Design and Simulation on Hand Skipping Rope Equipment

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Keywords: Hand, Count, Skipping rope equipment, Trundle, Circles.

Abstract. Hand skipping rope equipment is developed with braking trundles which can count. With the help of trundles people can move the machine to a right place. The right and left circle diameter are 2100mm. Distance of the two circles can be changed. Mechanical counter is installed on the handle. Turns can be moved to the left circle and the drive shaft by the counting handle. Meanwhile the counter begins to count. The shaft move turns from the chain to right circle. Four identical chain wheels are designed, the right and left circle can drive rope rotate at the same time. When the speed is 0.5r/s, centrifugal force of rope is 12.26N. When the acceleration was set with 3 valve the simulation shows the acting force of revolving axle is 64N, 11.8N, 23N, which is similar with calculation.

Research on Rope Skipping Equipment

Chen wenchao and Feng tian, teacher of Zhengzhou University, invented the double rope skipping machine with the help of electricity[1]. The machine breaks the traditional structure of single rope rotates with two ropes, which can count and record time. Liu lingli and Li rui, teachers at Donghua University, invent a automatic rope skipping machine. The machine can automatic throw rope, can positive automatic control and can automatic power-off protection[2]. Gao Luyao invented a rope skipping machine in 2010. The patent number is 201020236188.7[3]. The structure include columns and ropes. The column is equipped with positive and frequency conversion motor. The rope is connected to the two output shafts of the motor. The rope skipping machine can work without help. Lei Jianfeng, and Yang Yan invented a rope skipping machine in 2008. Patent number is 200610104458.7[4]. The rope skipping machine is a mechanical that can automatic turn rope. Two same rockers are connected with the rope. Through a belt the invention passes the energy of motor to planetary reduction gear, then to the drive shaft and the rocker arm. The machine can rotate rope with the help of controller. In 2010 Jin Jiayi invented an automatic rope machine. The patent number is 201010577281[5]. The machine is consists of two rocker arms and a rocking rope. The driving device includes power supply, control circuit, motor and rotating shaft. The machine automatically rotates rope. The common features of the rope skipping equipment mentioned above are the use of motor drive. But there are some disadvantages in using it. That electric drives rope skipping equipment can make it difficult to move to right place. Especially when it rains, or snows, or blows. The motor drive equipment needs technical personnel to maintain. The advantage of hand skipping rope equipment is that single operator can shake it. The elder or children can shaking rope. At the same time it can automatic count, which bring more entertaining. Six casters are installed under the rope skipping machine. So it be pushed to the appropriate situation to skip. Rope radius is suitable, not easy to stumble. The span of the rope skipping machine can be adjusted, which can adapt different numbers to skip.
**Principle Design**

The design of the rope skipping machine is shown in figure 1. Through a chain the count handle 2 passes the motion to the shaft 6. The shaft 6 passes the motion to the right transfer circle 8 through the chain. So the left and right circle will rotate at the same time. A rope is tied on the same side of the two circle. The axis of the circle and rope are tied on one same plane. Adjust rope tightness to make the rope wipe the ground.

![Image of Hand skipping rope equipment](image)

1. brake truckle 2. count handle 3. wheel 3 4. wheel 4 5. bearing seat 6. transmission shaft 7. wheel 7 8. wheel 8 9. right circle 10. rubber string 11. left circle

**Figure 1. Hand skipping rope equipment.**

**Transmission Design**

The rope skipping machine runs outdoors over a long period of time. Belt drive will be eroded by wind and rain. This transmission performs instability, so it is not suitable for belt drive. Chain drive has no elastic sliding. The average ratio can be kept accurate. It has no use for big tension. Chain drive is preferably for the machine. The left and right circle will rotate at the same time when the handle 2 is handed. As shown in figure 1.

\[
\frac{n_2}{n_6} = \frac{Z_{\text{wheel3}}}{Z_{\text{wheel4}}} \tag{3}
\]

\[
\frac{n_6}{n_9} = \frac{Z_{\text{wheel7}}}{Z_{\text{wheel8}}} \tag{4}
\]

According to (3), (4) \( \frac{n_2}{n_9} = \frac{Z_{\text{wheel3}}}{Z_{\text{wheel4}}} \times \frac{Z_{\text{wheel7}}}{Z_{\text{wheel8}}} \)

When the teeth of the four chain wheel are equal, \( \frac{n_2}{n_9} = 1 \), the left and right circle will synchronous rotate[6].

**Ground Installation**

Upright column is fix on the ground with the help of anchor bolt installed in cement foundation. The advantage is that the column is firm and the performance is stable, but the disadvantage is the distance is not adjustable, and it is not suitable to changes in the number of people. It is difficult to move the machine from wind, rain and snow weather. So that fix on the ground design is unsuitable. As shown in Figure 1, brake casters is installed under each column. Unlock the brakes and push the rope skipping machine to the right position. Step on the brakes, the machine stands on the ground stably.
Counting

Now there are two kinds of counting method, electronic and mechanical. The advantages of an electronic counter are accurate measurement, simple operation, and easy to read. The shortage is that the counter needs electricity and it is inconvenient to use outside. The mechanical counter does not need electricity, and it is accurate and convenient to observe. Press the reset button, the number of the three gears is all 0, that is, the counter is zero.

