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Application of Mathematical Model in Dynamic Analysis and Monitoring of Mechanical System

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Abstract: *With the increasing popularity of mechanical system power, mechanical system plays an increasingly important role in various projects in China. It is not only directly related to personal safety, but also affects the enormous economic benefits brought by mechanical engineering applications. Therefore, it is necessary to analyze and monitor its operation status in order to detect potential dangerous signals in advance and ensure the stable operation of its mechanical system equipment. The purpose of this paper is to give us a deeper understanding of the dynamic characteristics of rotating machinery systems. It also provides a dynamic basis for parameter optimization design, fault diagnosis, vibration control and so on. In this paper, the steady and transient steering characteristics of an automobile train system consisting of one tractor and five trailers with double axle steering are studied by using the concept of ADAMS. The research methods of design research analysis, experiment design analysis and optimum design analysis are adopted. The effects of structural parameters such as lateral stiffness of tire, length of tractor rod, position of articulation point, front wheel rotation angle and service parameters on trajectory follow ability of tractor and Trailer (i.e., the same rut of tractor and trailer) are analyzed. The optimization schemes of the Steady-state circular motion and the figure-8 motion of the train under different working conditions are put forward. The experimental results show that: the trajectory deviation obtained by the experimental method in this paper decreases by 70% to 80%, the deviation is smaller, and the operation of mechanical system equipment tends to be more stable.*

Keywords: *Mathematical Model, Mechanical System, Dynamic Analysis, Automobile and Train System*

1. Introduction

With the increasing complexity of mechanical equipment, the analysis of mechanical system dynamics has received increasing attention. Machinery is an important equipment in the modern industrial industry, especially large-scale power machinery, widely used in aerospace, electric power, machinery, transportation, chemical and other fields. Mechanical engineering applications bring enormous economic benefits. The most important one is the kinetic parameter optimization design technology. According to the dynamic characteristics of the rotating mechanical system, the dynamic parameters of the system are optimized, so that the rotating machine works at the optimal vibration frequency and amplitude to make a safer and more reliable rotation equipment[1].

Mathematical models are widely used in mechanical system dynamics. In some production machines, the equivalent moment is a function of the equivalent component angle and angular velocity. When the functional formula of the equivalent moment is too complicated to integrate, or the equivalent moment is given by a series of discrete data, the analytical method cannot be used, but the mathematical model must be used to solve[2].The mathematical model divides the differential equation into segments, and divides the time interval into many equal cells. It is considered that the function in the interval changes linearly or changes according to some approximation law, and then the initial value of the interval is used to find the end point value of the interval. Such an interval and a range of requirements[3].

In this paper, the steady state and transient steering characteristics of the simplest car train system are studied, and the parallel explicit method integral system is applied. By analyzing a large amount of kinetic information obtained by parallel calculation, it is found that these two kinds of simplest rotating mechanical systems contain extremely rich dynamic behaviors, and there are chaotic chaos, period-doubling bifurcation, bifurcation, saddle-node bifurcation. Road that eventually causes the movement of the centrifugal governor system to become unstable[4].Numerical analysis is widely used in various fields. Mechanical system dynamics involves a wide range of knowledge, but the core is to construct a dynamic model, analyze the model, list the differential equations, and finally solve. Knowledge of numerical analysis has been involved many times in this process. First of all, when building a model, this is an approximate process, which means that we are always assuming until we approximate the true value. This is like a function approximation in numerical analysis, using a known function to approximate a problem that is difficult to solve in reality. At the same time, it is inevitable to use the solution to the equation in numerical analysis again when solving the differential equation. In summary, numerical analysis has been fully applied in mechanical system dynamics, and mechanical system dynamics have been developed faster on the basis of numerical analysis.

The organization of this paper is as follows. The first part introduces the background and research significance of this field, as well as the innovation points of this article and the organization of the article. The second part introduces the significance of mathematical models, numerical analysis, mathematical modeling, and the application of numerical analysis in mechanical system dynamics. The third part selects the steady state and transient data of the car train system in the mechanical system to describe the experimental data set and model description. The fourth part introduces the result analysis and experimental numerical analysis method of the mathematical model in the mechanical system dynamic experiment. The fifth part is a summary of the full text description and mechanical system dynamics analysis monitoring.

