Motion and Static Simulation of Horse Riding Machine

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Abstract. Horse riding machine is a typical fitness equipment, which is widely used in various fitness places. 3D model of the riding machine is established by using SolidWorks to make people feel more comfortable. Motion simulation is conducted to obtain the position, velocity and acceleration of the saddle, pedal and armrest. Then, static simulation is performed to get the maximum stress of the horse riding machine.

1. Introduction

Horse riding machine is one of the most important fitness equipment, which belongs to the power and aerobic composite equipment. It can not only be used as a training device for professional athletes, but also as a family fitness device for mass exercise. It is also an ideal choice for health preservation, entertainment, rehabilitation and health care [1]. With the improvement of living standards, people have higher requirements on riding comfort and motion stability. Yu S, Zhang Q, etc. performed a motion simulation on the riding machine [2]. Zhao H, Zhang B, etc. optimized the riding machine [3].

In this paper, the motion structure of the riding machine is simulated and analyzed. The length of each rod in the moving mechanism is changed in turn. After getting the result, the effect of the length of each pole on the trajectory, velocity and acceleration are analyzed, and the length of each pole is optimized. In the end, the actual movement trajectory of the riding machine can ensure the riding comfort to the greatest extent.

2. Structure design of the riding machine

The riding machine is mainly composed of frame, armrest, back seat and connecting rod, as shown in Fig. 1. When the user sits on the back seat, the body is straight, hands are placed on the armrests, feet are stepped on the pedals, and both hands are forced to pull the armrests backwards, while the feet are stepped down. Then the armrest will drive the connecting rod to swing, and the connecting rod will transmit the motion to the back seat, and the back seat will move with smooth curve. In this way, the users can move their legs, buttocks, shoulders, waists and wrists simultaneously through the stretching movement of their arms and the forward and backward movement of their legs, thereby achieving the goal of physical exercise [4]. Based on ergonomics, our staff room has calculated the optimum parameters of the rod, L₁=95 mm, L₂=255 mm, L₃=310 mm, L₄=270 mm L₅=100 mm, and L₆=400 mm.
3. Analytical analysis of motion law

According to the length of the rods mentioned above, a three-dimensional model of the horse riding machine is built in SolidWorks, and its mechanism is simulated and analyzed in Motion module [5]. Combining with literature [6], its motion period is about 2 seconds, so the frequency of the motor is 0.5 Hz and the simulation time is 2 seconds. The simulation curves of C, D and G are shown in Figs. 3, 4 and 5.
Fig. 3. C point trajectory curve

Fig. 4. D point trajectory curve

Fig. 5. G point trajectory curve
The velocity curve and acceleration curve of C, D and G points obtained by SolidWorks are shown in Figs. 6, 7 and 8. It can be seen from the figure that the velocity and acceleration do not fluctuate dramatically, but fluctuate periodically in a fixed range, which meets the requirements of ergonomics.
Static stress simulation analysis

The weight of Chinese adults is 42kg~75kg. In order to ensure the safety of the machine, this paper considers the maximum force, that is, all the weight of the user is on the pedal, and the load on the horse riding machine is 1000N. In SolidWorks Simulation module, the static stress analysis is carried out. The material is AISI-304. The fixture is fixed to restrain the mechanism. The load of 1000N is applied to the pedal, and meshed. The mesh generation is a very important link in the modeling. Finally, an example is run. The Von Mises stress nephogram is shown in Fig. 9. Fig. 9 shown that the maximum stress is on the pedal position of the horse riding machine and its size is about $1.502 \times 10^8 \text{N/m}^2$, which is much smaller than the yield stress ($2.068 \times 10^8 \text{N/m}^2$) of 304 stainless steel.

![Fig.9. Stress nephogram of pedal crankshaft with diameter of 20 mm](image)

The models with diameters of 12 mm, 14 mm, 16 mm, 18 mm and 22 mm were established in SolidWorks for optimizing the pedal. The data of maximum stress were shown in Fig. 10. With the increase of the diameter, the maximum stress of the pedal decreases. When the diameter is 18 mm, the decrease trend of the maximum stress becomes slow. That is to say, when the diameter is less than 18 mm, the decreasing speed of the maximum stress becomes faster with the increase of the diameter. When the diameter is more than 18 mm, the decreasing speed of the maximum stress becomes slower. When the diameter is 18 mm, the maximum stress is $1.532 \times 10^8 \text{N/m}^2$, which is less than the yield stress of 304 stainless steel. Therefore, 18 mm is optimal, and the mechanism is optimized while ensuring safety.

![Fig.10. Changing trend of maximum stress of pedal](image)
5 . Conclusion
(1) The displacement, velocity and acceleration characteristic curves of points C, D and G are obtained by motion simulation in SolidWorks, which conforms to human habits.

(2) The maximum stress is on the pedal position by the Von Mises stress nephogram, which is obtained by static stress simulation analysis of the mechanism. The optimum diameter of the pedal position is 18 mm, which ensures the safe and saves the cost.

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