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Critical friction angle-based table tennis racket and table physical rebound model construction

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ABSTRACT

Table tennis is Chinese national ball event, and meanwhile is also one of Chinese sports achieved best performance events in international medium and large competitions. Therefore, Chinese scholars also make concrete researches from table tennis development history、development prospects, table tennis reserve talents reservation and cultivation, table tennis techniques and other aspects. The paper discusses table tennis and table tennis racket as well as table physical rebound model construction in table tennis movement process. By introducing critical friction angle concept, analyze academic problems form mechanical perspective, and utilize statistics and numerical value calculated methods to construct models, finally by fuzzy mathematical theories, it makes model evaluation, further affirms constructed model feasibility. In research, point out: table tennis movement in whole process belongs to trajectory problem, it reflects critical friction angle concept, and meanwhile the idea also is the foundation of the whole research, table tennis racket and table tennis table physical rebound model construction under critical friction angle is a kind of feasible research, its comprehensive evaluation weight is higher, which has certain reliability.

KEYWORDS

Critical friction angle; Physical rebound; Numerical calculation; Fuzzy mathematics.

INTRODUCTION

Table tennis as Chinese national ball, its development and all kinds of performance always affect Chinese sports image. In table tennis research, it has already sprung up more excellent works, but most targets at table tennis event athletes、referees、coaches development, competition performance, research on table tennis racket and table are still little. So the paper makes research on table tennis racket and table tennis table physical rebounding, and starts from critical friction angle, goes deeper into statements, and finally gets conclusions.

Critical friction angle is one of theoretical basis when carrying out table tennis analysis, critical friction angle's introduction solves table tennis racket and table friction problem. Therefore, many scholars have already made feasible researches on critical friction angle problem. Yan Feng put forward five main application modes for friction angle, by introducing friction angle concepts, made comprehensive introduction on the five modes, and in the following researches, it made concrete analysis of friction angle application problems in these modes; Xu Shang-Jie entered from suction internal friction angle, by analyzing suction internal friction angle determined premise, determined conditions, determined paths, and determined methods, pointed out and affirmed friction angle importance.

In addition, physical rebounding is also an important concept in table tennis movement process, it combines with movement and mechanical theory, is an important entry point to deepen analyze table tennis event. Here, many scholars have made feasible researches for physical rebounding theories and its application problems. Firstly, Ren Yan-Qing through researching on table tennis rotation process collision phenomenon with table tennis table and table tennis racket, regarded that as access board, constructed rotational ball and table tennis table as well as racket rebound model, the paper took constructing rebound model as goal, table tennis basic movement trajectory and rules as base, analyzed rebound phenomenon and rebound model construction from mathematical theoretical perspectives.

No matter critical friction angle or physical rebound phenomenon researches, all are used for making contributions to table tennis techniques. Therefore, scholars also make research on table tennis techniques. Such as, Tang Jian-Jun through constructing table tennis tactics system, analyzed technical motions tactics formation problem, and targeted as techniques formation, it further solved table tennis tactical application mode. And as Wang De-Hua made theoretical statement on table tennis technical system construction, by concrete examples illustration and analysis, carried out scientific statement on them, let reader to have scientific knowledge on table tennis technical system.

The paper bases on critical friction angle, researches on table tennis racket and table physical rebound model construction process. By theoretical analyzing critical friction angle 、physical rebound and others basic concepts, as well as making quantitative analysis of table tennis movement trajectory and features, construct critical friction angle-based table tennis racket and table physical rebound model from mathematics and mechanical angles to make theoretical contributions to table tennis research.

MODEL ESTABLISHMENT

Research base

In table tennis technical research process, it tends to get involved in mechanical problems. As force effects, table tennis movement process parabola problems, and table tennis racket as well as table tennis table physical rebound problem is one of inevitable problems in these problems.

Firstly, introduce physical rebound significances. No doubt as force effects are mutual, physical rebound refers to exert opponent acted physical assault rebounding to opponents. In table tennis movement process, table tennis racket due to suffer table tennis impacts and suffer its acted force, and table tennis table also suffers certain force effects because of table tennis falling and impacting, in the process, physical rebound phenomenon is very common.

Secondly, introduce critical friction angle concept. When object lies in sliding critical state, static friction force FS arrives at maximum value $F_{\max}$,now F_R and F_N included angle is also the largest, now ϕ_m is called friction angle. When object lies in sliding and static critical state now ϕ_m is called critical friction angle.