2. Proposed Method

2.1. Related Work

Considering the effects of chemotaxis inhibition due to drug action, Munoz A I proposed a mathematical model to describe the movement of tumor cells into the bone marrow to the metastatic site. This model considers the evolution of the signaling molecule CXCL-12 secreted by osteoblasts (osteocytes responsible for bone mineralization) and PTHRP (tumor cell secretion) that activates osteoblast growth. The model consists of a second-order PDE coupling system that describes the evolution of CXCL-12 and PTHRP, a logical ODE that simulates the density of osteoblasts, and an additional equation for each cancer cell. We also simulated the system to illustrate the qualitative behavior of the solution. Also introduced in detail the numerical method of resolution[5].Zagzoule M built a mathematical model of the brain cycle. It is based on a nonlinear equation for pulsating fluids in a dilatable catheter and is used to simulate a network of entire cerebral vessels, from the carotid and vertebral arteries to the sinus and jugular vein. The quasi-linear equations are numerically solved using the two-step Lax-Wendroff scheme. The results of this model are in good agreement with the pressure and flow data recorded by the human body during the break. This model is also used to study autoregulation during arterial hypotension. A close relationship between cerebral blood flow (CBF) and capillary pressure was obtained. Ventricular vasodilation does not maintain CBF at its control value at an arterial pressure of 80 mmHg. At the lower limit of autoregulation (60 mm Hg), the zero transmural pressure diameter of almost the entire arterial network is increased by 25%, thus maintaining CBF[6].

Similarly, treatment of type 1 human immunodeficiency virus (HIV-1) infection during the symptomatic period can significantly improve patient survival. Shiri T proposed a two-fold HIV mathematical model that captures dynamic changes in the immune system and two HIV-1 variants under antiretroviral therapy. Shiri T explored the effects of chemotherapy on the dynamics of two strains of virus and T lymphocytes, one of which is phenotypically resistant to drug action. Model calculations indicate a common pattern of increased CD4+ T cell counts. During the first weeks of treatment, CD4+ T cells increased dramatically and then gradually increased, and these increases were achieved entirely by clonal expansion of pre-existing CD4+ T cells. During the first week of treatment, plasma HIV RNA dropped dramatically to zero levels. If the drug efficacy is equal to or higher than the threshold efficacy, the viral load is maintained at zero level, and if the drug efficacy is less than the threshold efficacy, the viral load is gradually increased until stable. The viral rebound during treatment was entirely attributable to the recovery of CD4+ T cells. The results also indicate a dynamic balance between viral load and cytotoxic T lymphocyte (CTL) response in infected individuals during drug treatment[7].

Gan C and his team designed a system compensator to counteract the mechanical characteristics of power electronically controlled induction motor drives with coupled generator systems. Accurate simulation of high speed and high power mechanical system dynamics can be performed using a

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compensator simulation scheme. Considering the entire operating range of the test system, the compensator was developed based on the system transient response of the test set. The design process of the compensator is described and verified in the time and frequency domains. Finally, the effectiveness of the compensator is proved by simulation and experimental simulation of aero-engine dynamics[8]. Szalai R proposed a mechanical system that exhibits non-deterministic singularity, that is, a point in a non-deterministic system in which the forward time trajectory becomes non-unique. Coulomb friction exerts linear and angular forces on the wheels mounted on the turntable. In some configurations, friction is not uniquely determined. As the dynamics progress beyond the singularity and the mechanism slips, the future state becomes uncertain until a set of values that may occur. For some parameters, the system repeatedly returns to the singular point, resulting in frequent but unpredictable behavior, which constitutes an uncertain chaotic dynamics. The robustness of this phenomenon makes us hope that it will continue to exist under more complex friction models, manifested by extreme sensitivity to initial conditions and complex global dynamics due to local deterministic loss due to discontinuous friction limitations learn[9].

2.2. Mathematical Model

(1)Mathematical model theory

There is no standard definition of "mathematical model". The mathematical model in the broad sense includes "all concepts, theoretical systems, formulas, equations and algorithm systems" in mathematics, and narrowly explains "mathematical models" to include only some structure that reflects the mathematical relationship between specific problems or things. The mathematical model is the extension of the model, a broad term of social terminology in mathematics. Its purpose is to make it easier for people to continue to mathematically analyze and deal with the problem in order to obtain more and deeper information about the thing or system[10]. It can be said that many mathematical models have evolved naturally from life, and they are ordinary around us. For example, the mathematical formula of Newton's three laws, the formula expression of the Pythagorean theorem, the famous electromagnetic field theory Maxwell’s equation in physics, are all mathematical models of "creation" under the "unconscious" of previous scholars. At that time, people were not eager to refer to these conclusions as "mathematical models", but simply referred to as "mathematical expressions" of problems. In the subsequent development and research, people began to use "mathematical models" to formally express and solve these problems. And we can see that these mathematical models are not only used in the field of mathematics, it affects many different fields of knowledge and development.

