional model, the known diameter of the roller is 77mm, the thickness is 20mm; Pendulum length of 120mm, the main and secondary pendulum angle of 130 °, the two pendulum combined into a roller connector, the rollers were fixed on the roller connector, and finally its assembly. The initial 3D model of the conjugate cam mechanism is shown in Fig. 2. The parameters of the conjugate cam are shown in Table 1.

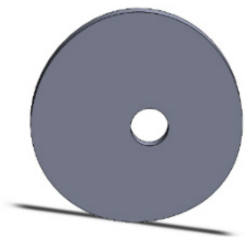

Fig. 1. cam section.

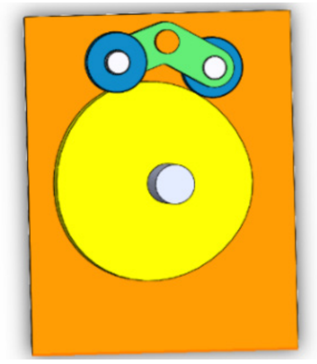

Fig. 2. Initial 3D model of conjugate cam mechanism.

Table 1. Parameters of conjugate cam parts.

Name	lengths/mm	breadth/mm	thicknesses/mm
foundation	430	340	5
rollers	77	77	20
pendulum	120	50	20

2.2 Auxiliary Cam Profile Design

First, various parameters of the main cam and the main cam are inversely calculated through MATLAB. Then, through the assembly function of SolidWorks, the main cam, the rocker arm, and the roller are reasonably assembled to form a conjugate cam. Finally, through the trajectory tracking command in the SolidWorks motion analysis, first select the displacement/velocity/acceleration option, then select the tracking path command, and finally select the main cam surface and the roller center as the tracking point to inversely calculate the theoretical profile of the auxiliary cam. The actual profile of the auxiliary cam can be obtained by subtracting the roller radius from the theoretical profile of the auxiliary cam. The main and auxiliary cams and the roller connectors are assembled to obtain the conjugate cam[4].

Use the motion simulation function in SolidWorks to add a motor to the camshaft, select the camshaft, enter the speed of 6RPM, and set the animation duration to 10s, that is, the conjugate cam mechanism completes one rotation.

Click the Results and Graphics command, select the roller center point and the conjugate cam secondary cam surface, select displacement, velocity, and acceleration in the selection category; select tracking path in the selection subcategory. As shown in Fig 3, add the results.

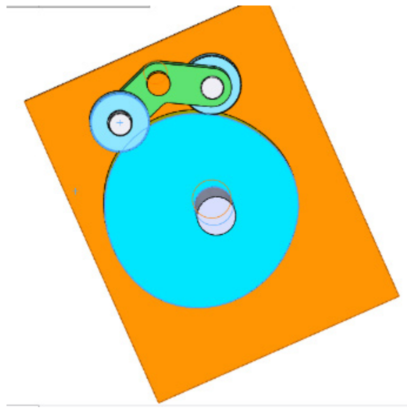

Fig. 3. Add results.

Click the calculation motion example to generate the auxiliary cam theoretical profile curve, as shown in Fig 4, which is the tracking and generation state of the auxiliary cam theoretical profile curve. As shown in Fig 5, the auxiliary cam theoretical profile curve is different from the actual profile curve by a roller radius. You need to use the equidistant curve to subtract a roller radius, and then form an actual profile curve. Finally, use the stretch command in SolidWorks to stretch the actual profile curve to get the auxiliary cam.Using the Template[5].

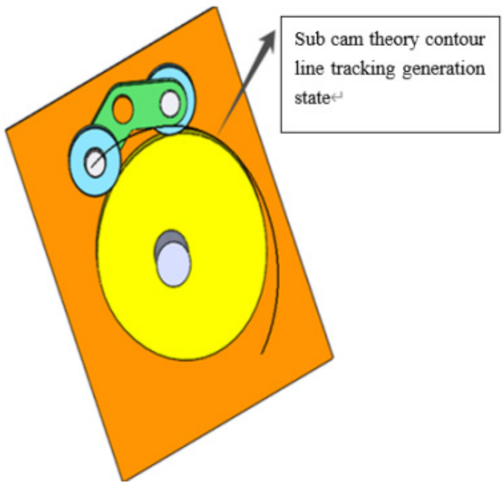

Fig. 4. Auxiliary cam theoretical profile tracking generation state.

