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Research Article

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Curling movement trajectory influence factor dynamic analysis and counter measurements

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ABSTRACT

Curling has been rapidly developed in the strong support of nation, and it gradually becomes a kind of newly-developed hot pot event. Though China curling gets rapidly development in a short time, it still faces some practical problems in developing. This paper applies biomechanics knowledge into analyzing curling influence factors. Considering athletes' delivery motion, ice wiping technique as well as team work affects the competition. By research, it designs simple program flow chart with indicator lamp flicker frequency to guide athlete training, in the hope that plays positive roles in assisting curling beginners and guiding athletes training as well as other aspects.

Key words: biomechanics, delivery motion, ice wiping technique, momentum conservation

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INTRODUCTION

With the development of social and the improvement of living standards, curling has gradually come into ordinary people's vision. In 2010, our country women curling team reached new heights in Vancouver Olympic Winter Games, they became world top team, and curling became more and more popular. However, curling mass foundation in our country is poorer; therefore scientific training is especially important to China curling development. While domestic current training mainly relies on experience to do training, it obviously doesn't work, so it is imperative to carry out scientific analysis of curling [1-3].

Curling pot body is a relative regular ampulla's, its sliding, rotating, colliding in ice surface all can be regarded as rigid rotation typical examples [4, 5]. In curling running process, athletes give it rotation, curling and rough ice surface friction force; wiping motion changed ice surface friction force and so on all are of great importance to curling movement trajectory. In curling movement process, it not only has forward translation, but also accompanies with some rotations, which causes curling making displacement in the lateral of forward direction, its motion trajectory is in arc not line [6-8]. The essence of curling runs in the ice surface is cylindrical rigid body mass center translation and rotation around mass center. In practical delivery application, experienced delivery athletes can give curling clockwise or anticlockwise angular speed and different linear initial speed with different tactics, so as let curling arrive at expected motion trajectory [9]. Scholar Denny.M in article "Curling rock dynamics", by experiment research comparative analysis, it found some forces that affected curling displacement deflection in movement process, and divided them into left-right asymmetric forces and fore-after asymmetric forces. While Mark R.A. Shegelski and other scholars by experiment verifying of left-right asymmetric force and fore-after asymmetric force, they found curling horizontal deflection movement mainly was affected by fore-after asymmetric force not left-right asymmetric force, the research results until now is still widely discussed but by far is relative universally accepted statement [10].

Therefore, define target as research curling movement distance influence factor, establish more rational physics model, and study ice wiping influences on curling trajectory these three aspects problems. Among them, it mainly utilizes some physics and mathematics knowledge to establish rational models, meanwhile carries out correlation analysis through network searching lots of curling data.

CURLING MOVEMENT TRAJECTORY INFLUENCE FACTOR MECHANICS ANALYSIS

This paper takes anticlockwise rotated curling as research target, makes analysis of curling movement trajectory.

Symbols explanation

m——Curling mass Unit: g
v——Curling instantaneous speed when it leaves from athletes' hand(initial speed) Unit: m/s
u——Ice surface dynamic friction coefficient
g——Gravity accelerated speed Unit: m^2/s
S——Curling total distance from leaving athlete hands to ending Unit: m
a——Curling average accelerated speed Unit: m^2/s

Curling dynamics analysis

Curling court ice surface is composed of lots of cobble like dewiness small particles that not smooth; the bottom of curling is a crooked and hollow concave plane, its contact surface with ice surface is a ring shape thin surface with diameter of 12.5cm, width only 3-5mm. On the condition that no artificial factors change ice surface friction coefficient, curling in proceeding process, affected by inertia, curling gravity center moves forward, the first half part of circular ring contact surface pressure acting on the ice surface is larger than the second half part pressure acting on the ice surface, positive pressure acting on the ice surface caused skin layer ice surface instantaneous melting, therefore curling bottom contact ring first half part friction force is smaller than the second part one, affected by ice surface unevenness, court inside and outside temperature differences as well as curling suffered different rotation and push force when athlete throws it out of hands these multiple factors, skin layer ice surface will accelerate melting, ice surface and curling contact surface form into a layer of quite thin liquid film. The film between curling and ice surface will generate an adhesive force; driven by curling rotation, the film will rotate together with curling, it will form a drag force opposite to rotational direction in the surrounding of contact surface that let curling first half part friction force become more small, so that for the most part, we can observe that in practical delivery process, anticlockwise rotating curling after a moment sliding, its movement trajectory will gradually appear an obvious left shifting . As Figure 1 show:

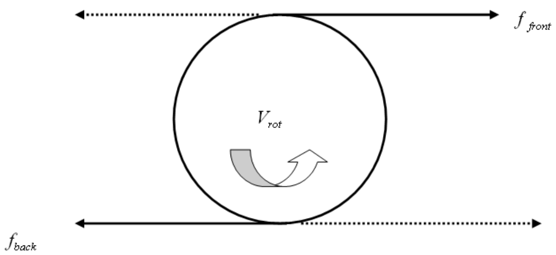

Figure 1: Anticlockwise rotating curling

In Figure 1, the dotted arrows respectively represent curling first half part contact surface and the second half part contact surface movement directions, solid arrow represents curling first half part contact surface suffered friction force f_{front} and second half part contact surface suffered friction force f_{back}, due to f_{back} larger than f_{front}, curling will appear leftward shifting phenomenon. Similarly, clockwise rotating curling movement trajectory will gradually show an obvious rightward shifting after sliding for a moment.

In whole movement process, curling is divided into linear movement and rotation two parts, so in exploring curling movement trajectory change process, we will respectively discuss different rotational linear speed and through mass center translational speed(in the paper just call straight-line speed for short) influences on shifting phenomenon.

By establishing rectangular plane coordinate system, it analyzes different situations straight-line speed and linear speed influences on curling deflection. At first, establish a round plane with curling sliding radius as radius, sliding radius is curling contact surface circular ring outside and curling mass center projection in round plane connecting line. Establish y axis in round plane with through curling mass center instantaneous linear speed V_{trans} direction, in plane y axis vertical direction to establish x axis. From this, we can divide round plane into 4 quadrants, and select one of them to make typical analysis, assume curling along anticlockwise direction rotation concrete speed direction as Figure 2 shows:

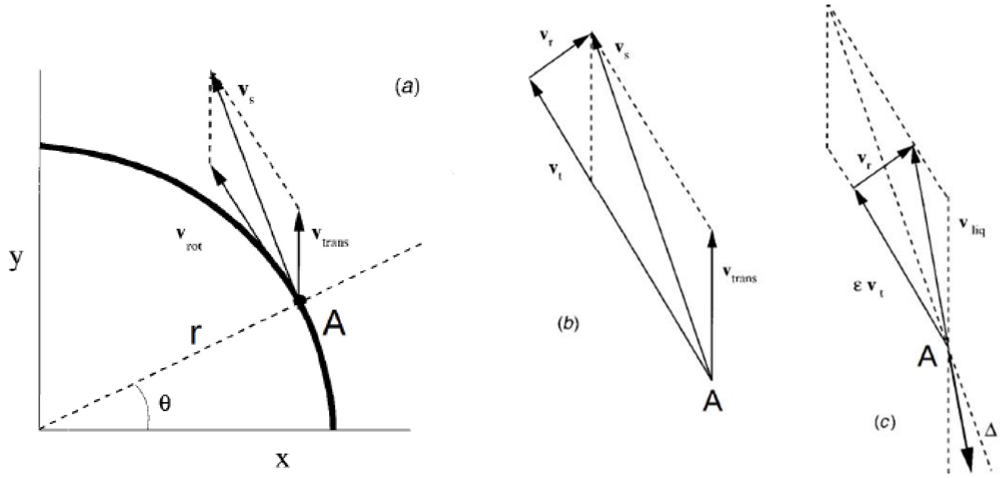

Figure 2: Curling rotating along anticlockwise status analysis

In Figure 2-a, random select curling contact ring point A, ω is curling angular speed, θ is x axis along y axis direction one included angle when curling rotates, from which $0 \leqslant \theta \leqslant \pi/2$ .The direction of y axis is the direction pass curling mass center linear instantaneous speed V_{trans}, establish x axis in the vertical y axis. V_{rot} is curling rotating instantaneous linear speed(V_{rot}=r× ω), V_{trans} is instantaneous linear speed through mass center, their joint speed can use Vs to express, then it has:

$$Vs = V_{rot} + V_{\text{trans}} \tag{1}$$

Among them, V_{trans} and V_{rot}, Vs all are curling speeds in solid ice surface, and Vs positions in x axis related θ angle.

In Figure 2-b, speed along tangent line V_{t} and speed along radius direction V_x form into joint force V_s, that is:

$$V_s = V_x + V_{\text{t}} \tag{2}$$

In Figure 2-c, we already knew point A one fix ice surface speed Vs, rotation linear speed V_{rot} and linear speed V_{trans}. Due to curling passes through liquid films, at that moment, it rotates quickest with curling connected upper surface, lower layer liquid film that close to ice surface will not rotate with curling but drawn to curling circular ring contact surface main tangent lines surrounding without being vertical to contact surface, V_t and V_r are speeds organized by solid ice surface along positive tangent direction and radius direction, V_{lip} is liquefying film joint speed , then it has:

$$V_{lip} = \varepsilon V_t + V_r \tag{3}$$

Among them, ε is a correlated angular coefficient($0 < \varepsilon < 1$), V_{lip} and Vs are not in the same direction, it exists a included angle, and curling in liquid film ice surface sliding speed V_{lip} is smaller than curling in solid ice surface sliding speed Vs, then it has:

$$V_{lip} = \varepsilon V_s \tag{4}$$

In Figure2-c, dotted line indication part is parallelogram, ΔF direction and speed V_s are not in one line , ΔF is V_{lip} direction opposite one acting force that is curling in liquid film ice surface rotational sliding generated friction force.
ε is a correlated angular coefficient , it exists in the range 0＜ε＜1, by consulting relative foreign documents, it finds out that ε value can be divided into 3 intervals, ε→0；0＜ε＜1；ε→1.Its time t correlated curling rotational linear speed duration trot and curling line sliding speed duration t_{trans} ratio $t_{\text{rot}}/t_{\text{trans}}$ is positive correlated to ε value. Then we can use ε value variable to discuss $t_{\text{rot}}/t_{\text{trans}}$, while $t_{\text{rot}}/t_{\text{trans}}$ ratio is positive correlated to V_{rot}/V_{trans} ratio, from which we can use ε value variable to discuss V_{rot}/V_{trans} ratio, further explore and discuss different V_{rot} and V_{trans} influences on curling.

When ε→0, $\varepsilon V_t \to 0$, then V_S along radius direction component speed V_r will also infinite get close to 0, at this time it will have no torque to slow down curling rotation, Mass center speed opposite joint force still exists; According to energy conservation, curling motion trajectory shows a gradually slowing line trajectory. Curling running in translational direction is a gradually slowing movement till ends in expected end point.

When 0＜ε＜1, contact ring point A exists one V_{lip} direction opposite joint force ΔF. At this time, it is not on the contrary with V_S direction, In curling rotation process, due to front ice surface pressure increases caused ice surface melting, makes front friction force become smaller and smaller, curling torque will also become smaller and smaller, force affects curling rotation will also become smaller and smaller, then at this time, curling rotation will last longer than linear movement that is $t_{\text{rot}} > t_{\text{trans}}$, while $V_{rot} > V_{\text{trans}}$ the point that we can obvious observe in practical curling, while due to curling rotation generated lateral displacement, especial in the final movement, we can see that curling movement trajectory has an obvious leftward deflection.