(2) Data analysis

Numerical analysis is a discipline that studies the numerical calculation method and its theory of solving mathematical calculation problems by computer. It is based on the theory and method of solving mathematical problems in digital computers. main part. The problem of numerical analysis is how to design an effective method to approximate the solution of a mathematical problem or mathematical model[11]. Since mathematical problems or mathematical models are generally mathematical expressions obtained by engineering practical problems through certain simplifying assumptions, the mathematical problem is actually an approximation of the actual problem to be solved. In this sense, the design seeks mathematical problems. The approximate solution is more appropriate than calculating its exact solution. There are several types of the essence of numerical analysis, including the nature of metrics, the nature of mapping, and the nature of the transformation of system space. The simplest and most understandable is the essence of its measurement. As the name implies, objects of mathematical models can be measured and expressed in mathematical language. The most common measure of metrics is the formula measure, which is one of the formula measures. The mathematical model mainly has four types of metrics:

1) System structure metrics, such as "vector" for system state;

2) Predictive metrics, such as probability problems, fitting problems;

3) Optimization value metrics Type, such as seeking the optimal value (point), extreme value problem;

4) Function equation metrics, such as function equations, root finding problems[12].

(3) Mathematical modeling

In the fields of nature, economy, society, science and technology, relevant problems can be

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approximated by relevant subject knowledge and mathematical language. This process is called mathematical modeling. In the actual process, these results often require a lot of calculations to get, and need the power of the computer. Therefore, the main research of numerical analysis is to use a variety of mathematical methods to model the actual problems in production, and to calculate the approximation by computer[13]. At the same time, the numerical analysis puts forward the actual problem according to the actual situation when solving the problem, then establishes the associated mathematical model, then selects the reliable numerical calculation method, carries on the computer program design, and finally approximates the process of calculating the result on the machine. The numerical analysis by computer application has the characteristics of strong computing ability, small error analysis, reliable theoretical basis and numerical experimental verification. The specific mathematical modeling process is summarized in the following four steps:

1) Analyse problem ;

2) Symbol conventions and model assumptions;

3) Model establishment and solution;

4) Model analysis and improvement.

These four steps are at the heart of mathematical modeling and are indispensable. The flow chart of the whole process is shown in Figure 1.

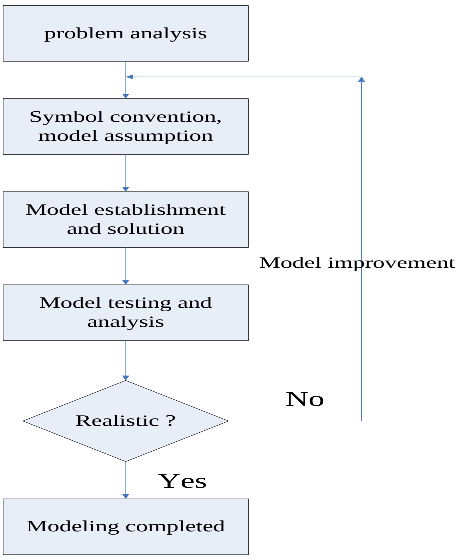

Figure 1: Mathematical modeling flow chart

2.3. Application of Numerical Analysis in Mechanical System Dynamics

(1)Theory of numerical analysis

Numerical analysis is widely used in mechanical system dynamics. In some production machines, the equivalent moment is a function of the equivalent component angle and angular velocity. When the functional formula of the equivalent torque is too complicated to integrate, or the equivalent moment is given by a series of discrete data, the analytical method cannot be used, but must be solved by numerical methods. The numerical method divides the differential equation into segments, and divides the time interval into many equal cells. It is considered that the function in the interval changes linearly or changes according to some approximation law, and then the initial value of the interval is used to find the end point value of the interval. Such an interval is sought in a range. The numerical method is implemented on an electronic computer. Although it is an approximation algorithm, it generally guarantees the accuracy required for engineering applications. Take the planer as an example:

Differential equation:

$$\frac{d\varpi}{dt} = \frac{M_e(\varpi)}{J_e} \tag{1}$$

Solving with the Runge-Kutta method, you can get an iterative:

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$$\left.\begin{array}{c} \varpi_{i+1} = \varpi_i + h(k_1 + 2k_2 + 2k_3 + k_4)/6 \\ k_1 = f(\varpi_i) \\ k_2 = f(\varpi_i + hk_1/2) \\ k_3 = f(\varpi_i + hk_2/2) \\ k_4 = f(\varpi_i + hk_3/2) \end{array}\right\} \tag{2}$$

Where h is the step size, ie the length of the divided small time segment. In this way, According to the given initial conditions $t = t_0, \varpi = \varpi_0$, The ϖ_1 of the angle of t_1 can be obtained. According to this method, the motion law of the equivalent member can be obtained by continuously solving the problem.

