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Table tennis spiking point position geometric mechanical features research

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ABSTRACT

According to Geometric principle, it establishes table tennis spiking model, according to high hitting and low hitting differences, it gets ball trajectory figure and dropping points position, by establish Lagrange equation, the paper gets restricted particle dynamical equation, and gets shoulder point and elbow point moment of force M_h and M_k . Then according to hitting points to net surface vertical distances differences, it gets table tennis drop points differences, six different hitting points lowest points landing data through net in the degree of 45° and 30° . When athlete spikes, he should try to manage to stretch arms to right ahead and remain vertical to hitting point, athlete take-off height gets higher, and ball over net probability would be larger.

KEYWORDS

Table tennis spiking; Moment of momentum theorem; Geometric model; Biomechanics.



INTRODUCTION

Table tennis event is a hold racket net separated competition event, and serving patterns are at will without suffering opponents' impacts, and meanwhile it also been studied by lots of experts. And at the same time, free service pattern is also a powerful way to restrain opponent. Spiking belongs to table tennis basic skills, is also stronger offensive link in table tennis event. For spiking mechanical analysis, it is also to build foundation for future researches and efficient competition strategic deployment. Release angle is not in 90° vertical incidence, and ball also does not vertical enter into opponent field, generally speaking, when athlete hits the ball, he hits the ball in a certain angle, ball oblique hitting and falling to opponent field, the paper makes considers and checks such phenomenon.

MODEL ESTABLISHMENT

Geometric model establishment

According to geometric principle, it establishes table tennis spiking model, according to high hitting and low hitting differences, it gets ball trajectory graph and hitting drop point position, as Figure 1 shows.

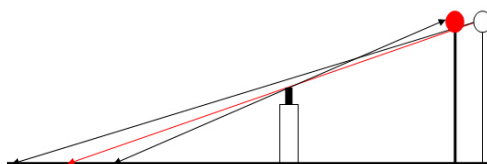


Figure 1 : High hitting and low hitting differences obtained ball trajectory

When athlete spikes, he should try to manage to stretch arms to right ahead and remain vertical to hitting point, athlete take-off height gets higher, and ball over net probability would be larger; with ball located hitting point height differences, presented over net trajectory and landing point are also different, therefore it gets long ball and short ball; according to hitting point vertical heights differences, the paper classifies six different heights phases that are respectively (2.6! 2.7! 2.8! 2.9! 3.0! 3.1). And it gets TABLE 1 according to hitting point to net vertical distance differences.

TABLE 1 : Ball flies across lowest net point's landing point data indication

Vertical height/H	0.6	0.7	0.8	0.9	1.0	1.1
Hitting point and net distance 0.75m	7.23	6.07	4.15	3.65	2.74	1.12
Hitting point and net distance 0.5m	5.55	4.05	3.10	3.01	2.49	1.08
Hitting point and net distance 0.25m	4.78	3.02	2.05	1.55	1.25	1.04

By TABLE 1, it is clear that athlete hitting points to net surface distances are different, table tennis drop points also have differences, and athlete hitting heights differences can let positions that ball over net to be different.

Low dropping ball's spiking trajectory and hitting drop point improvement under geometric model

Similarly, as Figure 2 show, the paper according to hitting point vertical heights differences, it classifies six different heights phases that are respectively (0.6! 0.7! 0.8! 0.9! 1.0! 1.1), and according to hitting point to net vertical distances differences and get TABLE 2.

By TABLE 2 and Figure 2, it is clear that shorten hitting point to net vertical distance 0.1m, which can clearly get that with respect to low hitting, though only shorten hitting point to net 0.1m vertical distance, ball hitting drop point positions have great differences. Hitting drop point in opponent area occurs to great changes.