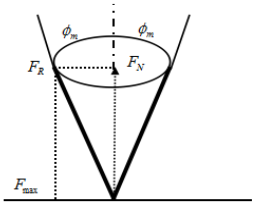

Figure 1 : The critical angle of friction

Now explain it by Figure 1 :

(1) Friction angle tangent is equal to static friction coefficient,that: $\tan\varphi_m = F_{\max} / F_N = f \bullet F_R / F_N = f$;

(2) By friction angle, it can define static friction coefficient ;

(3) When movement initiative direction that is trend direction changing, $F_{\max}$ and supporting plane whole counter-force F_R direction will also change ;

(4) When whole counter-force F_R active line continuous changes in space, it will appear friction cone that is special cone ;

(5) For object balance range, $\varphi \le \varphi_m (F \le F_{\max})$, it can use friction angle to express as Figure 2.

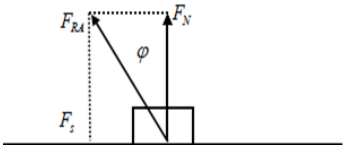

Figure 2 : The critical friction angle diagram

Thereupon, for table tennis racket and table physical rebounding process, friction angle, especially for critical friction angle application is very important.

For table tennis racket and table tennis table physical rebounding research under critical friction angle, it has very important significances, it can summarize as following TABLE 1:

TABLE 1 : Research significances

	Research significances
1	Research table tennis racket and table physical rebounding is helpful for analyzing table tennis movement problem of movement trajectory;
2	For appeared physical rebounding phenomenon, reasonable arrange table tennis racket and table positions:
3	Research on it table tennis movement process physical rebounding has profound significances in implementing more regular table tennis movement and normative motions;

By above research significances summarizing, it is clear that table tennis racket and table tennis table physical rebound model construction in critical friction angle is a feasible research.

Table tennis movement trajectory-based critical friction angle theory

In table tennis and table physical rebounding process, table tennis movement trajectory shows parabolic shapes, in the process, it can be used for critical friction angle solving. Below Figure is table tennis movement trajectory simple graph, analyze the simple graph; its analysis process is as following Figure 3 shows:

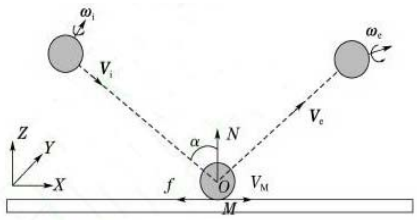

Figure 3 : Table tennis movement

At first, establish three-dimensional coordinate system that are respectively x, y, z three coordinates axes, from which define table as x, y axis, and longer side is x axis, shorter side is y axis,take direction that is vertical to table tennis table plane is z axis positive direction, according to table tennis flight trajectory, it can get following scale TABLE 2:

TABLE 2 : Variables table

	Variable
Incidence before collision	Table tennis incidence speed: V Angular speed: ω_i
After collision	Table tennis releasing speed is V_e Angular speed is ω_e

Among them,Speed and angular speed components in x, y, z axis are respectively using suffix x, y, z to express. In the process, set table tennis ball center O to contact point M vector is $\vec{OM} = (0,0,-r)^T$, M point movement speed is :

$$V_M = V + \vec{OM} \times \omega = \begin{bmatrix} v_x - r\omega_y \\ v_y + r\omega_x \\ 0 \end{bmatrix}$$

M point speed in table tangential direction is:

$$v_{xy} = \sqrt{(v_x - r\omega_y)^2 + (v_y + r\omega_x)^2}$$

After table tennis racket and table occurring physical rebounding, table tennis angular speed and speed meet :

$$\begin{cases} V_e = \begin{bmatrix} V_{ix} \\ V_{iy} \\ -eV_{iz} \end{bmatrix} \\ \omega_e = \omega_i \end{cases} \quad \textbf{(1)}$$

$$\begin{cases} V_{ex} = k_{vx1}V_{ix} + k_{vx2}V_{iy} + b_{vx} \\ V_{ey} = k_{vy1}V_{ix} + k_{vy2}V_{iy} + b_{vy} \\ \omega_{ex} = k_{wx1}V_{ix} + k_{wx2}V_{iy} + b_{wx} \\ \omega_{ey} = k_{wy1}V_{ix} + k_{wy2}V_{iy} + b_{wy} \end{cases} \quad \textbf{(2)}$$

On this basis, construct critical friction angle theory-based table tennis racket physical rebounding model and table tennis table physical rebounding model.