In addition, numerical analysis has great applications in the decoupling of multi-degree-of-freedom vibration equations. At present, we usually use the modal superposition method and the direct integration method to solve the equation of motion of the linear system. Under normal circumstances, the damping does not have orthogonality to the modality. We use the complex modal analysis method to first convert the approximate state equation to the first order, and then use the solution eigenvector and the generalized eigenvalue method to form the transformation matrix. Complex modal superposition solution[14]. For the presence of a proportional or modal damping system, the line is decoupled by a real modal analysis method and then solved by a modal superposition method. For arbitrary damping matrices, it is not necessary to adopt eigenvalue and eigenvector column equations, nor need to use coordinate transformation method to decouple, directly use a direct integration method to find the dynamic response of the system in the time domain. This method is more suitable for computers operation[15].

From the theory of linear algebra, any vector of the space can be represented by a linear combination of the set of substrates:

$$X = \eta_1 \phi^{(1)} + \eta_1 \phi^{(1)} + \ldots + \eta_n \phi^{(n)} = \phi\eta \tag{3}$$

After conversion：

$$\phi^T M \phi \ddot{\eta} + \phi^T K \phi \eta = 0 \tag{4}$$

According to the orthogonal properties of the regular mode matrix, the above equation can be transformed into:

$$\ddot{\eta} + \Omega \eta = 0 \tag{5}$$

Since the matrix is a diagonal eigenvalue matrix, the above formula can be expanded to:

$$\left.\begin{array}{c} \ddot{\eta}_1 + \varpi_1^{\,2} \eta_1 = 0 \\ \ddot{\eta}_2 + \varpi_2^{\,2} \eta_2 = 0 \\ \cdots \\ \ddot{\eta}_n + \varpi_n^{\,2} \eta_n = 0 \end{array}\right\} \tag{6}$$

Obviously, the above equations are composed of n single-degree-of-freedom vibration equations. From the perspective of the equations, a multivariate equation is transformed into multiple unary equations by linear transformation. From the point of view of mechanical dynamics, a vibration problem with n degrees of freedom is transformed into n single (one) degrees of freedom vibration problem, that is, a vibration problem consisting of n degrees of freedom is decomposed into n independent the main vibration. This state of motion is derived from the superposition of the main vibrations of each order. This method is called a mode superposition method. The mode superposition method can decouple the multi-degree-of-freedom motion state and solve the practical problems in a great way.

Emphasis on mechanical dynamics theory development and application innovation.There are also some other mature mathematical tools applied to mechanical dynamics research. Many components, components, and mechanisms in machinery are complex motion systems. From the perspective of reducing computational complexity, it is urgent to establish a reasonable approximate mechanical

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model to describe the inherent characteristics of mechanical structures. For example, for a multi-degree-of-freedom damped vibration system, the vibration linear differential equation can be established as follows:

$$M\ddot{X} + C\dot{X} + KX = f(t) \tag{7}$$

Where M, C, K represent the mass, damping and stiffness matrix of the vibration system, respectively. $X = [X_1, X_2, ..., X_n]^T$ is a generalized coordinate array with multiple degrees of freedom. According to the multi-degree-of-freedom equation (7), the numerical solution method can be designed or studied. It can calculate the modal parameters such as natural frequency, natural matrix and natural damping of the vibration system. The dynamic behavior characteristics of the vibration system are analyzed under the condition of parameters and input changes. Furthermore, the nonlinear dynamics of the nonlinear vibration differential equation analysis system can be considered by considering the nonlinear factors of the system[16]. It is necessary to deeply understand the mathematical systems such as the dynamic system theory of ordinary differential equations, the numerical calculation method and the dynamic behavior analysis method[17].

