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The influence of different friction methods on curling

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Abstract: With the Beijing Winter Olympics, curling has become one of the big hits. To research, professional curlers will brush ice at 40 ° - 60 °, because the curling brush is a universal head when the force and the direction are fixed, changing the curling deceleration movement. This work aims to use Solidworks modeling, Unity virtual simulation, mathematical regression statistical prediction, and MATLAB data visualization to find the most suitable gimbal pole angle under the integration of the sports and physics, to make curling adjustable and provide a reference for improving its competitive level. The conclusion represents the gimbal pole angle is 54.7°, and the angular acceleration is 17°rad/s², which slows down the curling deceleration and has a longer relative displacement. At 60.1°, the angular acceleration is 31°rad/s², relative displacement is the shortest. So as to help athletes formulate real-time strategies, and also promote curling to be better popularize and theoretical.

Keywords: curling, friction, mechanics, geostatics.

1. Introduction

We know that professional curling athletes will choose the ice brush with a sharp angle of 40° - 60° range through the investigation of professional curling coaches. Under the condition of the same pressure and direction, the different angles of the curling brush and its universal head will change the curling's speed or slow down the deceleration movement after rubbing the ice surface. Figures 1 and 2 show the object of this project---curling and curling brushes.

This experiment aims to find the most suitable universal angle to adapt to different situations in the curling field in the context of the integration of the Beijing Winter Olympics research and sports physics department. At the Beijing Winter Olympics, Olympic athletes showed remarkable achievements and tireless Olympic spirit. In these Winter Olympics, the venue team has gradually upgraded, and curling has become one of the most popular sports in these Winter Olympics. However, the current lack of research on curly materials and ice surfaces in the field of science, as well as the different methods of friction of the forces of the curling brush, lead to different states of ripple motion. The ripple can be approximated as a cylindrical rigid body, the bending movement on the ice surface can be considered the typical movement of the rigid body, and the sliding and spiraling contain different mechanical principles. Curling will obtain different angular and linear accelerations to adjust the curling movement to help athletes adjust their strategies and scores in real time when the curling brush and the angle of the ice rubbing force are determined. (The direction of acceleration after the curling brush rubs against the ice surface is the opposite direction of the curling movement, and its role is to slow down the curling movement speed rather than increase it.)

Deduce from this; we can adjust the curling movement so that curling can obtain different angular and linear accelerations to help athletes adjust their strategies and improve their scores in real time. And we will help curling athletes understand the physical principles of curling and formulate strategies both in their training and match. Provide Not only professional athletes reference for continuously improving their competitive level in different situations on the field but also help ordinary people love curling. Curling will be better popularized and promoted in China and the world (Figure 1 and Figure 2).

Figure 1. Original overall system of curling brush and curling.

Figure 2. Curling track (taken at the time of the experiment).

2. Research problem

The physical model analysis of the curling brush as a whole, as well as the influence of different friction methods of athletes on the motion state of curling itself, to carry out data statistics, find the most suitable curling brush and universal head plane angle in two extreme cases (slowest deceleration, fastest deceleration), and finally applied to the actual training of curling.

3. Research purpose

With the Beijing Winter Olympic Games holding, the athletes have shown impressive achievements and unremitting Olympic spirit. In this Winter Olympic Games, the venue equipment is gradually updated, and curling has become one of the hottest events in this Winter Olympic Games. However, there is currently a lack of research in the scientific field on the curling material and the ice surface, as well as the different ways of friction of the curling brush force, resulting in other curling movement states.

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Curling can be approximated as a cylindrical rigid body, curling on the ice surface of the movement can be seen as a typical authoritarian body movement, and gliding and spiraling all contain different mechanical principles. After reading about 60 physical and sports literature on curling at home and abroad, it was concluded that there are studies on curling and friction as keywords at home and overseas, mainly including the following aspects: curling spin, different friction directions, stagnant adhesion analysis with the ice surface, and linear regression model analysis of curling rotation angle. These phenomena show that the scientific community has been paying much attention to the project. Still, there is a lack of scientific research projects on different friction methods and the material as research objects. Therefore, this research project intends to conduct physical analysis from different angles and force things and then, based on the theory of rigid body angular momentum rotation, strict body translation, frictional force work, etc., through experiments and data analysis, to provide athletes with training suggestions for effectively wiping ice surface, and provide a specific theoretical basis for the improvement of their sports performance.

4. Assumptions

The angle between the curling brush and the ice surface, due to the construction of the curling brush itself, the universal head is not close to the ground, the concave and convex structure of the silicone makes the angle in the case of the curling brush head not locked, the pitch is measured and investigated by calculation The minimum is 41.3 °, and the maximum grade is 60.7 °. This practical curling exercise involves movement in two situations – linear motion and rigid body translation (involving angular momentum). The friction coefficient of the ice surface after friction and the curling end speed is calculated by the formula, and the influence of temperature on the deceleration movement of curling is excluded. Through data analysis, it is concluded that assuming that the angle of the curling brush is 55 °, the friction of the curling brush on the ice surface can minimize the friction coefficient of the ice surface, reduce the friction, slow down the curling, and have the most extended movement displacement in the same time interval, assuming that the angle is 60 °, the conflict of the curling brush on the ice surface maximizes the friction coefficient of the ice surface, increases the friction, makes the curling decelerate most rapidly. The movement displacement is shortest in the same time interval.