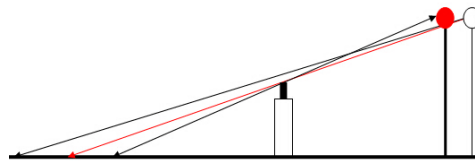


Figure 2 : Spiking trajectory and drop points

TABLE 2 : After shortening hitting point to vertical net 0.1m ball flying across lowest net point landing point data indication

Vertical height/H	0.6	0.7	0.8	0.9	1.0	1.1
Hitting point and net distance 0.75m	10.16	7.01	6.73	5.45	4.6	3.15
Hitting point and net distance 0.5m	6.32	3.89	2.68	1.48	0.98	0.87
Hitting point and net distance 0.25m	5.66	4.49	3.09	2.15	1.48	1.08

Change hitting angle

Spiking release angle is not in 90° vertical incidence, and ball also not vertical enters into opponent field, generally speaking, when athlete hitting, it will hit at certain angles, and oblique hit ball down to opponent field.

Set hitting point and field edge vertical distance is 0.5m, when athlete hits, deflects rightward 45° to release and hit, and get hitting point to drop point distance *S* is

$$S = \frac{0.5}{\cos 45^\circ} = \frac{0.5}{\frac{\sqrt{2}}{2}} = 0.7072m$$

Similarly when deflection angle is 30°, it gets hitting point to dropping point vertical projection distance *S* is:

$$S = \frac{0.5}{\cos 30^\circ} = \frac{0.5}{\frac{\sqrt{3}}{2}} = 0.574m$$

Combine with Figure 3 Table tennis' table size graph; it draws lateral view, as Figure 4 shows.

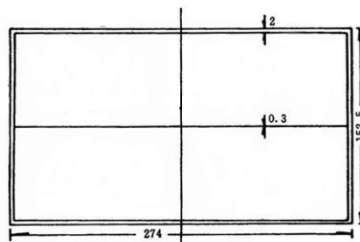


Figure 3 : Table tennis table size graph

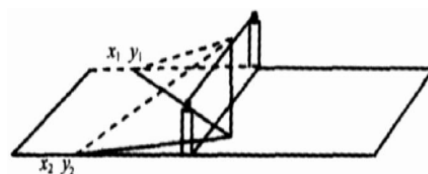


Figure 4 : Angle changes hitting drop point schematic graph

According to Figure 3, it gets data and establishes TABLE 3 to make analysis.

TABLE 3 : 6 different hitting points over net lowest point drop point data

Angle	Vertical angle	45°	Drop point coordinate $\begin{pmatrix} x \\ y \end{pmatrix}$	30°	Drop point coordinate $\begin{pmatrix} x \\ y \end{pmatrix}$
2.65m	10.45m	16.52m	$\begin{pmatrix} 11.15 \\ 11.15 \end{pmatrix}$	13.56m	$\begin{pmatrix} 11.45 \\ 6.24 \end{pmatrix}$
2.75m	6.04m	8.54m	$\begin{pmatrix} 6.05 \\ 6.05 \end{pmatrix}$	6.98m	$\begin{pmatrix} 6.02 \\ 3.476 \end{pmatrix}$
2.85m	4.2m	5.6m	$\begin{pmatrix} 4.12 \\ 4.12 \end{pmatrix}$	4.75m	$\begin{pmatrix} 4.08 \\ 2.356 \end{pmatrix}$
2.95m	3.15m	4.37m	$\begin{pmatrix} 3.25 \\ 3.25 \end{pmatrix}$	3.64m	$\begin{pmatrix} 3.08 \\ 1.86 \end{pmatrix}$
3.05m	2.49m	3.52m	$\begin{pmatrix} 2.18 \\ 2.18 \end{pmatrix}$	2.89m	$\begin{pmatrix} 2.48 \\ 1.42 \end{pmatrix}$
3.15m	2.11m	2.98m	$\begin{pmatrix} 1.95 \\ 1.95 \end{pmatrix}$	2.41m	$\begin{pmatrix} 2.05 \\ 1.47 \end{pmatrix}$

By TABLE 3, it is clear six different hitting points over net lowest point drop point data under 45° and 30° degree.