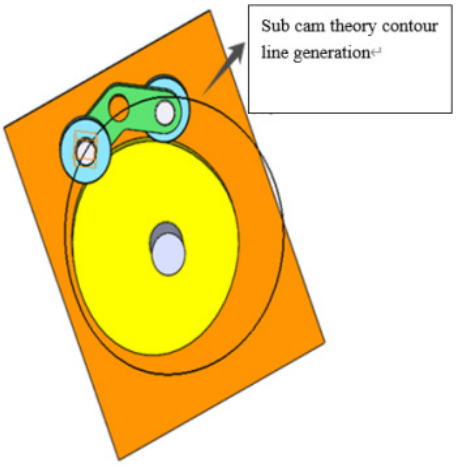

Fig. 5. Theoretical profile curve of auxiliary cam.

2.3 Conjugate Cam Mechanism Assembly

The design and manufacture of the conjugate cam structure assembly need to take into account the shape of the cam, the size and material of the roller, the size and material of the rocker, etc., to ensure accurate and reliable transmission effect. Through reasonable design and material selection, the purpose of reducing friction, increasing stability, improving transmission efficiency and extending service life can be achieved.

The conjugate cam designed in this paper is mainly composed of a main cam, a secondary cam, two rollers, and a roller connector composed of two rockers, as shown in Fig 6.

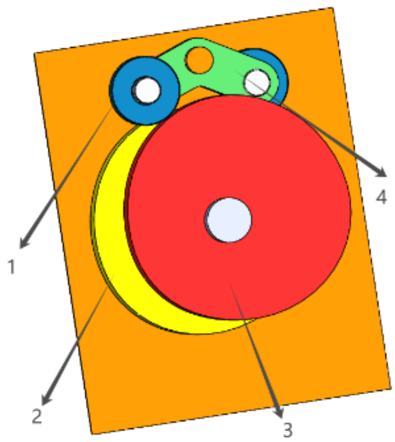

Fig. 6. Conjugate Cam Assembly.
1- Roller; 2- Main Cam; 3-Secondary cam; 4-Swing rod

3 Kinematics Simulation

3.1 Simulation Analysis of Conjugate Cam Rocker

To facilitate kinematic analysis, a rotary motor is applied to the camshaft, the driving speed is set to 300 r/min, and the simulation time is 0.2 s. The angular displacement, angular velocity, and angular acceleration of the pendulum are simulated and calculated, and the operation results are shown in Fig 7 for the angular displacement of the pendulum, Fig 8 for the angular velocity of the pendulum, and Fig 9 for the angular acceleration of the pendulum. It can be seen from the results that the curve is smooth and continuous without strong impact, but the acceleration curve has abrupt changes at the beginning and end, which conforms to the cosine acceleration motion law[6].

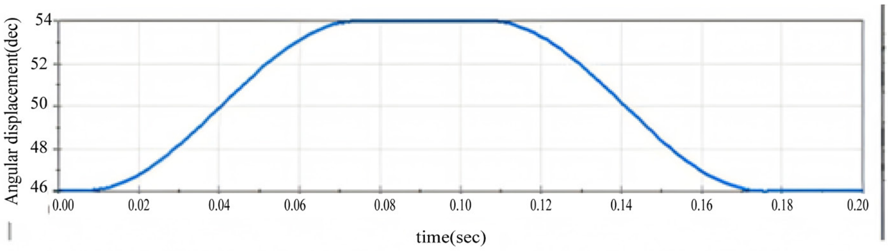

Fig. 7. Angular displacement of the pendulum.

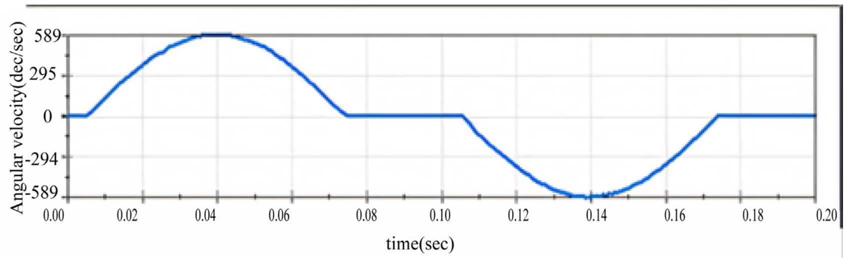

Fig. 8. Angular velocity of pendulum.

