# The dynamic simulation model for table tennis ornamental value research

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**Abstract:** Using the analytic hierarchy process (AHP), and the influence factor of weight value and quality of athletes experience and the relation between the various influencing factors. The results to the diameter of the table tennis athletes experience quality. Consider ping-pong ball diameter changes on the quality of the audiences, table tennis fall time of mathematical programming model is established. In the case of spectators and athletes are satisfied, establish fall time and kinetic energy integrated optimization control of mathematical programming model, will get into the table tennis dynamics simulation model, work out the best table tennis diameter.

## 1 Introduction

In 2000, international table tennis federation increased international table tennis professional competition official ball diameter from 38mm to 40mm. The aim is to further increases table tennis air resistance during air running , slow down competition's ball running speed, so that achieve the purpose of further increasing and enriching table tennis professional athletes hitting techniques and skills, and finally increase table tennis competitions' overall appreciation. However, since incoming of table tennis "big ball era" up to now, ball diameters disputes never cease. Chinese and foreign coaches and athletes from all walks of life have mixed [1-3]. It is worth noting that due to professional athletes' height, playing habit, gripping habit differences, their sensitivities to ball diameter changes is also different [4-7]. Almost all literatures were considering problems that started from athletes perspective, little people researched on audience appreciation quality, the paper analyzes from athletes' experience qualities and audiences' appreciation qualities two aspects, makes comprehensive consideration and research on table tennis best diameter.

## 2 Table tennis dynamical simulation model

In small ball era, athlete tends to win by service; it greatly reduces mass appreciation quality. And in big ball era, table tennis ball speed and rotational speed are main factors affect competition appreciation, accordingly establish table tennis dynamical simulation model, by which it looks for big ball and small ball's ball speed and rotational speed changes status after diameter changing so as to verify its relation with audience appreciation quality. In the following, it respectively researches on audience appreciation quality influence from table tennis ball speed and table tennis rotational speed two aspects.

### 2.1 Table tennis diameter increasing to speed influence

Rotational table tennis in running process mainly suffers gravity, buoyancy force, additional mass force, air resistance and Magnus force effects. Among them, gravity direction is opposite to buoyancy force, air resistance direction is opposite to table tennis movement direction.

Gravity $F_g$ expression is as following: $F_g = mg = \frac{1}{6}\pi\rho_d d^3 g$ From which, $\rho_d$ is table tennis density, $d$ is table tennis diameter,

Buoyancy force $F_b$ is equal to table tennis sphere arranged same volume air mass force, its computation formula is

$$F_b = m_a g = \frac{1}{6}\pi\rho_a d^3 g .$$

For induction magnetic field generated additional mass force, its size is: $F_{m'} = \frac{1}{12}\pi\rho_a d^3 \frac{dv}{dt} = \frac{1}{2}m_a \frac{dv}{dt}$

$\frac{1}{2}m_a$ is always recording as $m'$, is called additional mass. Additional mass force can be ignored when table tennis speed hasn't greatly changed.

Spherical object suffered resistance in fluid is equal to the spherical object radius, speed, fluid viscosity and 6π product. The law is called Stokes law. Suffered resistance is called Stokes force. Its $F_S$ computing formula is: $F_S = 6\pi r v\mu = 3\pi d v\mu$

When a rotational object rotational angular speed vector and object flight speed vector don't overlap, it will produce a horizontal force in rotational angular speed

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vector and translational speed vector composed plane vertical direction. Under the horizontal force effects, object flight trajectory occurred deviation phenomenon is called Magnus effect. To Magnus effect, by scholars researching, main mechanisms have, 1) asymmetric displacement thickness, 2) asymmetric centrifugal force, 3) asymmetric wall friction stress, 4) asymmetric transition, 5) asymmetric separate and vortex, 6) asymmetric secondary flow. To sphere, Magnus force can be expressed by following formula: $F_M = \frac{1}{8}\pi\rho_a d^3 V\omega$

Calculation adopted initial condition is as Table 1 show.

Table 1: Model initial parameter

| Parameter | Value |
|---|---|
| Big ball rotational speed | $116.5r/s$ |
| Small ball rotational speed | $133.5r/s$ |
| Big ball | m = 2.7g, d = 40mm |
| Small ball | m = 2.5g, d = 38mm |
| Environment | T = 20 ˚C, P = 1atm |
| Air density | $\rho_a = 1.293kg/m^3$ |
| Viscosity | $\mu = 1.86\times10^{-5} Ns/m^3$ |

Input small ball known data into rotating table tennis horizontal direction and vertical direction dynamical equations, and get $v_x = \frac{dx}{dt} = 12m/s$, $v_y = \frac{dy}{dt} = 13m/s$ and $v = 17.6918m/s$

Input big ball known data into rotating table tennis horizontal direction and vertical direction dynamical equations, and get $v_x = \frac{dx}{dt} = 13m/s$, $v_y = \frac{dy}{dt} = 11m/s$ and $v = 17.0294m/s$.

If athlete hits different sizes two balls with same way and equal size force, because big ball and small ball rotational inertia are different, then ball movement state changes will have obvious differences, two balls rotational inertia computing formulas are:

$$I_2 = 2/3 m_2 r_2^2 = 7.9312(g\cdot cm^2);$$
$$I_1 = 2/3 m_1 R_2^2 = 6(g\cdot cm^2)$$

Calculate according to small ball rotational speed is 50 turn/second, according to moment of momentum theorem, it can calculate big ball rotational speed $\omega_2$ is: because: $M\cdot t = I_1\omega_1$ $M\cdot t = I_2\omega_2$ then: $I_1\omega_1 = I_2\omega_2$ $\omega_2 = I_1\omega_1 / I_2 = 40.59(r/s)$ two balls angular speed difference is: $\Delta\omega = \omega_1 - \omega_2 = 9.4112(r/s)$

By calculation, it is clear when hitting different sizes two balls with same way, big ball rotational speed reduces $9.4112(r/s)$ (near to1/5) to small ball rotational speed.