When ε≈1, $\varepsilon V_{\text{trans}} = V_{\text{trans}}$, while at this time $V_{lip} \approx V_S$, curling sliding process ice surface doesn't melt or just only a little melting that its rotation is very slow; at this time acting force on contact surface is on the contrary with ice surface force direction, it will has no change on torque; therefore when ε→1, then it has $V_{rot} \to V_{\text{trans}}$, Curling rotation and linear movement will almost simultaneously stop; Curling movement trajectory will get close to a line. Curling mass center lies in geometric center that is pot center, according to mechanics theorem of centroid movement, when curling suffered force through pot center, it forms into translation, the translation conforms to impulse theorem, and its impulse value is equal to momentum variable. If curling suffered momentum $P = \int F dt$ the momentum variable: $K = m \times \Delta V$ then it has:

$$F \times t = \Delta m \times V \tag{5}$$

Among them, P is the impulse that curling suffered when athlete pushes out it, F is curling suffered force, t is force acting time, m is curling mass, ΔV is curling running process speed variable. Its translation kinetic energy formula is:

$$E = m \times V^2 / 2 \tag{6}$$

Among them, E is translational kinetic energy, m is curling mass, V is curling running linear speed. Due to curling court ice surface has lots of different sizes and certain heights dewiness small protuberance; to achieve tactics requests, when athlete makes delivery out of hand, it often internal rotates or outside rotates handle, let curling rotate 2 to 3 weeks. In case ignoring ice surface friction force change situation, due to suffered eccentric force(not pass pot center force) influence, pot body has translation and turning, curling actually makes forward vertical rotational translation movement. As Figure 3 shows:

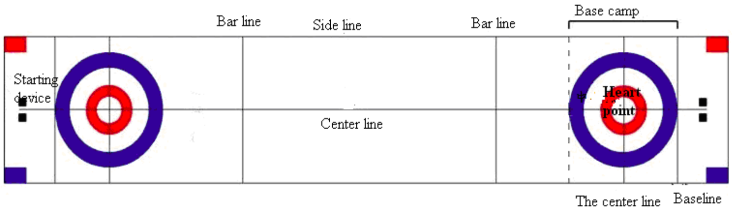

Figure 3: Curling movement process

When only discuss curling movement from leaving athlete hands to static such phase, and assume curling suffered friction force sizes and direction don't change.

Athlete pushes out curling from starting point, let it stop in ice tunnel terminal numerous concentric circles, and tries to crash opponent pot out. Let's see curling movement process. The thrower pushes curing, they takes accelerate movements together (the process not be analyzed), curling therefore gets initial speed. When thrower lets it go, curling due to suffered ice surface friction, temporarily assume it makes constant decelerated linear movement, till speed arrives at O.

CONCLUSION

By research, it is clear that curling movement distance is in direct proportion to initial speed square while has no connection with curling mass. Distance from service point to target center is around 29.6m, then combining with ice surface practical dynamic friction coefficient, it can calculate roughly initial speed when delivery. But unchangeable friction force and constant straight-line movement are just ideal state status, in fact due to first base deviation; second base athlete is required to amend curling movement trajectory and distance by wiping ice. Wiping ice is to increase ice internal energy by overcoming friction force work, let ice surface melt with a layer of thin water so as to reduce friction coefficient, in this way, curling can move forward further and straight.

In dry surface, when sphere moves, front suffered friction force is larger than the back one, and its rotational direction and sliding direction are different. While the status is just on the contrary in liquid ice surface, because liquid layer reduces front friction, sphere sliding and rotational direction are the same. When member wipes ice, two athletes use brush wiping curling ice surface in front of them, let liquid film become more smoothly to control crooked extent and sliding distance when curling proceeds. American group implemented test shows the ice wiper can let curling walk around 4.8m farther.

Curling track transversal surface is in the shape of U not horizontal, reason for such design is not ice maker fault but reflection of ice maker professional level. Because U shape ice surface can help high level athletes play loop. Ice tunnel surface is also not smoothly therefore different part frictions will be different when rotating, rotational speed and translational speed are different, then coordinates with ice wiping, so it can play loop. In short, it can change direction, wipe curling in one side and another side not that can cause curling wiped side friction force small and the other side friction force big, so that changes direction.

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