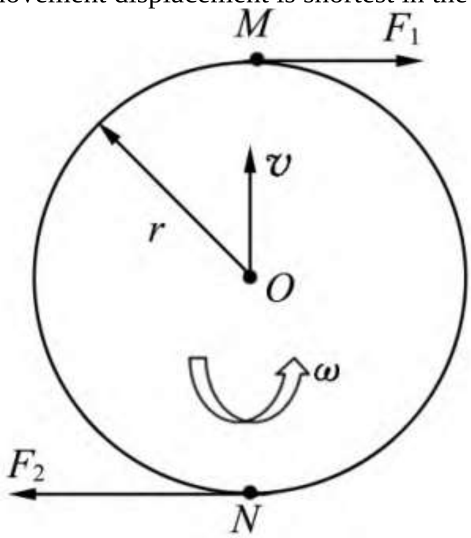


Figure 3. Force analysis of curling rotation (when the moment rotates counterclockwise).

5. Derivation of materials and theoretical knowledge

Curling originated in Scotland in the 1st century and was listed as an official Winter Olympics sport in 1998. Curling, as one of the sports with high precision in calculating data and game scores, is known as "ice chess". The curling raw materials used in the official competition are derived from Scotland's micafree high-density proto-mountain granite, which is highly precise and therefore prohibitive—high precision, curling weight of 19.96kg, diameter of 29.19cm, thickness of 11.43cm. The bottom of the curling is a curved and hollow depression surface, and the contact surface with the ice surface is only a thin annular surface with a diameter of 12.5cm and a width of 3-5mm. When curling comes into contact with the ice surface, a water film is formed due to the temperature difference, which increases the ice surface's smoothness and reduces friction. At the same time, the curling brush rubs against the ice surface, which will melt the ice surface and form different ice surface sticky forces, reducing the ice surface's friction coefficient and increasing the ice surface's smoothness. [1,2]. Figure 3 shows the force analysis of curling rotation (when the moment rotates counterclockwise) Curling itself moves on the ice, sliding close to perfectly into the base camp by bypassing the opponent's obstacle pot. Therefore, brushing ice can not only make the curling spiral farther into the ground but also control the forward trajectory of the curling.

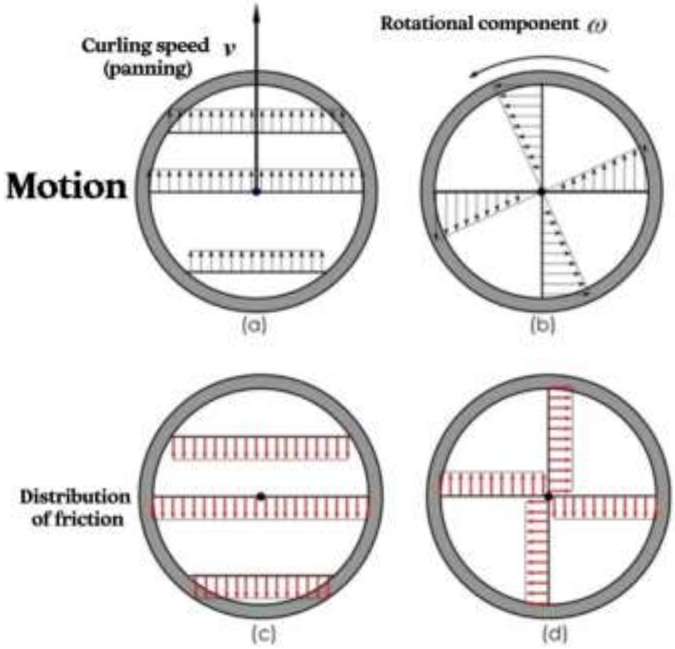
By investigating the specific rules of curling competitions, the coefficient of friction on the ice surface is about 0.0126-0.0127. Athletes with good ice polishing techniques can slow down the movement of deceleration curling. Extraordinary athletes can rub ice surfaces for up to 30.275m in 10s. The literature reports that different friction directions impact curling collision and spiral movement.

Curling can be approximated as a cylindrical rigid body, and its movement on the ice surface can be seen as a typical authoritarian body movement. Gliding, rotation, and collision all contain rich mechanical principles. The relevant physical theories and formulas used to analyze the curling spiral motion (Figure 4):

In Figure 4(e), F, R is associated with the speed direction, so friction slows the curling in this type of motion.

Figure 4(b) is a rotational-only case, and Figure 4(d) is the corresponding distributed friction force. As long as there is relative movement, there is friction, and according to the Coulomb model, the conflict is independent of the relative speed (however, in more accurate models, especially for high speeds, friction is definitely related to the size of the rate [3].

The distributed friction on the left half of the bottom of the pot can be reduced to the potent force $F\omega L$, and the distributed friction on the right half can be reduced to the concentrated force FR, as shown in Figure 4(f). According to the symmetry, there is $F\omega L = F\omega R$ For this sport, the curling center is not moving; $F\omega L$ and $F\omega R$ form a force couple, and the steering of the force couple is the opposite of the rotational angular velocity, so the rotation gradually slows down [4].



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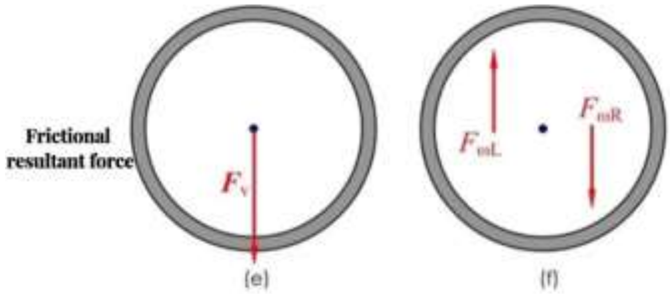

Figure 4. Force analysis of curling rotation (torque vs. angular momentum).