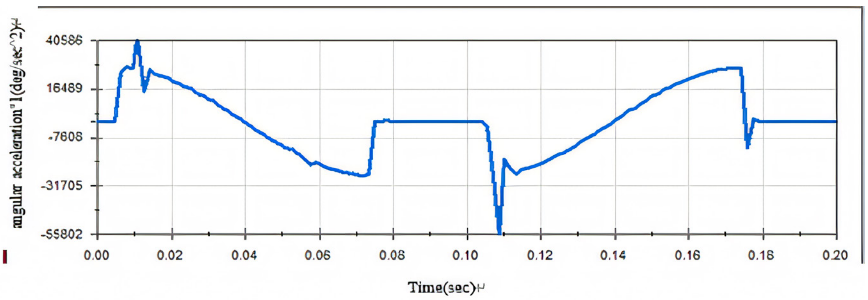

Fig. 9. Angular acceleration of the pendulum.

3.2 Simulation Analysis of Conjugate Cam Rocker

The rotary motor is applied to the gear shaft. Since the gear ratio is 2:1, the driving speed is set to 600r/min and the simulation time is 0.2s. The angular displacement, angular velocity and angular acceleration of the two-arm lever are simulated and calculated. The operation results are shown in Fig 10, Fig 11, and Fig 12. The curve is smooth and continuous without strong impact, but the acceleration curve has abrupt changes at the beginning and end, which conforms to the cosine acceleration motion law[7].

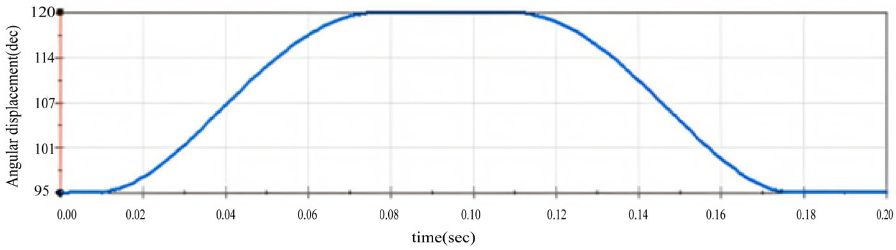

Fig. 10. Angular displacement of the two arm.

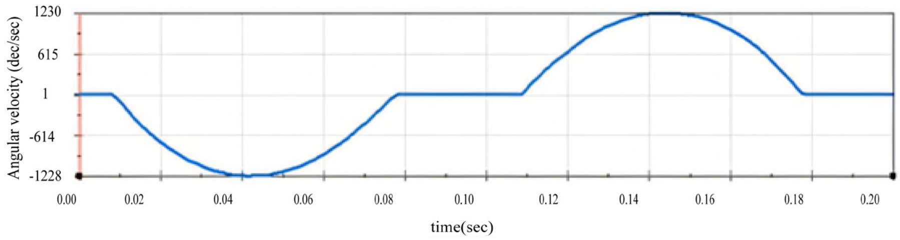

Fig. 11. Angular velocity of the second arm.

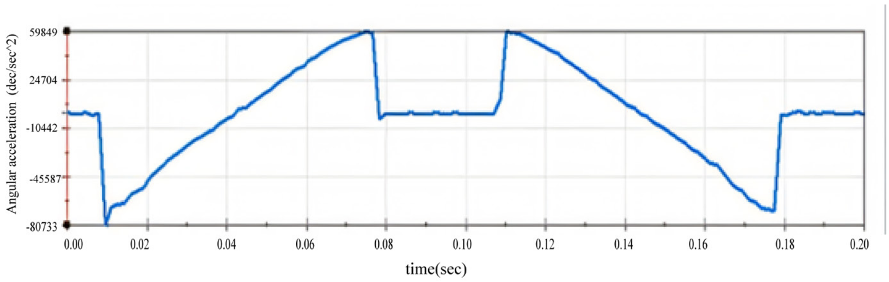

Fig. 12. Angular acceleration of the two-arm.

3.3 Heald Frame Simulation Analysis

A rotary motor is applied to the gear shaft. Since the gear ratio is 2:1, the drive speed is set to 600r/min and the simulation time is 0.2s. The linear displacement, linear velocity and linear acceleration of the heald frame are simulated and calculated, and the operating results are shown in Fig 13 for the linear displacement of the heald frame, Fig 14 for the linear velocity of the heald frame, and Fig 15 for the linear acceleration of the heald frame. From the results, it can be seen that the curve is smooth and continuous without a strong impact, but the acceleration curve has mutations at the beginning and end, so it conforms to the law of cosine acceleration motion. And in general, it can be divided into four stages, namely "push stroke-far rest-return stroke-near rest", which conforms to the segmented characteristics of the cam theoretical profile[8].