Hitting instant arms rotational inertia calculation

The paper establishes Lagrange equation, the paper gets restricted particle dynamical equation, from which Lagrange function L is difference between system kinetic energy K and potential energy P : $L = K - P$

System dynamical equation is: $F_i = \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i} \right) \quad i = 1, 2, L, n$

In above formula \dot{q}_i is corresponding speed, q_i is dynamic energy and potential energy coordinate, F_i is the i coordinate acting force, thigh and shank included angles with coordinate axis are respectively θ_1, θ_2 , lengths are respectively l_1, l_2 , Arms front part and arms post part gravity center position distances with elbow joint center and knee joint are respectively p_1, p_2 , therefore it is clear that arms gravity center coordinate (X_1, Y_1) is:

$$\begin{cases} X_1 = p_1 \sin \theta_1 & Y_1 = p_1 \cos \theta_1 \\ X_2 = l_1 \sin \theta_1 + p_2 \sin(\theta_1 + \theta_2) & Y_2 = -l_1 \cos \theta_1 - p_2 \cos(\theta_1 + \theta_2) \end{cases}$$

Similarly, arms gravity center coordinate (X_2, Y_2) can also be solved. System dynamic energy E_k and system potential energy E_p expressions are:

$$\begin{cases} E_k = E_{k1} + E_{k2}, E_{k1} = \frac{1}{2} m_1 p_1^2 \dot{\theta}_1^2 \\ E_{k2} = \frac{1}{2} m_2 l_1^2 \dot{\theta}_1^2 + \frac{1}{2} m_2 p_2^2 \left(\dot{\theta}_1 + \dot{\theta}_2 \right)^2 + m_2 l_2 p_2 \left(\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2 \right) \cos \theta_2 \\ E_p = E_{p1} + E_{p2}, E_{p1} = \frac{1}{2} m_1 g p_1 (1 - \cos \theta_1) \\ E_{p2} = m_2 g p_2 [1 - \cos(\theta_1 + \theta_2)] + m_2 g l_1 (1 - \cos \theta_1) \end{cases}$$

Write above formula into Lagrange function expression, by Lagrange system dynamical equation, it can get hip joint and knee joint moments of force M_h and M_k as:

$$\begin{bmatrix} M_h \\ M_k \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix} \begin{bmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} + \begin{bmatrix} D_{111} & D_{122} \\ D_{211} & D_{222} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1^2 \\ \dot{\theta}_2^2 \end{bmatrix} + \begin{bmatrix} D_{112} & D_{121} \\ D_{212} & D_{221} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \dot{\theta}_2 \\ \dot{\theta}_2 \dot{\theta}_1 \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix}$$

In above formula, D_{ijk} is as following result:

$$D_{111} = 0 \quad D_{222} = 0 \quad D_{121} = 0$$

$$D_{222} = m_2 p_2^2$$

$$D_{111} = m_1 p_1^2 + m_2 p_2^2 + m_2 l_1^2 + 2m_2 l_1 p_2 \cos \theta_2$$

$$D_{122} = m_2 p_2^2 + m_2 l_1 p_2 \cos \theta_2 \quad D_{211} = m_2 p_2^2 + m_1 l_1 p_2 \cos \theta_2$$

$$D_1 = (m_1 p_1 + m_2 l_1) g \sin \theta_1 + m_2 p_2 g \sin(\theta_1 + \theta_2)$$

$$D_{122} = -m_2 l_1 p_2 \sin \theta_2$$

$$D_{211} = m_2 l_1 p_2 \sin \theta_2$$

$$D_{112} = -2m_2 l_1 p_2 \sin \theta_2$$

$$D_{212} = D_{122} + D_{211}$$

$$D_2 = m_2 p_2 g \sin(\theta_1 + \theta_2)$$

Combine with theoretical equation, analyze when table tennis players spike, hand joint mechanical movement combines with shoulder joint, elbow joint mechanical analyses to research on table tennis spiking technique.