Angular acceleration and displacement formula： $\Delta\theta = \omega\theta + \frac{1}{2}\alpha t^2$

Angular momentum theorem for rigid bodies: $\int_0^t Mdt = L2 - L1 = r \times dI$

Conservation of momentum theorem: $F = frac\{dp\}\{dt\}$

Sliding friction formula: $F = \mu \times Fn$

Accumulation of energy(F) **in space:** $A = \int_{a\ (L)}^{b} F \cdot dr = \int_{a\ (L)}^{b} (Fxdx + Fydy + Fzdz)$ (Energy consumed by friction)

Momentum theorem: $\sum miv1 - \sum mivi0 = \sum \int_{t0}^{t} Fidt$

Kinetic energy analysis of deceleration movement (friction work) (beginning and end state): curling to do deceleration movement, friction to do negative work, provided to curling and ice surface can make the ice surface temperature rise, the ice surface at the bottom of the curling to form a layer of water film, reduce the friction coefficient between the surface of the ice and the ice surface, so that the distance of curling movement is longer.

Specific analysis of ice surface temperature and surface stagnant adhesion: Ice surface temperature rises with friction. The greater the relative velocity, the greater the viscosity of the ice surface at the solid-liquid junction. **F Hysteretic adhesion=** $\boldsymbol{\mu \cdot S \cdot \frac{dv}{dr}}$, the greater the relative movement speed of curling, the greater the lateral velocity gradient of curling, and the faster the actual sliding speed of curling [5].

Curling edge point velocity formula: $vP = v_{1（2）} + \omega R$

6. Research protocols and data analysis methods

(1) Theoretical analysis of physical plane force analysis diagram.

(2) Physical modeling of curling, athletes, and curling brushes (Solidworks), and the built model is applied to the simulation of the curling track built by Unity simulation software, and the minimum and maximum angle angles of curling deceleration movement acceleration are calculated. (Calculated value: 53.6° /59.8°) (Figure 5)

(3) Carry out specific experiments to measure the angular velocity deflection size, displacement size and deflection angle, and movement time of curling movement (excluding the influence of temperature changes on the ice surface of the work)

(4) The statistical regression model and linear fitting are used to fit the data for the data processing of ordered categorical variables, and the theoretical derivation calculation is carried out to analyze the number of variations, and the relationship between the prediction results is modeled to calculate the angle and angular acceleration that are most suitable for control [6].

(5) Use Matlab software to visualize the data, represent the vector and matrix with graphics, and annotate light and chromaticity processing of the pictures to fit the curling process and the different deflection angles in the experiment.

(6) Put forward physical suggestions for the friction angle of curling, and invite professional curlers from the Beijing team to implement the experimental conclusions and verify their effectiveness.

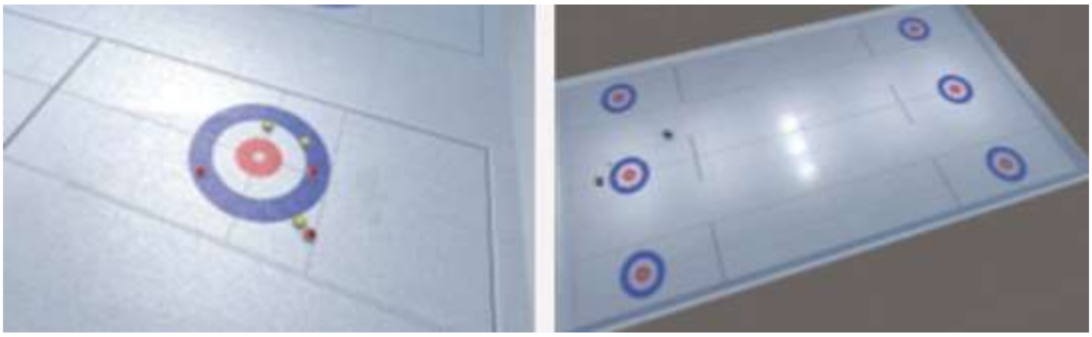

Figure 5. A virtual curling track is simulated by Unity software (Source: Harbin Institute of Technology) [7].

7. X-Y coordinate deceleration movement (invariant of this experiment: curling mass is 19.96kg, the friction coefficient of ice surface without friction is 0.0127 under general conditions, curlers rub the ice surface in the same direction and the force control applied to the curling brush is equal)

The simulated scene of this experiment is in the range of 40-60° of the professional universal head angle, through literature research, it is found that the rotation of curling angle momentum is calculated and calculated at 1.5° angle data interval, so this experiment also draws on the data and calculates the angle difference of 1.5° as the data interval. (Figure 6) This experiment recorded three times of time data: in 1. the time when the curling was from the throwing point to the avant-garde line (Figure 8) 2. The time when the ice surface was rubbed from the avant-garde line so that the curling ran for 11 meters and stopped the friction 3. The time point when the friction is stopped until the time when the curling stops moving. The difference between the motion displacement and the curling at rest is calculated through three different time intervals, the acceleration and average velocity of curling are analyzed in the beginning-end state, and the friction coefficient before and after friction ice, respectively, respectively, are calculated. Using Newton's second law and kinetic energy theorem, the influence of friction on the curling motion trajectory caused by curling brush friction on the ice surface is calculated. The work of coiling with friction on curling is calculated. It is obtained that in the x-y plane when the angle between the curling brush and the universal head is 54.7° , the friction coefficient of the ice surface is the smallest, and the curling will move the most extended displacement in the same time interval; When the angle between the curling brush and the universal head is 60.1° , the friction coefficient of the ice surface is the largest, and the curling will move the shortest displacement in the same time interval. (Figure 7)

