Taking table tennis vertical movement as an example to explore the combination of mechanical problems and computational simulation

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Abstract. With the gradual progress of systematic science, computational simulative technology has become a new subject. It can be applied in every field of daily life. Mechanics in physics has always been the focus of academic attention. In this paper, the vertical movement of table tennis is analyzed and the motion state of table tennis in the falling process is described. It gets the mathematical equation and the division equation of the movement and designs the corresponding simulative program by using the computer, so as to study the movement law of the ball. This research method can promote and improve students' interest and level in studying mechanics, mathematics and computational science. It has a far-reaching influence on the development of physics in China.

Keywords: Table tennis, Mechanics, Simulation

1. Introduction

Computer simulative technology is an important means to analyze and study the system operation behavior and dynamic process[1]. In recent years, with the rapid development of informational processing technology, the development of simulative technology is very rapid. In the past, the complex analysis problems that people are difficult to complete can be easily completed by simulative technology today[2]. The research of scholars has achieved good results.

As we all know, the movement process of table tennis is very complicated. It includes: vertical movement, rebound movement and horizontal movement. In this paper, we only study the rise, fall and motion of the small ball after its interaction with the object[3]. The state change after the collision between the ball and the table is an important factor to be studied. Therefore, the study of the vertical movement of table tennis has a profound impact on the future progress of mechanics.

2. Summary of computational simulative technology

Computational simulation technology is a kind of technology that uses computer software to simulate the actual environment and carry out scientific experiments[4]. It has the advantages of economy, reliability, practicality and safety. It is based on the mathematical theory and it takes the computer and various physical facilities as the equipment to use the system model to simulate the envisaged system. In some important
fields of science and technology in China, simulative technology has become an indispensable research method.

2.1 The development of computational simulative technology

With the development of computer technology, computing technology, image forming technology and system modeling technology, computational simulative technology has gradually become the focus of attention. It has experienced four stages of development:

1. Simulative experiment of the model
   In the original simulative idea, the model experiment is based on the physical theory\[5\]. However, this approach lacks flexibility and accuracy.

2. Model simulation based on digitization
   This method uses computer to analyze and calculate the assumed model, but the results are not intuitive.

3. Image model simulation
   Compared with the above three methods, graphical simulation uses a large number of graphics and images to express the simulative results. This method is intuitive and concrete.

2.2. Research on the method of simulative technology

1. Simulative method of system modeling
   The traditional model building method is based on the experimental identification technology\[6\]. In recent years, the system identification technology has developed rapidly. Therefore, scholars put forward a structured modeling method based on model base. This method is suitable for the modeling of simulative objects. It can realize the splicing and reuse of the model on the basis of the database.

2. Simulative modeling method
   In order to adapt to the development of computational hardware and software environment, modern simulative technology also adopts the separation technology of model and experiment. It can be divided into parameter model and parameter value to improve the flexibility and efficiency of simulation.

3. Simulative method of virtual experiment
   The experimental framework includes: model parameters, input variables and output variables. Modern simulative technology can distinguish the experimental framework from the control area of simulative operation. In this way, when we need different output variables, we do not need to modify the simulative model or even do simulation experiments again.

3. The research object and method of this simulative experiment

3.1. Research object
   We study the mechanical problems in the vertical movement of table tennis, so the object of this study is table tennis in the movement.

3.2. Research methods
   The research method used in this experiment is computational simulation. It uses the modeling function of simulation software to build complex mechanical model. According to the model we can solve the algebraic equation to determine the table tennis movement state and force. This process can easily get the important parameters in the falling process of table tennis.

3.3 Establishment of corresponding system model
   Before the computational simulation of table tennis, we need to establish the system model of the research object. The internal and environmental parameters of table tennis are needed to build the model. If the
parameters are not complete, the theoretical calculation of theoretical mechanics can also be used as the calculation method of the parameters of the solid model.

4. The establishment of mathematical equation and difference equation of table tennis
In the process of table tennis movement, it is assumed that the collision recovery coefficient between table tennis and vibration table is \( \alpha \). The collision between table tennis and table top is elastic collision. Therefore, in the process of collision, there is no loss of mechanical energy of table tennis. The experiment of the falling motion of the ball is shown in Fig 1.