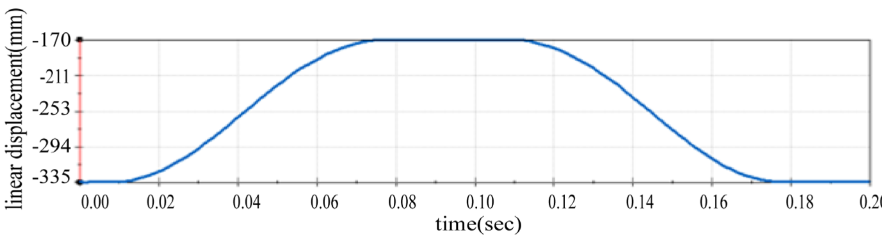

Fig. 13. Heald frame linear displacement.

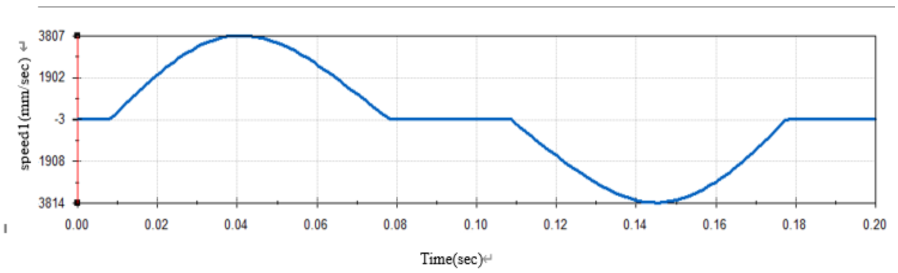

Fig. 14. Heald frame linear speed.

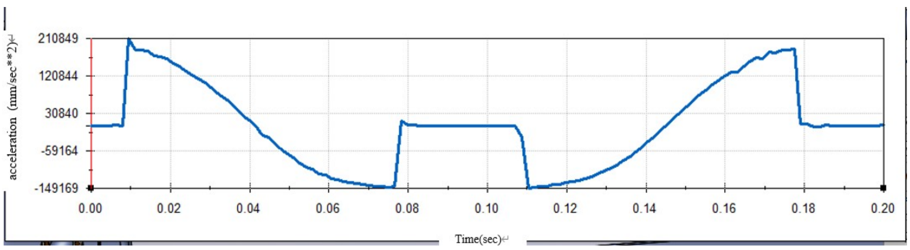

Fig. 15. Heald frame linear acceleration.

3.4 Simulation Results Analysis

By comparison, when the camshaft rotates one circle in the time range of 0-0.2s, the motion law curves of the rocker, heald frame and two-arm lever have the same changing trend, which can be generally divided into four stages, namely "push stroke-far rest-return stroke-near rest", which conforms to the segmented characteristics of the cam theoretical profile. The conjugate cam opening mechanism after inverse analysis can open at a higher speed than the opening mechanism manufactured by direct mapping under the same working conditions, and the transmission is smoother and the dynamic performance is greatly improved.

Comparing the two-arm lever, heald frame and rocker lever, it can be seen that the speed is in the opposite direction to the angular velocity, and the acceleration curve has certain mutations at the beginning and end, indicating that the cam opening system has a flexible impact when starting and stopping, which conforms to the cosine acceleration motion law, indicating that the design is reasonable. Therefore, from the simulation results, the lifting law of the heald frame conforms to the motion law of the follower, indicating that the design of the conjugate cam opening system is reasonable[9].

4 Finite Element Analysis of Opening Systems

4.1 Conjugate Cam Initial Setting

The simulation module of SolidWorks software is mainly used to perform finite element analysis on the conjugate cam mechanism. The example added to the conjugate cam mechanism is static stress analysis. The material is set to alloy steel. The elastic modulus of alloy steel is 2.1×1011 N/ m^2, the Poisson's ratio is 0.28, the maximum yield strength that the material can withstand is 2.95×108 N/ m^2, and the mass density of the material is 7800 kg/ m^3. These are some parameters of the materials used for the conjugate cam. The specific settings are shown in Figure 16. Finally, the conjugate cam will be subjected to finite element analysis to obtain stress and displacement results. Then, by comparing the maximum yield strength of the material, the rationality of the conjugate cam design can be determined.