In the face of flexible mechanical systems, it is necessary to understand the theory of distributed parameter systems, such as nonlinear vibration modeling of flexible rotor systems and dynamic behavior analysis of large wind turbine blades[18]. Taking the nonlinear vibration model of the flexible rotor system as an example, the flexible rotor system is forced to vibrate under the action of the eccentric centrifugal force synchronous with the rotor speed due to the eccentricity of the mass at high speed, that is, the center of mass deviates from the nominal center of the rotor. Since the vibration between different points on the flexible rotor has mutual influence, that is, there is a coupling relationship, the nonlinear vibration of the flexible rotor system has the characteristics of space-time coupling, which is essentially an infinite dimensional distribution parameter system. In many cases, if the elastic system is studied as an infinite multi-degree of freedom system, the mathematical physics equation, that is, the partial differential equation, is needed to describe the dynamic behavior of the distributed parameter system:

$$\frac{\partial X(z,t)}{\partial t} = AX(z,t) + Bu(z,t) + F(X(z,t), u(z,t)) \tag{8}$$

Equation (8) represents a mathematical physics equation (partial differential equation) with a first derivative in time, where t is a time variable, $z \in \Omega$ is a spatial variable, $X(z,t), u(z,t)$ represents state variables and input variables related to time variables and spatial variables, respectively. A, B are the corresponding spatial differential operators, $F(X(z,t), u(z,t))$ is a nonlinear function related to state variables and input variables and their derivatives. In addition, equation (2) also needs to meet certain boundary conditions and initial conditions. Similarly, this requires a deep understanding and mastery of the dynamic system theory and solution methods of partial differential equations, numerical calculation analysis methods and other theories.

In addition, in the process of model identification and parameter estimation of mechanical systems based on the input and output data obtained from the test, intelligent identification algorithms such as neural networks, support vector machines, extreme learning machines, and optimization calculation methods such as descent algorithms and evolutionary algorithms are needed. Parameter estimation algorithms such as least squares and maximum likelihood estimation can be mastered and applied. It can be seen that the study of the dynamics of mechanical systems requires a lot of mathematical knowledge and theory[18-20].

3. Experiments

3.1. Experimental Data Set and Model Description

In this paper, the modeling concept of ADAMS is used to study the steady-state and transient steering characteristics of a vehicle train system consisting of a trailer and a five-axis dual-axle trailer. The concept of the graph theory, the rigid body is defined as a vertex, the hinge is defined as an edge, and the relationship between the edge and the connected vertex is called an association. Such a set of vertices and edges is called a graph. The mechanical model of the automobile train system can be represented as the structural diagram shown in Figure 2. As can be seen from the figure, the model

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consists of 29 rigid bodies, 1 plane hinge constraint, 27 rotary hinge constraints, 12 kinematic constraints, 5 coupler constraints and multiple gravity, hinge friction, tire force. The degree of freedom is DOF=(29-1)×6-1×3-27×5-12×1-5×1=13. Since the speed of the car train is up to 8Km/h, the tire model uses a linear model. The biaxial steering effect of each trailer is simulated by coupler constraints, which reduces the number of constraint equations and improves the efficiency of the solution.

In the calculation, the origin of the overall coordinate system is selected at the center of the front axle of the main vehicle, and the origin of the joint coordinate system is selected at the centroid of each rigid body. The y plane of the joint is parallel to the ground plane, the X axis points in the opposite direction of the forward direction, and the y axis points. On the right side, the Z axis is up in the right hand coordinate system.positive.