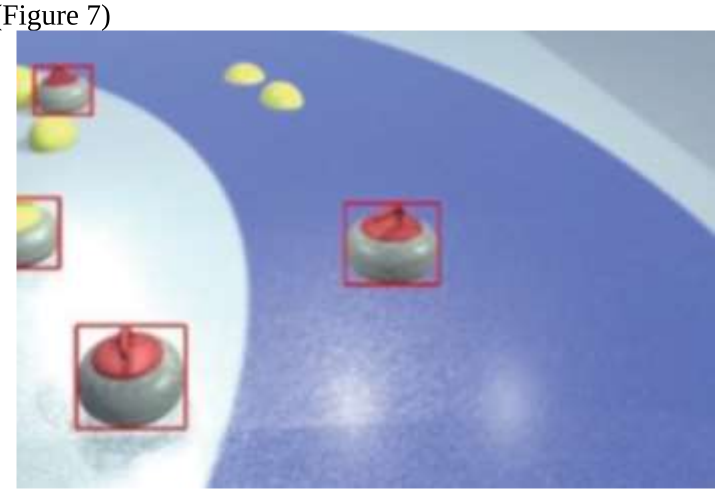

Figure 6. Simulating curling track scenarios.

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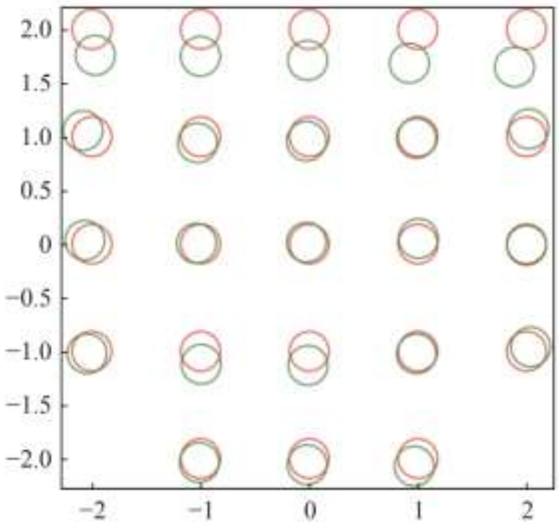

Figure 7. Time displacement fit state plot for two experimental data.

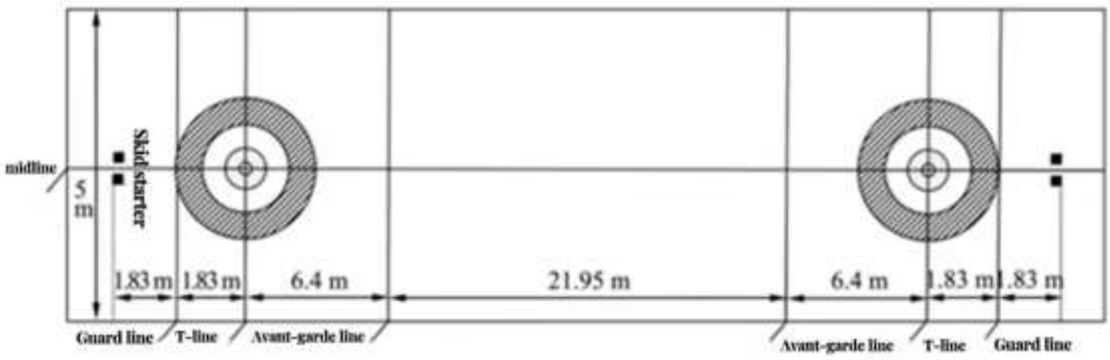

Figure 8. Track specifications in curling.

$$2ax = vt^2 - v0^2 = 2 \times 1.8017 \times 17.41,$$

$$\int_0^t Mdt = L2 - L1 = 19.96kg \times 17.41 \times 12.51$$

$$A = \int_{a(L)}^{b} F \cdot dr = \int_{a(L)}^{b} (Fxdx + Fydy + Fzdz) = 17.41^2 \times 10.23^2 \ldots$$

$$\text{F Hysteretic adhesion} = \mu \cdot S \cdot \frac{dv}{dr} = 0.0126 \times 20.05 \int_r^v 15.98$$

$$Q = f\Delta x = 10.05 \times (17.41 - 8.66)$$

And calculate 30 sets of data based on the above calculation method.

