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Badminton smashing point position and smashing move relational mechanical model research

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ABSTRACT

Badminton is backbone fitness event in national fitness industry, the paper carries out detailed analysis of badminton smashing technique, and analyzes from the perspectives of mechanical and geometrical analysis so on. By mechanical analysis, it gets that when athlete makes smashing move, athlete takes-off and arrives at top point, he should keep body stable and reduce rotational angular speed, raise two legs and let gravity center to be far away from rotational axis. Establish stable base between racket and ball, and then construct geometric model, it gets when athlete smashes, they should try to stretch arms to the right ahead and keep vertical to hitting point, athlete's take-off height gets higher, and probability that all crosses net would be bigger, ball located hitting points are different and presented trajectory and landing points after netting are also different.

KEYWORDS

Badminton smashing;
Moment of momentum theorem;
Geometric model.

INTRODUCTION

Chinese badminton takes leading position in the world, and based on national fitness strategy, badminton ranks the second in sports events participation, is well received by national people. Badminton can drive body each organ coordinate movements, let body to get high-efficiency exercising in the aspects of strength, speed, endurance and flexibility so on.

In recent years, Chinese badminton researches are mainly about techniques, strategies, current status analysis and other aspects. Researches on specified actions are relative fewer. In relative "Chinese badminton brief development history", Chinese badminton was introduced from European and American countries to Chinese some developed cities around 1910, and subsequently it achieved higher honors in world badminton championships and badminton world cup.

However, summarize Chinese badminton development from taking leading roles in the world to competition results of big rise and fall, and until now on the basis that China positively develops badminton, Chinese badminton have gained higher level acceptance, and got excellent results.

MODEL ESTABLISHMENTS

Geometric model establishment

According to geometric principle, it established badminton smashing model, according to high stroke and low stroke differences, it gets trajectory figure and shooting down points positions, as Figure 1 show.

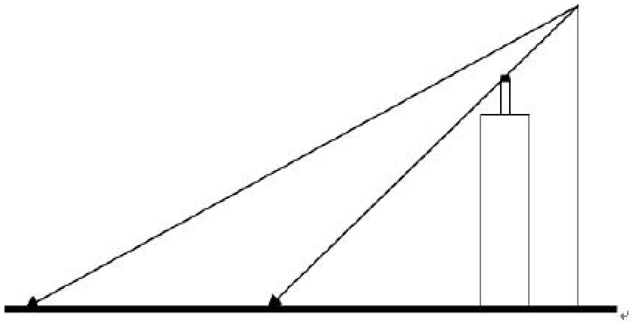

Figure 1 : Get ball trajectory by high stroke and low stroke differences

When athlete smashes, he should try to stretch arms to the right ahead and keep vertical to hitting point, athlete's take-off height gets higher, and probability that ball crosses net would be bigger, ball located hitting points are different and presented trajectory and landing points after netting are also different, therefore it gets long serve and short serve, according to hitting points vertical heights differences, the paper classifies into six different height phases that are respectively as 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, and then according to hitting point to net surface different vertical distances, it gets TABLE 1.

By TABLE 1, it is clear that hitting points to net surface distances are different, badminton landing points also have differences, athletes hitting heights differences can let ball to have different positions after crossing the net.

Low dropping ball's smashing trajectory under geometric model and shooting down point improvements

Similarly, according to hitting point vertical heights differences, the paper classifies into six different height phases that are respectively 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, then according to different vertical distances between hitting point and net surface, it gets TABLE 2.

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

Vertical height/H	1.6	1.7	1.8	1.9	2.0	2.1
Distance between hitting point and net is 0.75m	17.23	9.07	6.15	4.65	3.74	3.12
Distance between hitting point and net is 0.5m	10.55	6.05	4.10	3.10	2.49	2.08
Distance between hitting point and net is 0.25m	5.78	3.02	2.05	1.55	1.25	1.04

TABLE 2 : Ball landing point data indication after shortening hitting point and vertical net surface distance for 0.1m

Vertical height /H	1.6	1.7	1.8	1.9	2.0	2.1
Distance between hitting point and net 0.75m	45.16	25.01	12.73	9.45	5.6	3.15
Distance between hitting point and net 0.5m	6.32	2.89	2.68	2.48	1.57	0.68
Distance between hitting point and net 0.25m	8.98	6.58	4.08	3.12	2.95	1.68

By Figure 2 and TABLE 2, it is clear that shorten hitting point and net vertical distance for 0.1m, it is clear that for low stroke, though only shorten hitting point and net 0.1m vertical distance, ball shooting down positions have great differences. Shooting down points occurs to great changes in the opponent area.