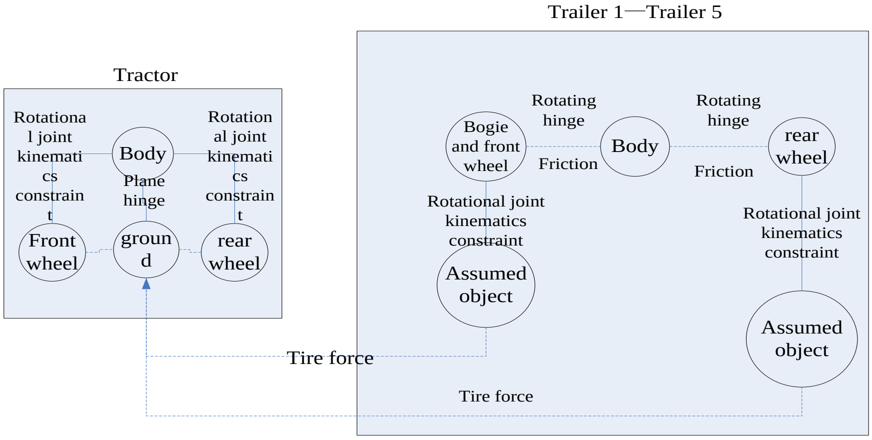

Figure 2: Structure diagram of multi-body system for two-axle steering car train

3.2. Experimental Process

The original parameter data in the model is obtained by combining the measured data with the empirical formula. Table 1 lists the main parameters of the two trains, where train 1 is a warehouse transport train that has been put into use, and train 2 is a warehouse transport train being developed. In order to verify the correctness of the model numerical simulation results, the train was tested. The test was carried out at the Armory Training Ground of an ammunition warehouse of the People's Liberation Army. The driver's fixed steering wheel angle was used to control the front wheel of the tractor to travel according to a certain circular trajectory. The trajectory of the tractor and the center of the rear axle of the last trailer was recorded. The measurement results show that the lateral deviation of the trajectory is 205mm, and the trajectory of the trailer is smaller than the main vehicle. The calculation results are in good agreement with the test results.

Table 1: Main parameters of the two trains

	Quality (full/empty)kg	Centroid to front axle distance (mm)	Wheelbase (mm)	Traction length (mm)	Tire model
Train 1				505	
Tractor	900	600	970		High-elastic solid tire
Trailer	416/80	350	700		High-elastic solid tire
Train 2				780	Before: 5.00-8
Tractor	1950	950	1300		After: 6.00-9
Trailer	1250/250	400	800		4.00-8

4. Discussion

4.1. Experimental Numerical Analysis Method

Figure 3 is the simulation result of the steady state of the front wheel angle step input of the train 1 (the front wheel step amplitude 20 fly step speed 200/5) enters the steady state. It can be seen from the

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figure that the tractor and the last section are trailered. The lateral deviation of the motion path at the center of the shaft is 159mm.

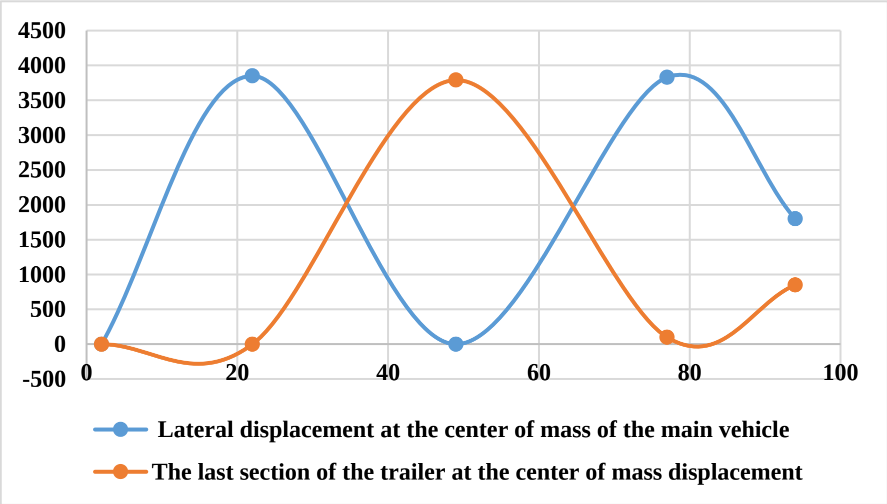

Figure 3: Displacement curve of the tractor and the last trailer when the front wheel angle of the train 1 is lost

(1) Functions of three parameterized analysis methods

The previous simulation analysis is the calculation result when a set of design values is taken for each design parameter of the train. For further determination.The influence of different values of each design variable on train homogeneity uses three parametric analysis methods, namely design research, experimental design and optimization analysis. Firstly, the design analysis is carried out to discuss the influence of the single design variable of the length of the drawbar on the train's homogeneity. Then the experimental design analysis was carried out. The effects of the length of the drawbar, the position of the hinge l, the position of the hinge 2, the lateral stiffness of the tractor and the trailer, and the position of the center of gravity of the tractor on the train's homogeneity were discussed. Finally, the optimization analysis is carried out, and several optimization schemes of design variables are proposed. The characteristics of the three parametric analysis methods are shown in Table 2, and the parametric analysis algorithms are compared as shown in Figure 4.The previous simulation analysis is the calculation result when a set of design values is taken for each design parameter of the train.

(2) Interaction of various analytical methods

As far as most mechanical systems are concerned, if only one design parameter is considered to affect the system performance, a design study method can be used. The experimental design method should be used when determining the parameters (parameter sensitivity) that are most sensitive to performance effects among multiple design variables and the interaction between the various parameters. The above two methods provide suitable initial values for the optimization analysis, and ensure that the solution result is a global optimal solution. Finally, the constraint function and the optimization method are determined according to the actual problem, and an optimized design scheme can be obtained by performing optimization analysis.