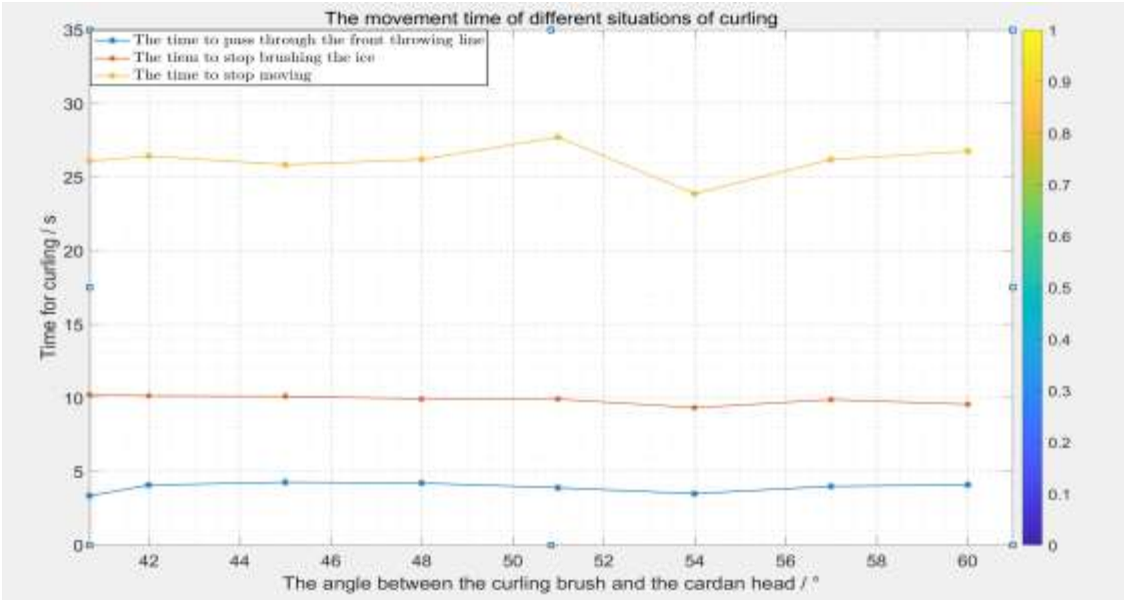

Figure 9. Time 1: Curling from the throwing point to the front throw line.

According to the time 1 chart (Figure 9), 16 (2 times and 1 time according to statistics) measurements in this period of time, curlers keep holding the curling handle before the curling passes through the front throwing line in the professional competition. They may have different manual throwing forces, while curling’s relative speed difference in 16 experiments is less than 1m/s, a very small difference. The subsequent friction of the ice surface at curling exercise in this period has a minor impact. However, it is worth paying attention to. Thus, the ice surface is rubbed, the friction coefficient of the ice surface is unchanged, and the granite is not in complete contact with the ice surface; the friction must be ignored. Thus, curling on the x-y axis is accelerated. Curling does not rotate during this time interval, and we only need to consider Newton's first law of motion and kinetic energy theorem in calculating the increase in curling speed and prove that the kinetic energy of curling is increasing [8,9] (Figure 10).

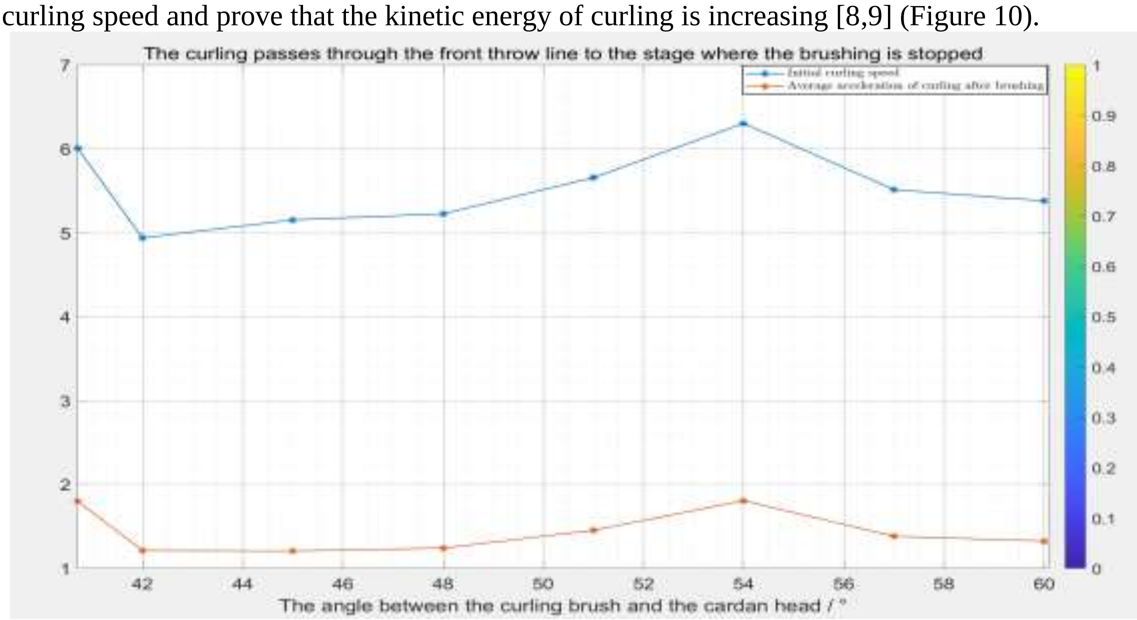

Figure 10. Time 2: The time from the forward throwing line to the time when the friction is stopped when the curling movement is 11 meters in the x-y axis (Figure 10).