Establish moment of momentum theorem model

When apply mechanical conservation law into solving problems, at first it should select reasonable research objects, and make correct force analysis of researched objects, the next is on the basis of force analysis, refer to conservation law to check problems, and finally according to conservation law, establish equation and solve problems.

Set I is one rigid body rotational inertia, suffered torque M effects, from which angular accelerated speed β is constant, the rigid body at time t_1 angular speed is ω_1 , the rigid body at time t_2 angular speed is ω_2 , and get:

$$M = I\beta = I \frac{\omega_2 - \omega_1}{t_2 - t_1}$$

Transform and get: $M(t_2 - t_1) = I(\omega_2 - \omega_1)$

When $M = M(t)$, it has: $M(t)(t_2 - t_1) = I(\omega_2 - \omega_1)$

It gets moment of momentum formula, from which $M(t_2 - t_1)$ is impulsive moment, $I\omega$ is moment of momentum, from formula, it is clear that rigid body impulsive moment variable quantity and moment of momentum variable quantity are equal.

In moment of momentum theorem, time and torque product is equal to impulsive moment that represents object rotational accumulation effect under external force moment influences. Angular speed and rotational inertia product is rigid body state when rotating. With external force moment increases and acting time enlarges, rigid body rotational state changes are increasing accordingly.

When human body moves, human body generated rotational inertial is changing, due to rotational variables changes, different times rotational inertias are different, set t_1 time rotational inertia is I_1 , t_2 time rotational inertia is I_2 , therefore, above formula can be revised into: $M(t)(t_2 - t_1) = I_2\omega_2 - I_1\omega_1$

For Human body basic movement rules, it should meet: $I\omega = 0, \sum M \Delta t = 0$

Now it enters into soaring phase, assume human body meets: $I_1\omega_1 + I_2\omega_2 = 0$

Besides, it should also meet human body surround $I_1\omega_1$ to rotate, then the kind of movement form is lengthwise relative movement, in spiking process, solve the sum of human body moment of momentum vectors is 0, according to correlation law, we get that human body will suffer ball acted a reaction force that let people produce moment of momentum, so that reduce spiking process strength sizes and it is bad for spiking stability, but if in the spiking process, due to body each part suffered active force effects, which causes rotational inertia increase, it will further produce an advancing moment of momentum effects; according to energy conservation law, we know that human body also will produce a reverse active force effects at this time, so that let human body move relative to ball, based on which it increases arms swinging distance and concentrates on whole body strength to hit the ball.

Hand air angular speed changes, in case moment of momentum remains unchanged, rotational inertial will reduce with angular speed increases, when athlete prepares for swinging racket, athlete himself can further control rotational angular speed by changing self-rotational inertia.

Athlete take-off legs slightly bend and let gravity center and body rotational axis come to terms and reduce so that can reduce rotational inertia, and then it further achieves the efficiency of increasing rotational angular speed, when athlete takes off and arrives at top point, athlete should try to adjust body stability and let rotational angular speed reduce as much as possible, at this time, athlete should lift two legs backward, and let gravity center to be far away from rotational axis. Then arrive at stable contacting ball state.

CONCLUSION

Spiking belongs to table tennis basic skills, is also stronger offensive link in table tennis event. For spiking mechanical analysis, it is also to build foundation for future researches and efficient competition strategic deployment. According to establish geometric model, it gets when athlete is spiking, he should try to manage to stretch arms to right ahead and remain vertical to hitting point, athlete take-off height gets higher, and ball over net probability would be larger, by ball located hitting point height differences, presented over net trajectory and landing point are also different, therefore according to hitting point vertical heights differences, the paper classifies (0.6, 0.7, 0.8, 0.9, 1.0, 1.1) six different heights phases to analyze. And according to athlete spiking release angle is not in 90° vertical incidence, and ball also does not vertical enter into opponent field such phenomenon, researches that spiking is certain angle hitting, ball oblique hitting and falling to opponent field position differences.

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