Table 2: Characteristics of three parameterized analysis methods

Design research	Experimental design	Optimization Analysis
Single variable	Multiple design variables	Multiple design variables
Number of Japanese and Japanese standard functions	Number of Japanese and Japanese standard functions	Number of Japanese and Japanese standard functions
Unconstrained function number	Unconstrained function number	Unconstrained function number
Easy to use and powerful		

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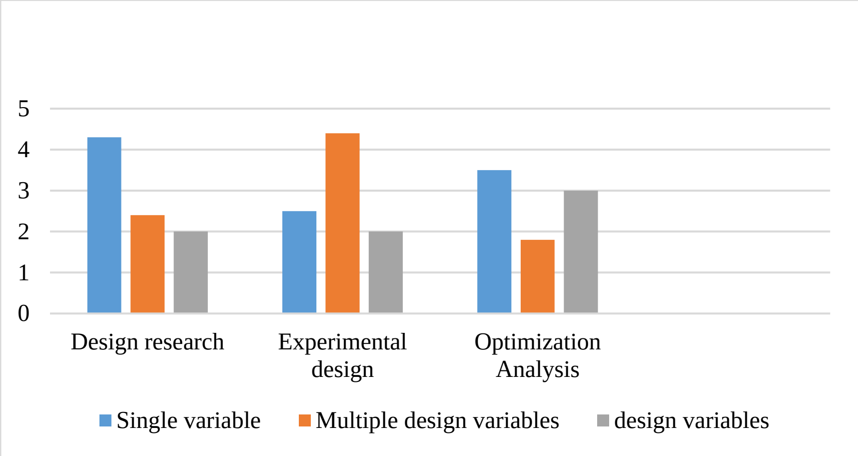

Figure 4: Comparison of three parametric analysis algorithms

4.2. Analysis of The Results of Mathematical Models in Mechanical System Dynamic Experiments

(1) Parametric model description

1) Selection of design variables: length of the tow bar, position of the hinge 1, position of the hinge 2, lateral stiffness of the tractor and trailer, position of the center of the tractor, a car consisting of a tractor and a five-axle double-axle trailer A schematic diagram of the train system model is shown in Figure 5.

2) Selection of constraint function: each design variable is in a reasonable design range.

3) Selection of objective function: the lateral deviation between the center of the rear axle of tractor and the center of the rear axle of the last trailer is the smallest.

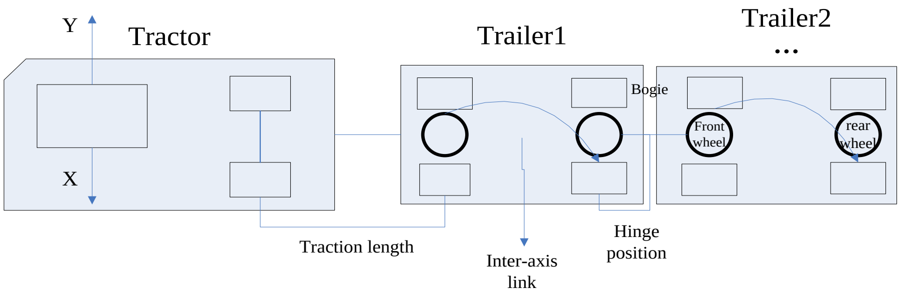

Figure 5: Schematic diagram of a two-axle steering car train

(2) Simulation results

Figure 6 is the results of trajectory deviation design. The length of the tractor rod is selected as the variable in calculation. It can be seen from the graph that when the length of the traction rod is 78 mm, the same rutting is the best. If the length of the traction rod is too large or too small, the same rutting will be worse. The animation simulation results show that the maximum lateral deviation between the tractor and the trailer occurs at the inflection point when the train is moving in the 8-shaped motion. This is due to the obvious change of train motion at the turning point. Therefore, the objective function of homology optimization should be chosen to minimize the lateral deviation of the track at the inflection point. The experimental design and simulation results of the influence of two variables, the length of the tractor rod and the distance of the hinge position 1, on the track homology during the steady circular motion of the train are presented. From the graph, it can be seen that the length of traction rod has the most obvious effect on train rutting. When the length of traction rod is appropriate (75 rows m), the same rutting is good, too large or too small, and the same rutting is bad; the distance of hinge position 1 has little effect on the same rutting. The modified feasible direction method is used to optimize the simulation results of the 8-shape motion of the automobile train. The trajectory deviation of the optimized results is reduced from 318 mm to 228 mm. The maximum lateral deviation of the trajectory between the tractor and the center of the rear axle of the last trailer decreases from 94.15 mm to 7696 NNN when the train is in steady circular motion. Parametric analysis method is used to optimize the track homology between tractor and trailer when the train is in steady circular motion and figure 8 motion. The optimization results show that the maximum lateral deviation of the track is reduced from 94.15 RNN to 76.96 . when the train is in steady circumferential motion, and from 318 mm to 228 mm when the train is in 8-shape motion.