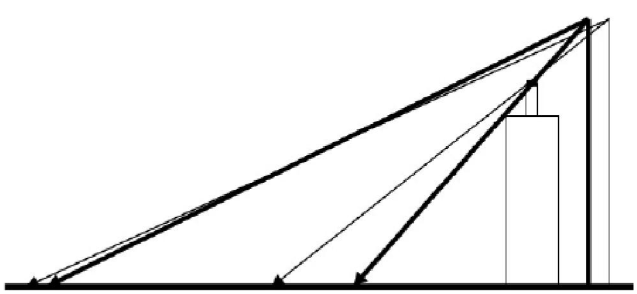

Figure 2 : Low dropping point smashing trajectory under geometric model and shooting down point

Change hitting angle

Smashing release angle is vertical entering in 90°, and the ball is also not vertical entering into opponent field, in general, when athlete hits, he is hitting with certain angles and slant shooting the ball down to opponent field.

Set hitting point and field edge vertical distance is 0.5m, when athlete hits, shifts rightwards 45° and starts hitting, it gets hitting point to landing point distance S is:

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

Meanwhile, When smashing deflection angle is 30°, it gets landing point and hitting point vertical projection

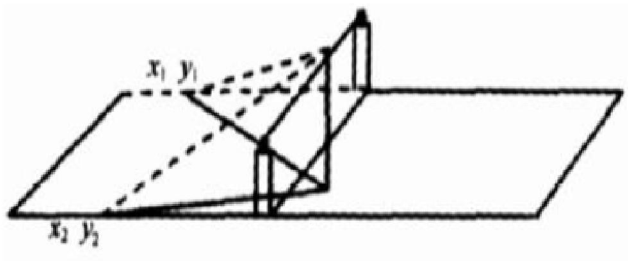

Figure 3 : Angular variation hitting points

distance S is:

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

As Figure 3 shows.

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

Hitting moment arms rotational inertia calculation

By Lagrange equation, the paper gets constraint particle dynamical equation, from which Lagrange function L is system kinetic energy K and potential energy P generated differences:

$$L=K-P$$

System dynamical equation is:

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

In above formula, $\dot{q}_i$ is corresponding speed, q_i is kinetic energy and potential energy coordinate, F_i is i coordinate acting force, thigh and shank together with coordinate axis included angles are respectively θ_1,θ_2,

TABLE 3 : 6 different hitting points crossing net lowest point landing points data

Angle	Vertical angle	45°	Drop point coordinate $\begin{pmatrix}x\\y\end{pmatrix}$	30°	Drop point coordinate $\begin{pmatrix}x\\y\end{pmatrix}$
1.65m	9.45m	12.45m	$\begin{pmatrix}11.15\\11.15\end{pmatrix}$	11.47m	$\begin{pmatrix}11.45\\6.24\end{pmatrix}$
1.75m	6.14m	8.57m	$\begin{pmatrix}6.05\\6.05\end{pmatrix}$	5.68m	$\begin{pmatrix}6.02\\3.476\end{pmatrix}$
1.85m	4.2m	5.6m	$\begin{pmatrix}4.12\\4.12\end{pmatrix}$	4.75m	$\begin{pmatrix}4.08\\2.356\end{pmatrix}$
1.95m	3.15m	4.37m	$\begin{pmatrix}3.25\\3.25\end{pmatrix}$	3.64m	$\begin{pmatrix}3.08\\1.86\end{pmatrix}$
2.05m	2.49m	3.52m	$\begin{pmatrix}2.18\\2.18\end{pmatrix}$	2.89m	$\begin{pmatrix}2.48\\1.42\end{pmatrix}$
2.15m	2.11m	2.98m	$\begin{pmatrix}1.95\\1.95\end{pmatrix}$	2.41m	$\begin{pmatrix}2.05\\1.47\end{pmatrix}$

lengths are respectively l_1,l_2, arms front and back gravity center position to elbow joint center and knee joint distances are respectively p_1, p_2, therefore it is known that arms gravity center coordinate (X_1,Y_1) is:

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

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

$$\begin{cases} E_k = E_{k1} + E_{k2}, E_{k1} = \frac{1}{2} m_1 p_1^2 \dot{\theta}_1^2 \\ E_{k2} = \frac{1}{2} m_2 l_1^2 \dot{\theta}_1^2 + \frac{1}{2} m_2 p_2^2 \left(\dot{\theta}_1 + \dot{\theta}_2 \right)^2 + m_2 l_2 p_2 \left(\dot{\theta}_{01}^2 + \dot{\theta}_1 \dot{\theta}_2 \right) \cos\theta_2 \\ E_p = E_{p1} + E_{p2}, E_{p1} = \frac{1}{2} m_1 g p_1 (1 - \cos\theta_1) \\ E_{p2} = m_2 g p_2 [1 - \cos(\theta_1 + \theta_2)] + m_2 g l_1 (1 - \cos\theta_1) \end{cases}$$