Design and Analysis

Circle Design

Shake handle 2, circle will drive rope to rotate. The top should be above the head, and the bottom should wipe the ground. The height of an adult is usually between 1600 and 1800mm. The jumping height usually is below 300mm. The diameter of the large circle is 2100mm. In consideration of a person with strong ability, increase the circle diameter by 100mm. So the diameter is 2200mm. When the circle is assembled, the lowest point of the circle is 150mm distance from the ground, as shown in Figure 2. The spoke in the middle of the circle is made of stainless steel, which wide is 30×40 mm and thick is 1mm. The spoke and the ring is riveted firmly first. Then the spoke and the circle is welded by TIG welding. So rotating circle does not hurt the onlookers.

![Figure 2. Turning mechanism.](image)

1. Count handle 2. turning circle 3. spoke

Force Analysis

When shaking the machine, without installing the rope, the centrifugal force will balance because of the symmetric structures. When the rope is installed, balance is broken. The rope will produce centrifugal force when it turns. Shown in figure 3, centrifugal force $F_{\omega} = \omega^2 rm$, $F_\theta = \omega^2 rm \sin \theta, F_\omega = \omega^2 rm \cos \theta$

$\omega$: angular velocity, $r$: radius of gyration, $m$: The quality of the rope. The diameter of the rope skipping is 20 mm. When the span is 3 meters, the rope mass is 1.13kg. After testing, $\omega=0.5\text{r/s}$ is rather better for circle rotating. When the rope rotate to the highest point, $F_{\text{power}} = \sum F_{\text{friction}} + F_{\text{person}} = 0$. The centrifugal force reaches the maximum in horizontal direction, $F_{\text{max}} = 12.26\text{N}$. [7];
Maximum static friction force $F_f = Mgf$, $M$: quality of the rope skipping machine, $f$: Friction coefficient. Modeling analysis, The quality of the rope skipping machine is 62kg. The friction $f$ takes 0.5. The maximum static friction force $F_f = 62 \times 9.8 \times 0.5 = 303.8N$.

The rate of the maximum static friction and the centrifugal force of the rope

$$\frac{F_f}{F_{max}} = \frac{303.8}{12.26} = 24.78$$

So the enough static friction can be produced to balance the centrifugal force of the rope. Rope skipping machine will not move back and forth when the rope is rotating.

When $\theta = 90^\circ$ the centrifugal force is opposite to the direction of gravity $F_n = \omega^2 rm = 12.26N$. It's far less than the weight of the machine 612.5N. The rope skipping machine won't jump up and down.

Simulation Study

The calculation of the force is relatively simple when shaking the rope skipping machine with a constant speed. When shaking with change speed. The computational model becomes complicated. Computer simulation is more simple than manual calculation. To test the reliability of the simulation. Set a segment of acceleration close to 0, that is, close to uniform motion. Compare with the 4.1 results. Using INVENTOR software to simulate the motion. Adding motion constraints and motion pair, to motion parts. For example, a revolving motion pair is added to the center axis of the circle and the shaft sleeve. A rotary pair is added between the drive shaft and the bearing seat, and then the material properties are added. As shown in figure 4, three forms of variable speed motion are performed in one second. The allocation is as follows: 0 to 0.46 seconds of acceleration motion speed is increased from 100 deg/s to 160 deg/s, from 0.46 to 0.85 seconds to 175 deg/s, speed is increased from 175 deg/s to 190 deg/s within 0.85 to 1 second. Simulation results are shown Fig.4[8]. The corresponding force is shown in figure 5.
Shown in figure 5. Turning pair of The circle center has the greatest slope in 0 ~ 0. 46 seconds. And then the force comes from the centrifugal force. The force reached 60 N. So in order to avoid vibration, acceleration should not be too large. The slope of the middle section is the smallest section, near uniform motion. The force of the handle rotate pair is 11. 8 N. Close to that result of centrifugal force calculation shown in fig. 3. The simulation results have high reliability.

Summary
The rope skipping machine uses a single rocking handle. The movement passes through the chain wheel to the drive shaft and then to the chain drive, which cause synchronous rotation of the left and right circles. That rubber band keep large radian lead to not easy to stumble. Suitable for multiple people skipping at the same time. The diameter of the circle is 2100mm. Jumper won't touch the rubber band, also ensure onlookers are not hurt. The impact force of the rope skipping machine is simulated. Different acceleration outputs different forces. It brings convenience to study the sports. The greater the rotational acceleration is, the greater the force of the pair is, the greater the vibration is. The theoretical calculation of uniform centrifugal force is 12. 26N, which close to the simulation results. The simulation results have high reliability. This paper does not study the influence of the length of the drive shaft on the stability of the machine. This needs to be further studied in the future.

Acknowledgement
This research on Hand Skipping Rope Equipment was financially supported by Tianmen Vocational College. So I express my sincere gratitude for this. Also I express my sincere gratitude to all friends who care about and support the research.

Reference