Through the on-site measurement of the angle of the universal head against the ground and the curling brush handle, the smallest angle is 40.7 ° , (Figure 11) through literature research, and interviews with the Curling Coach of the Beijing Team, it is known that there are two ways to hold the curling brush: leaning over and grabbing the curling brush with both hands, the human center of gravity is lowered, and the navel is facing the curling brush handle. Hands flex the arms, and the brush handle is under more pressure. Because the friction coefficient before the ice surface is rubbed is the same, due to the transmutability of the force, the greater the pressure on the brush handle, the greater the pressure on the ice surface, the larger the N, the greater the F, the greater the friction force, the greater the friction force, then after the ice surface friction, the ice friction coefficient becomes smaller, and the ice surface melts and the stagnant adhesion increases, so that the deceleration relative to the speed of motion becomes slower, which is conducive to moving a long distance. (Figure 12) However, according to the chart, when the angle is 54.7 ° , the force of the curling brush belongs to the second situation of the curling competition rubbing the ice surface, grasping the curling brush vertically and tilting slightly, professional athletes in this case, it is conducive to finding the direction, the curling brush handle is higher, the visible range is wider [10].

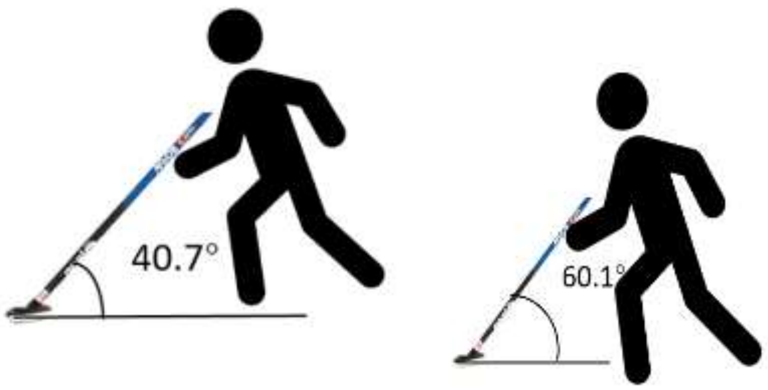

Figure 11. Track specifications in curling.

During the time interval between curling through the front throwing line and the curler stops brushing the ice, the curling is in a state of deceleration movement, and due to the ice brushing, the friction coefficient of the ice surface can be reduced and the deceleration movement of curling can be slowed down. The ice surface temperature rises with friction. The greater the relative velocity, the greater the viscosity of the ice surface at the solid-liquid junction. F Hysteretic adhesion= $\mu \cdot S \cdot \frac{dv}{dr}$, the greater the relative movement speed of curling, the greater the lateral velocity gradient of curling, and the faster the actual sliding speed of curling. By $\Delta\theta = \omega 0 + \frac{1}{2}\alpha t^2$ when the curling brush angle is 54.37° , the acceleration of curling motion on x-y coordinates is the smallest, and the slowing effect of curling deceleration is minimal, which is conducive to curling athletes adjusting their tactics and making curling exercise longer distances. By analyzing the chart, bending at 60° , curling deceleration has the most significant acceleration, and the most extended movement time through 11 meters is beneficial to curlers to make curling shorter distances.

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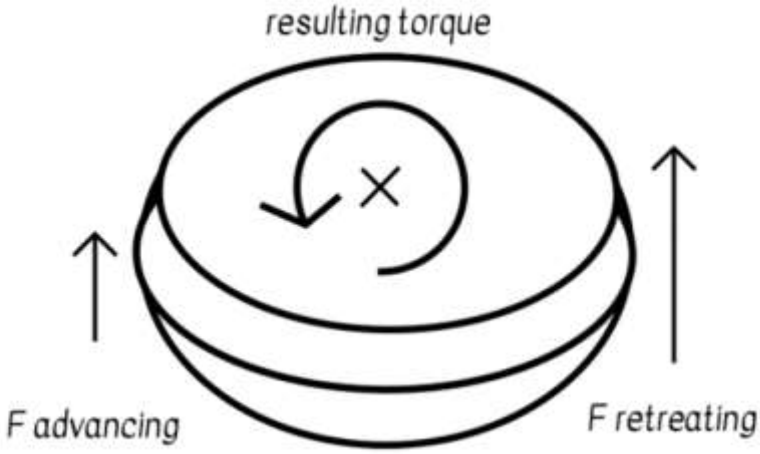

Figure 12. Force analysis during curling rotation.

Through the kinetic energy theorem, Newton's first law of motion, and the formula of friction force, it is concluded that after the curling brush stops rubbing the ice surface, the stagnant viscosity of the ice surface decreases and the speed of curling decreases relative to the friction. However, the law is still similar to the above two cases, at an angle of 54.7° the curling acceleration is smaller, and curling in the same time interval is the most extended movement displacement. At a rise of 57.1-60.1°, the acceleration of curling is more significant, the kinetic energy of curling is reduced even more, and the movement time displacement of curling in the same time interval is the shortest (Figure 13).

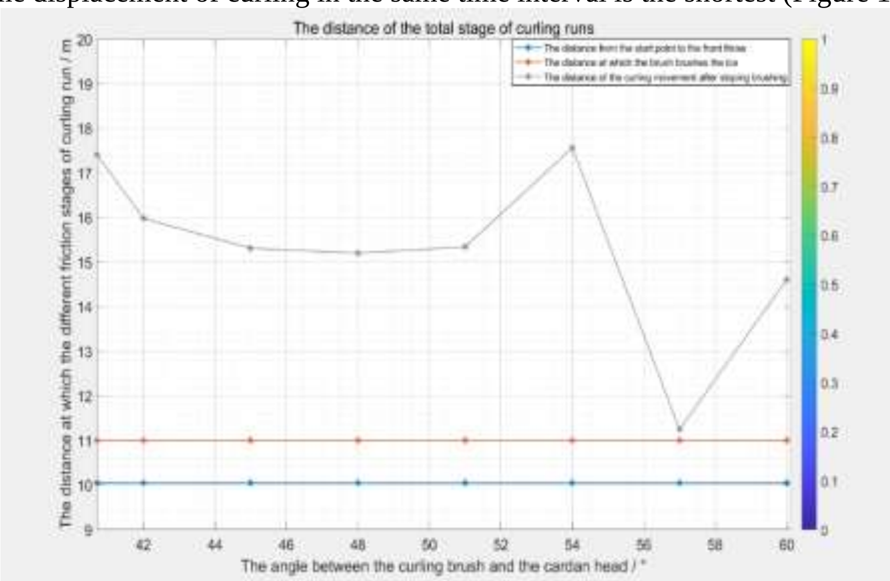

Figure 13. Time 3: The curling brush stops brushing the ice until the curling stops (Figure 13).