![Figure 1. An experiment on the falling movement of table tennis](image)

The displacement of the vibration table is \( -\beta \sin \omega t \). We can assume that table tennis does free fall, and its initial position is \( h \) from the table. Let \( t_j \) be the time of the \( j \)-th collision. The velocity before the \( j \)-th collision is \( -u(t_j) \). After setting various parameters, we can calculate the movement speed of the vibration table as follows:

\[
w(t) = -\beta \omega \cos(\omega t)
\]

It can be seen from the formula of free falling body in Physics:

\[
t_{j+1} - t_j = 2v(t_j)/g
\]

We can introduce two dimensionless parameters as the state parameters of the system:

\[
\varphi = \omega t V = \frac{2\omega v}{g}
\]

The \( \varphi \) shown above is regarded as the phase of collision between the small ball and the table. \( V \) is considered as the velocity of the ball after collision with the table. We introduce a dimensionless parameter as the control parameter \( \gamma \) of the system. Then the following equation forms will appear:

\[
\gamma = \frac{2\omega^2 (1 + \alpha) \beta}{g}
\]

It can be seen from the above derivation that the expression of the speed of table tennis at the corresponding time is very complex. Therefore, we need to use the difference method to solve the equation. Then the
following equation forms will appear:

\[ \varphi_{j+1} = \varphi_j + V_j \]

The impact between table tennis and table top will produce dissipative effect. Then the following second-order difference nonlinear equations will appear:

\[ V_{j+1} - w(t_{j+1}) = \alpha(-u_{j+1} + w(t_{j+1})) \]
\[ v_{j+1} = \alpha v_j - \gamma \cos(\varphi_{j+1}) \]

5. Design and result analysis of computer simulation program

In order to describe the relationship between the rebound speed and time of table tennis intuitively, it is very important to use some data to explain it in the process of simulation. We can use the non-vibration table to analyze the movement state of table tennis, which can better describe the physical properties of small balls.

The initial value of dimensionless given in the above formula is:

\[ \alpha = 0.8 \quad \beta = 0.01 \quad \omega = 3.14 \quad h = 1 \quad G = 10 \]

The relationship between rebound speed and time of table tennis is shown in Fig 2.

![Figure 2. The relationship between rebound speed and time of table tennis](image)

From the data, we can estimate that the general change of motion speed is a decreasing trend. After our simulation calculation and analysis, we find that the vibration of the table top will prolong the vibration time of table tennis, and it will make the rebound height of table tennis higher. From the data we find that when the table is not involved in the movement, the number of small ball vibrations is 69. When the table is in motion, the number of vibrations of the ball is 27.

6. Conclusion

In this experiment, the mathematical equation and difference equation of the small ball colliding with the table in the process of table tennis vertical falling are derived. After designing the corresponding computer simulation program, we also get the corresponding result analysis. It can be said that the conclusion of this
experiment has a very positive effect on the research of the law of table tennis movement and physical
mechanics. In addition, it really also promotes and enhances students’ interest in learning physics and
computer technology.

References
[1] Katti D K K. Computational Mechanics Routes to Explore the Origin of Mechanical Properties in a
Biological Nanocomposite: Nacre[J]. 2004, 844.
[2] Amin, M. H. M, Arifin, A. M. T, Hassan, M. F,等. An Evaluation of Mechanical Properties on Kenaf
Natural Fiber/Polyester Composite Structures as Table Tennis Blade[J]. Journal of Physics:
Conference Series, 914:012015.
[3] Sze Yee Lye, Joyce Hwee Ling Koh. Review on teaching and learning of computational thinking
through programming: What is next for K-12?[J]. Computers in Human Behavior, 41(dec.):51-61.
[4] ZHU Xun-hua. Establishment of Table Tennis Clubs on the"Integration of Sports and Education"in
Universities--Taking East China University of Science and Technology(ECUST)as an Example[J].
Sport Science Research, 2008.
[5] Ph. Lorong, J. Yvonnet, G. Coffignal,等. Contribution of Computational Mechanics in Numerical
Simulati of Machining and Blanking[J]. Archives of Computational Methods in Engineering, 2006,
13(1):45-90.
[6] Anquetil E, Lorette G. Perceptual Model of Handwriting Drawing Application to the Handwriting
Segmentation Problem[C]// 1997.