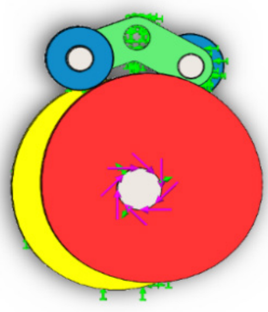

Fig. 16. Adding Fixtures and External Loads.

4.2 Conjugate Cam Meshing

The conjugate cam is meshed and the mesh density is set to good. There are 47595 cells and 74924 nodes. The finite element mesh division is shown in Fig 17.

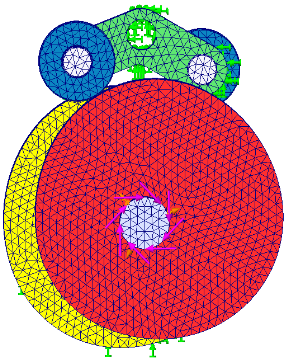

Fig. 17. Finite Element Meshing.

4.3 Stress and Displacement Analysis of Conjugate Cams

The finite element analysis results are shown in Figs 18 and 19, where Fig 18 is the finite element stress result. It can be seen from the Fig that the maximum stress result is1.804×107N/ m2, which is much smaller than the maximum yield strength of alloy steel 2.95×108N/ m2, Fig. 19 is the finite element displacement result, and the maximum displacement is 2.222×10-2mm. The results show that the displacement is very small and the impact on the mechanism is almost negligible[10].

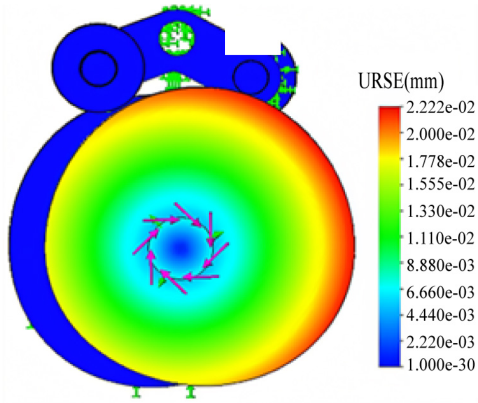

Fig. 18. Finite Element Stress Results.

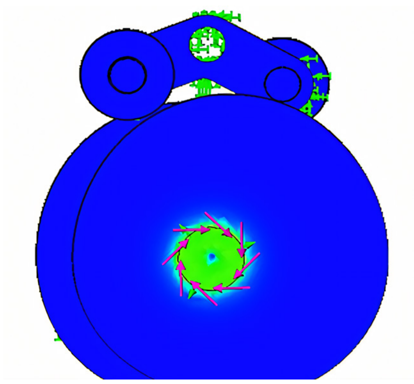

Fig. 19. Finite element displacement results.

The finite element analysis results of the conjugate cam mechanism show that, under a torque of180N·m., compared with the material properties of alloy steel, both the stress and displacement results meet the requirements, indicating that the strength and stiffness of the conjugate cam mechanism are sufficient, so the design of the conjugate cam mechanism is reasonable.

5 Conclusion

The theoretical contour line of the master cam was inverted by Matlab, and the pendulum angular displacement curve and the master cam pressure angle curve were calculated. According to the law of motion of the follower, the cosine acceleration law of motion is used, and the pressure angle is finally calibrated to ensure the working life of the conjugate cam mechanism. The CAD theoretical contour line of the main cam is imported into SolidWorks software to derive the main cam, and the theoretical contour line of the slave cam is inverted by the tracking path in Motion analysis to finally obtain the conjugate cam. The design and modelling of the drive mechanism parts and heald frame components in the conjugate cam opening mechanism of the high-speed rapier loom are completed in SolidWorks, and the parts are assembled to finally complete the conjugate cam opening mechanism. The kinematic simulation of the conjugate cam mechanism and conjugate cam opening mechanism was carried out using the Motion analysis module of SolidWorks software. By analysing the motion results of the pendulum bar, the two-arm bar and the heald frame, it is concluded that the conjugate cam mechanism and the conjugate cam opening mechanism are reasonably designed. Using the Simulation module of SolidWorks software, the finite element analysis of the conjugate cam and the heald frame is completed, and the results show that the stresses and displacements are within a reasonable range, which verifies the reasonable design of the conjugate cam mechanism and the heald frame.

Acknowledgments

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