Big ball speed $v = 17.0294m/s$ and small ball speed $v = 17.6918m/s$, big ball speed is smaller than small ball speed. Comparing with using small ball, every round competition time will be extended, competition intense degree will be increased, and audience appreciation quality is greatly improved.

Small ball rotational speed is 50 turn/s, and big ball rotational speed is 40.59 turn/s, according to Bernoulli's theorem, high speed rotating ball's flight trajectory in the air is a curve not a straight line, curve crooked level is up to eccentric force leads to ball produced rotational speed and seed compound vector size and direction. Therefore, rotational speed reduction will affect ball assaulting, increase table tennis competition round numbers, and let audience appreciation quality improve.

### 2.2 Best diameter model establishment and solution

On the condition that athlete is satisfied, establish table tennis maximum falling kinetic energy mathematical planning model, and get maximum falling kinetic energy $\omega$, input obtained $\omega$ into table tennis dynamical simulation model, and get maximum table tennis diameter. After that, on the condition that audience is satisfied, establish minimum table tennis falling time planning model, and get minimum falling time $\omega$, input obtained $\omega$ into table tennis dynamical simulation model [8], and get minimum table tennis diameter. To get best table tennis diameter, it should consider conditions that both audience and athlete are satisfied, therefore establish falling time and kinetic energy comprehensive optimization control mathematical planning model, and get best $\omega$, input it into table tennis dynamical simulation model, and get best table tennis diameter.

Table tennis initial speed value is: $v_{10}$, $v_{20}$, $v_{30}$, table tennis initial rotational speed value is: $\omega_{10}$, $\omega_{20}$, $\omega_{30}$ .Let: $x_{10}(t) = \omega_{10}$; $x_{11}(t) = \omega_{20}$; $x_{12}(t) = \omega_{30}$

**Table tennis maximum falling kinetic energy mathematical planning model**:

(1) Model establishment

$$\min f = \frac{1}{T(t_f)}, g_1 = v_{\max} - (\sqrt{v_0^2} + \frac{2}{3}\frac{r^2\omega_0^2}{\sqrt{v_0^2}}) \ge 0;$$

$$g_2 = 1 - \frac{2}{3} r\sqrt{\frac{\omega_0^2}{\sqrt{v_0^2}}} \ge 0; h_1 = v_0\omega_0 = 0$$

(2) Model solution

When initial position coordinate is: $x_1(0) = 0, x_2(0) = -10, x_3(0) = -1,$ $x_4(0) = 0, x_5(0) = 0, x_6(0) = 0,$ and $v_{\max} = 200$ ,it solves:

$$t_f = 0.15681\text{s};\ v_0 = \{0, 94.233, 78.271\};$$

$$\omega_0 = \{-909.924, 0, 0\};\ \omega = \frac{909.924}{2\pi} = 144.819r/s$$

Input $\omega = \frac{909.924}{2\pi} = 144.819r/s$ into table tennis dynamical simulation model, and can get maximum diameter is $d = 37.2015mm$.

**Falling time and kinetic energy comprehensive control mathematical planning model**:

(1) Model establishment

$$\min f = \mathrm{k}\frac{t_f}{0.09443} + (1-k)\frac{46.653}{T(t_f)};$$

$$g_1 = v_{\max} - (\sqrt{v_0^2} + \frac{2}{3}\frac{r^2\omega_0^2}{\sqrt{v_0^2}}) \geq 0;$$

$$g_2 = 1 - \frac{2}{3}r\sqrt{\frac{\omega_0^2}{\sqrt{v_0^2}}} \geq 0; h_1 = v_0\omega_0 = 0;$$

(2) Model solution

k value range is $0 \sim 1$, when $k = 1$, it is time optimal control, when $k = 0$ it is kinetic energy optimal control, during model calculating $k = 10\%$.

When initial coordinate position is: $x_1(0) = 0, x_2(0) = -10, x_3(0) = -1,$ and $v_{\max} = 200$, it solves: $x_4(0) = 0, x_5(0) = 0, x_6(0) = 0,$

$$t_f = 0.11964\mathrm{s}; v_0 = \{0,153.013,44.049\};$$

$$\omega_0 = \{-752.455,0,0\}; \omega = \frac{752.455}{2\pi} = 119.757r/s;$$

Input $\omega = \frac{752.455}{2\pi} = 119.757r/s$ into table tennis dynamical simulation model, and can get best diameter is: $d = 39.634mm$.

# 3 Conclusion

Apply analytic hierarchy process [9] analyzing athlete experience quality influences factors, decompose a complicated qualitative analysis problem into several factors that can make quantitative analysis and solve, obtained result is relative intuitional. Utilize table tennis dynamical simulation model more vividly combining ideal state mechanical research with practical mechanical trajectory, it describes table tennis mechanical state in specific running, obtained conclusion is correct and conforms to practice. Apply falling time and kinetic energy comprehensive optimization control mathematical planning model, combine table tennis speed with rotational speed, on the premise audience appreciation quality is ensured, let athlete experience quality arrive at maximum, and finally get table tennis best diameter. For table tennis dynamical simulation model, it can promote to research on loop flight trajectory and flight speed as well as different rotational speeds impacts on loop such problems.

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