7.1. Rigid body screw-in motion

Curling should rotate at a sufficiently large angular velocity. The greater the angular momentum, the closer the dividing line $x = -v/\omega$ is to the y-axis, and the greater the friction area in the same direction as the curling speed. If w is so tiny that v/ω is greater than the radius of curling, acceleration is unlikely.

The greater the difference in friction factors between the two sides of the dividing line $x = -v/\omega$, the more likely it is. If there is no difference in friction factors between the two sides, acceleration is unlikely. Athletes can achieve a difference in friction factor between the two sides by rubbing ice on one side (full rubbing is still deceleration).

As long as there is relative movement, there is friction, and according to the Coulomb model, conflict is independent of relative velocity.

The lateral velocity component corresponds to the lateral friction force, but because the lateral part above and below the x-axis is symmetrical, the lateral friction force is also 0 due to the anti-symmetry of the x-axis.

The longitudinal component of the distributed friction force is related to the longitudinal velocity component. At the point of the polar coordinate (r, q), the longitudinal velocity component $vy = V - \omega r cos\theta = v - \omega(-x) = v + \omega x$. (Figure 14) which is shown below determines the momentum theorem of curling angular spin.

Through data analysis and chart calculations: curling will rotate at least 4Π from the starting line to the curling stationery when the curling brush and the cardan gimbal pole angle is 54.7°, the minimum angular acceleration is 17rad/s², the friction work is the smallest, and the kinetic energy is reduced. When the angle between the curling brush and the gimbal pole is 60.1°, the angular acceleration is up to 31 rad/s², the friction work is the greatest, and the kinetic energy is reduced.

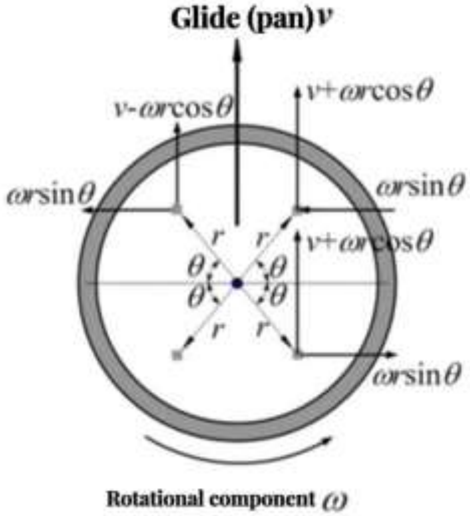

Figure 14. Curling angular momentum analysis.

7.2. Curling brush friction coefficient of the ice surface

Through literature research, looking for ice surface-related data, it is concluded that the friction coefficient of the ice surface when it is not friction is between 0.0126-0.0127, and by rubbing the ice surface, friction heating will make the ice surface melt, and a layer of water film will be generated on the surface of the curling so that the stagnant viscosity is increased, thereby increasing the relative speed of the ice surface and relatively slowing down the deceleration movement. According to the sliding friction formula $F = \mu N$, the larger the N, the greater the friction force. μ also decreases as the friction increases. Thus, the coefficient of friction decreases when the curler rubs the ice surface with passion (at an angle of 54.7°), resulting in a more extended displacement of the curling movement in the same time interval. Conversely, when the curler reduces the force against the ice surface, the friction coefficient increases relatively as it does when rubbing the ice surface so that the curling moves closer to the displacement in the same time interval.

7.3. Exclude the influence of temperature

According to the frictional heat generation formula $Q = f\Delta t$, the greater the friction, the more heat is generated by the curling brush and the ice surface, and the ice surface temperature rises and melts, creating a "water film" on the surface of the curling. In the specific experiment, the temperature difference between the curling brush before wiping the ice is t before the ice rub - t after the ice wipe =

3.1° C - 7.8° C = -4.7° C. The temperature of the ice surface varies little due to the influence of thermal expansion and contraction and the temperature of the surrounding environment: from -7.8° C to -6.6° C, but when the ice surface is in close contact with the curling brush, the temperature between the two is higher than 0° C, the ice surface melts and forms a "water film" attached to the curling surface [11].

8. Research result

In the same force size and force direction, the friction temperature of the ice surface heating does not affect the curling exercise. When the curling brush and the Cardan head have an angular acceleration of 17° rad/s^2 at an angle of 54.7° , the curling deceleration movement is minimized and the movement distance is longer at the same time. In contrast, at an angle of 60.1° , the angular acceleration is 31° rad/s^2 , with the most significant acceleration, maximizing the curling deceleration movement and minimizing the distance.

9. Discussion

Feasibility and significance of this study:

Since professional athletes cannot precisely control the force size during the competition, but the angle clearly indicates the path of curling, the force size can be prevented when the hook is this value. It is conducive to guiding the curling and the rotation angle when flat.