Critical friction angle theory-based table tennis racket physical rebounding model

For moving table tennis, in establishing physical rebounding model process, according to :

$$\text{Table tennis absolute movement} = \textit{Tabletennistoracketrelativemovement} + \textit{tableracketmovement}$$

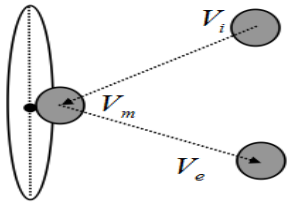

Figure 4 : Table tennis racquet rebound physical model

As Figure 4,then it can establish critical friction angle theory-based table tennis racket physical rebounding model. Among them, in three-dimensional coordinate system, established speed expression method and racket coordinate system established speed expression method relation is :

$$V = \dot{T} \bullet^e Q + T \bullet^e V$$

V : Speed in three-dimensional coordinate system;

T : Three-dimensional coordinate system to racket coordinate system transformation matrix;

$\dot{T}:T$ derivative;

${}^{e}Q$: Racket coordinate system's homogeneous coordinate;

${}^{e}V$: Racket coordinate system's speed;

By calculating, it can get:

$$ {}^{e}V_i = T^{-1}(V_i - V_{ph}) ; {}^{e}V_e = T^{-1}(V_e - V_{ph}) $$

Input above two formulas into (1)and (2),it can get regarding critical friction angle theory-based table tennis racket physical rebounding model.

Critical friction angle theory-based table tennis table physical rebounding model

Table tennis movement in table can be understood as parabolic movement, is defined according to its movement trajectory. In general, it can be described as following Figure 5 status:

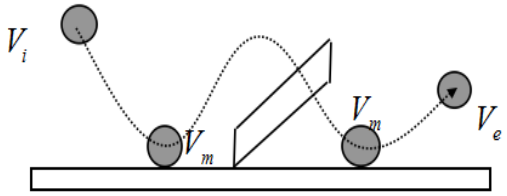

Figure 5 : Table tennis physical model of the rebound

For static table tennis table, in table tennis parabolic movement trajectory process, force status can be decomposed into two cases in tangential direction and normal direction. In tangential direction, speed gradually reduces, but angular speed remains unchanged, and then before and after physical rebounding, their relations can be:

$$ \begin{cases} V_e = \begin{bmatrix} V_{ix} \\ V_{iy} \\ -eV_{iz} \end{bmatrix} \\ \omega_e = \omega_i \end{cases} $$

And in its tangential direction, the two relations can be expressed as:

$$ \begin{cases} V_{ex} = k_{vx1}V_{ix} + k_{vx2}V_{iy} + b_{vx} \\ V_{ey} = k_{vy1}V_{ix} + k_{vy2}V_{iy} + b_{vy} \\ \omega_{ex} = k_{wx1}V_{ix} + k_{wx2}V_{iy} + b_{wx} \\ \omega_{ey} = k_{wy1}V_{ix} + k_{wy2}V_{iy} + b_{wy} \end{cases} $$

By experiment, measured individual parameters multiple groups of numerical values, input into above formulas and then can get critical friction angle theory-based table tennis table physical rebounding model.

MODEL COMPREHENSIVE EVALUATION

For table tennis racket and table physical rebounding model construction in critical friction angle, to further evaluate two models' reliability, it can make quantitative evaluation on the two evaluation index through mathematics fuzzy comprehensive evaluation method and then define above analysis reliability.

Define evaluation indicator set

According to lots of literature information and above analysis process, it can get two kinds of table tennis movement physical rebounding model in critical friction angle theory that is table tennis racket physical rebounding model, table tennis table physical rebounding model, table tennis racket and table relative sliding rebounding model. According to:

$$U=\{u_1,u_2,\cdots;u_m\},m=1,2,3$$

Evaluation indicator set is ={table tennis racket physical rebounding model, table tennis table physical rebounding model, table tennis racket and table relative sliding rebounding model}.

Define evaluation grade set

For systematic evaluation grade, mainly determination method is expert evaluation method. In table tennis movement physical rebounding model evaluation, its evaluation grade set is as following, according to:

$$V=\{v_1,v_2,\cdots,v_n\},n=1,2,3,4$$

Table tennis movement physical rebounding model evaluation grade set is={very good, good, general, bad}.