Write above formula into Lagrange function expression, by Lagrange system dynamical equation, it can get hip joint and knee joint moment 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:

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

$$D_{22} = m_2 p_2^2$$

$$D_{11} = m_1 p_1^2 + m_2 p_2^2 + m_2 l_1^2 + 2 m_2 l_1 p_2 \cos\theta_2$$

$$D_{12} = m_2 p_2^2 + m_2 l_1 p_2 \cos\theta_2 \quad D_{21} = m_2 p_2^2 + m_1 l_1 p_2 \cos\theta_2$$

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

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

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

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

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

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

Combine with theoretical formula, when analyze badminton player smashing, hand joint mechanical movement, combining with shoulder joint and elbow joint mechanical analysis to make research on badminton smashing technique.

Establish moment of momentum theorem model

When apply mechanical conservation law to solve problems, firstly it should select reasonable research objects, and make correct force analysis of research objects, secondly on the basis of force analysis, reference conservation law to check problems, finally according to conservation law, establish equation and solve problems.

Set I to be one rigid body rotational inertia, it suffers moment M effects, from which angular accelerated speed β is constant, the rigid body at t_1 instant angular speed is ω_1, the rigid body at t_2 instant angular speed is ω_2, it gets:

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

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 and moment of momentum variable are equal.

In moment of momentum theorem, time and moment product is equal to impulsive moment which represents object rotational accumulative effect under external forces moment. Angular speed and rotational inertia product is rigid body rotating moment state. With external forces moment increasing and acting time enlarging, rigid body rotating state changes are accordingly increasing.

When human body moves, human body generated rotational inertia is changing, due to rotational variables' changes, different time's rotational inertias are different, set t_1 instant rotational inertia is I_1, t_2 instant rotational inertia is I_2, therefore above formula can be changed into :

$$M(t)(t_2 - t_1) = I_2\omega_2 - I_1\omega_1)$$

To human body motion law, it should meet:

$$I\omega = 0, \sum M \square t = 0$$

Then enter into soaring phase, if human body meets:

$$I_1\omega_1 + I_2\omega_2 = 0$$

In addition, it should also meet people rotates around $I_1\omega_1$, then the kind of movement form is lengthwise relative movement, during smashing process, it solves that human body moment of momentum vector sum is 0, according to correlation law we are clear that human body will suffer ball acted a reaction force that lets people generate moment of momentum, so that reduce smashing process forces sizes, so it is bad for smashing stability; but if during smashing process, due to body each part suffers active force acting, it leads to rotational inertia increase, and further it will generate an advancing moment of momentum acting, according to energy conservation law, we know that now human body similarly will generate an reaction force, and further let human body move relative to ball so that increase swinging arms distance, and concentrate whole body strength to hit the ball.

In the whole hitting process, each limb will generate opposite directions but equal sizes moment, and every pair can offset, when athlete lands, sole part rapidly lands to support the whole body, meanwhile it will occur abdomen contracting, knees bending to buffer falling strength and make preparation for next motion.

Air angular speed changes, in case that moment of momentum remains unchanged, rotational inertia will reduce with angular speed increases, when athlete takes-off and flies, athlete himself can change his rotational inertia to further control rotational angular speed.

Twist smashing is smashing though changing upper body faced directions when athlete takes-off and hits, when athlete takes-off, he should increase himself rotational angular speed, so athlete take-off legs arrive at flat and straight, let gravity center and body rotational axis come to terms so that can reduce rotational inertia, and further arrive at efficiency of increasing rotational angular speed, and at the same time of taking-off, twist upper body can also continue to increase self rotational angular speed let contacted ball to be more rapidly.

When athlete takes off and arrives at peak, athlete should try to adjust body stability, let rotational angular speed to reduce as much as possible, now, athlete should raise two legs backward, let gravity center to be far away from rotational axis and arrive at stable touching ball state.

CONCLUSION

Smashing belongs to badminton basic techniques, is also strong offensive linkage in badminton. Mechanical analysis of smashing is also building basis for further researching and carrying out high efficiency competition strategic deployment. By geometric model establishment, it gets when athlete smashes, they should try to stretch arms to the right ahead and keep vertical to hitting point, athlete's take-off height gets higher, and probability that ball crosses net would be bigger, ball located hitting points are different and presented trajectory and landing points after netting are also different; therefore, the paper according to hitting points different vertical heights, it classifies into 2.6, 2.7, 2.8, 2.9, 3.0, 3.1 six different heights phases to make analysis, which provides theoretical references for athletes and coaches proceeding with technical training.

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