Establish and verify theories:

When the experiment was completed, he contacted Mr. Dong Jun, director of the Beijing Sports Committee, and invited professional curlers to implement the experimental results. Compared with the results of the calculated measurements, only a tiny error was obtained. The athlete teacher evaluated the experiment to help them grasp the displacement values of curling exercises, resulting in higher scores.

Application Value:

In terms of competition, the results of this experiment can help curling athletes understand the physical principles of curling sports, formulate strategies in real time under different situations on the field, provide a reference for continuously improving their competitive level, and also help to wind to be better popularized and promoted in China and even the world, so that the whole people understand and love curling. In addition, the research angle of this project is novel, which provides a theoretical basis and ideas for the future development of physics and sports science to form an interdisciplinary integration development.

Deficiencies of the study:

Deficiencies in this study.

(1) Because the temperature difference between the ice surface temperature and friction is within 0.5 degrees, the influence of temperature on the thick viscosity of the ice surface is ignored, which is not rigorous enough.

(2) The default athlete in this experiment is to rub the ice surface in the same direction, but in fact, the athlete will choose different paths and places to wipe the ice surface so that the curling is put into the base.

(3) This experiment defaults to the equal amount of pressure the athletes apply to the curling brush. Thus, the experimental equipment is relatively simple, and extensive experiments are not supported by highly accurate professional equipment, so the results are not accurate enough [12].

(4) This study does not consider all perspectives, but only finds the professional attitude of athletes and uses professional sports knowledge to help carry out scientific research.

10. Conclusion

When the angle between the curling brush and the gimbal pole is 54.7° , the friction coefficient of the ice surface is the smallest, and the curling will move the most extended displacement in the same time interval.

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When the angle between the curling brush and the gimbal pole is 60.1°, the friction coefficient of the ice surface is the largest, and the curling will move the shortest displacement in the same time interval.

11. Application and outlook

Innovations of the project:

(1) The topic of the frontier is a cross-cutting hot topic about the current stage of physics and sports.

(2) Analysis of object innovation: The previous related research is based on curling as the subject of scientific research (including the physical theory and specific experiments behind it), but this topic is based on winding as the object of experimental verification, the primary analysis object is athletes and curling brushes, and the study is the impact of curling brushes on curling sports.

(3) Research innovation, through a large number of literature research, found that there is still a lack of comparative study on curling itself; the theoretical investigation of Yangzhou University is about the direction of curling brush friction (but the main body of analysis is still curling), this research is to use specific experiments and theoretical analysis methods, two-way synchronous data processing, aimed at popularizing the national sport curling, and for curling athletes to improve their performance, real-time formulation of strategies to provide theoretical basis and foundation.

This experiment and research angle is applied to the analytical mechanics of the interdisciplinary disciplines of physics and sports, rigid body translation, etc., and provides a theoretical basis for professional curlers in professional fields such as sports competitions and formulates competition strategies in real-time on the principles of kinematics and improves their scores. The research is expected to promote the convergence of the two disciplines of physics and physical education and innovate from different perspectives. In addition, it helps to promote curling, so that everyone loves the sport and thinks about its physical principles in practice.

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Appendix 1

Raw data from the experiment

The angle between the curling brush and the ice surface	Initial curling speed	The time it takes for the curling to pass through the front throwing line	The moment to stop brushing the ice	The time at which curling stops moving	Front throwing wire	The distance at which the brush brushes the ice	Stop brushing the distance of the curling movement after brushing	The speed at which the curling passes through the front throw line	The initial speed of curling when not rubbing the ice	The amount of change in ice surface temperature before and after friction	The amount of change in temperature after the curling brush rubs the ice in front of the ice	Coefficient of ice friction	Average acceleration of curling after brushing
40.7	6.01	3.34	10.23	26.08	10.05	11	17.41	6.01	6.01	-6.6——-6.5	3.1——7.8 After contact with the ice-6.4	0.0126-0.0127	1.8017
42	4.9385	4.07	10.13	26.42	10.05	11	15.98	4.9385	4.9385	-6.6——-6.6	3.1——7.8 After contact with the ice-6.5	0.0126-0.0127	1.2134
45	5.1522	4.27	10.1	25.84	10.05	11	15.31	5.1522	5.1522	-6.6——-6.7	3.1——7.8 After contact with the ice-6.6	0.0126-0.0127	1.2066
48	5.2256	4.21	9.93	26.19	10.05	11	15.2	5.2256	5.2256	-6.6——-6.8	3.1——7.8 After contact with the ice-6.7	0.0126-0.0127	1.2412
51	5.6555	3.89	9.91	27.71	10.05	11	15.34	5.6555	5.6555	-6.6——-6.9	3.1——7.8 After contact with the ice-6.8	0.0126-0.0127	1.4538
54	6.3037	3.49	9.33	23.87	10.05	11	17.56	6.3037	6.3037	-6.6——-6.10	3.1——7.8 After contact with the ice-6.9	0.0126-0.0127	1.8062

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57	5.5137	3.99	9.88	26.19	10.05	11	11.25	5.5137	5.5137	-6.6——-6.11	3.1——7.8 After contact with the ice-6.10	0.0126 -0.0127	1.3819
60	5.3789	4.09	9.56	26.75	10.05	11	14.61	5.3789	5.3789	-6.6——-6.12	3.1——7.8 After contact with the ice-6.11	0.0126 -0.0127	1.3248

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