Define each evaluation indicator weight

Weight mainly expression method is:

$$w=\{\mu_1,\mu_2,\cdots,\mu_m\},m=1,2,3$$

mong them: $\sum_{m=1}^{6}\mu_m=1$

Define evaluation grade indicator weights methods are mainly analytic hierarchy process and normalization method, from which normalization formula is as following:

$$w_i=\frac{\frac{C_i}{\overline{S_i}}}{\sum_{i=1}^{n}\frac{C_i}{\overline{S_i}}},(i=1,2,\cdots,m)$$

Among them, w_i is evaluation parameter i monitoring value; $\overline{S_i}$ is evaluation parameter i standard arithmetic mean value of m grade, then weight set is: $w=\{w_1,w_2,\cdots,w_m\}$

Here, apply normalization method to calculate weight, result is: $w=\{0.345 \quad 0.350 \quad 0.305\}$

Define evaluation matrix

Comprehensive evaluation matrix R evaluation method is mainly experts' evaluation method, analytic hierarchy process, membership function method. Here use membership function method, define fuzzy relation matrix R ,from which : $R=(R_1,\quad R_2,\quad R_3,)^T$。

Evaluation grade on the 1 grade:

$$\mu_{i1(u_i)}=\begin{cases}0 & u_i\geq v_{i2}\\ -\dfrac{u_i-v_{i2}}{v_{i2}-v_{i1}} & v_{i1}<u_i<v_{i2}\\ 1 & u_i\leq v_{i1}\end{cases}$$

]

(2)Evaluation grade on the j grade:

$$\mu_{ij(u_i)}=\begin{cases}0 & u_i \le v_{ij-1} \text{ or } u_i \ge v_{ij+1}\\ \dfrac{u_i-v_{ij-1}}{v_{ij}-v_{ij-1}} & v_{ij-1}<u_i<v_{ij}\\ -\dfrac{u_i-v_{ij+1}}{v_{ij+1}-v_{ij}} & v_{ij}\le u_i<v_{ij+1}\end{cases}$$

(3)Evaluation grade on the n grade:

$$\mu_{in(u_i)}=\begin{cases}0 & u_i \le v_{in-1}\\ \dfrac{u_i-v_{in-1}}{v_{in}-v_{in-1}} & v_{in-1}<u_i<v_{in}\\ 1 & u_i \ge v_{in}\end{cases}$$

Input data into above each parameter's each grade standard membership function formula, it can solve each evaluation parameter membership to each evaluation grade, and then construct fuzzy relation matrix R , that is:

$$R=\begin{pmatrix}0.1 & 0.2 & 0.2\\ 0.3 & 0.3 & 0.25\\ 0.5 & 0.4 & 0.5\\ 0.1 & 0.1 & 0.05\end{pmatrix}$$

Carry on comprehensive evaluation

Known $W=(\mu_j)_{1\times m}$, $R=(r_{ji})_{m\times n}$, by:

$$S=w\circ R=(\mu_1\ ,\ \mu_2\ ,\cdots,\ \mu_m)\circ\begin{pmatrix}r_{11} & r_{12} & \cdots & r_{1n}\\ r_{21} & r_{22} & \cdots & r_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ r_{m1} & r_{m2} & \cdots & r_{mn}\end{pmatrix}=(s_1\ ,\ s_2\ ,\cdots,\ s_n)$$

It can get fuzzy evaluation set S ,from which "$\circ$" is fuzzy composition operator. Here take fuzzy operator as $M(\cdot\ ,\oplus)$ operator,that:

$$s_k=\min\left(1,\sum_{j=1}^{m}\mu_j r_{jk}\right),k=1,2,\cdots,n$$

Input above computation result into above formula and can get: $S=(0.3431\quad 0.3452\quad 0.3117)$

By above evaluation, it is clear that in critical friction angle theory, table tennis racket and table physical rebounding model comprehensive evaluation are both above 0.34, and table tennis racket and table tennis table physical rebounding model <0.34 ,so it is clear that above provided two models construction has certain reliability.

CONCLUSION

In table tennis racket and table physical rebounding model construction research, introduce critical friction angle concept, combine sports with mechanical ideals, and then analyze and get conclusions: firstly, introduce relevant critical friction angle concept,by graphic and research significance statement, it is clear that tablet tennis racket and table tennis table physical rebounding model construction in critical friction angle is a kind of feasible research and then build basis for next step researching. Secondly, for table tennis movement process trajectory problem, put forward critical friction angle

calculation method, and propose critical friction angle-based table tennis racket physical rebounding model and table tennis table physical rebounding model. In model establishment and evaluation process, it finds: in critical friction angle theory, table tennis racket and table physical rebounding model comprehensive evaluation weigh is higher and has certain reliability.

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