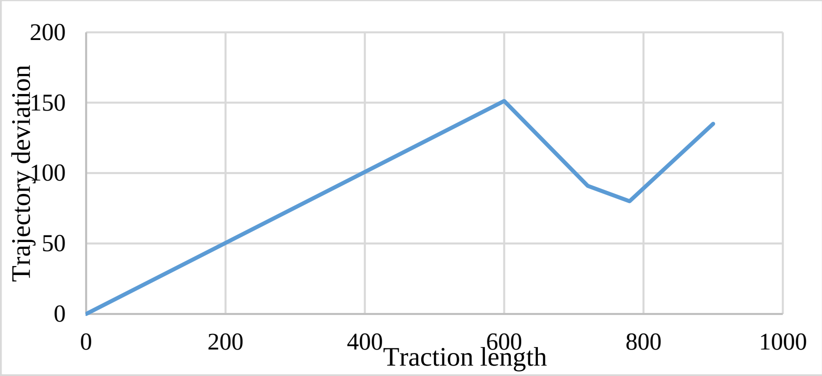

Figure 6: Research results of homology design

5. Conclusions

In this paper, the steady state and transient steering characteristics of the simplest car train system are studied, and the parallel explicit method integral system is applied. By analyzing a large amount of kinetic information obtained by parallel calculation, it is found that these two kinds of simplest rotating mechanical systems contain extremely rich dynamic behaviors, and there are chaotic chaos, period-doubling bifurcation, bifurcation, saddle-node bifurcation. The road eventually leads to instability of the motion of the centrifugal governor system . For the hexagonal centrifugal governor, the bifurcation instability is its main dynamic characteristic, and the clamping structure in the parameter space, that is, the tongue structure formed by various subharmonic responses are arranged in sequence, which is the hexagonal centrifugal speed regulation. The commonality of the mode-locked structures in each pair of parameter planes of the system. This structure is different from the fractal structure formed by other bifurcation sequences. The area of the fractal unit follows the self-similarity of the fractal, but the number of cycles remains unchanged. This is also one of the dynamic characteristics of the simple rotating mechanical system in the parameter plane. Commonality. In addition, the frequency entrainment structure of such systems is not arranged according to the farey sequence, but is arranged according to the more general Stern-Broot sequence, and the Farey tree is one of the subtrees. Finally, the classification of the oscillations of various dynamic variables of the centrifugal governor is described in detail, and it is found that there is a mixed mode oscillation phenomenon, and different dynamic variables form different oscillation modes, and the distribution of the number of peaks is equal.

In the application of the ADAMS modeling concept, the steady-state and transient steering characteristics of a vehicle train system consisting of a tractor and a five-section twin-axle trailer are studied. The design parameters, design analysis (DOE), optimization design (Optimization) and other research methods were used to analyze the structural parameters and operating parameters of the tire's cornering stiffness, drawbar length, hinge point position, front wheel angle and other parameters. The influence of the trajectory followability of the tractor and the trailer (ie the homogeneity of the tractor and the trailer). The optimization schemes of steady-state circular motion and 8-shaped motion of vehicle trains under different working conditions are proposed. The simulation results are verified by the experimental results. The research results can help us to understand the dynamic characteristics of rotating mechanical systems more deeply, and provide the dynamic basis for large-scale parameter selection for parameter optimization design, fault diagnosis, vibration control, etc. At the same time, to explore the dynamics of large complex rotating mechanical systems. The study of characteristics provides new methods and new ideas, and also contributes to the National Natural Science Foundation of China.

In summary, numerical analysis is widely used in various fields. Mechanical system dynamics involves a wide range of knowledge, but the core is to construct a dynamic model, analyze the model, list the differential equations, and finally solve. Knowledge of numerical analysis has been involved many times in this process. First of all, when constructing the model, this is an approximate process,

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which means that we have been assuming until we approximate the true value . This is like a function approximation in numerical analysis, using a known function to approximate a problem that is difficult to solve in reality. At the same time, it is inevitable to use the solution to the equation in numerical analysis again when solving the differential equation. In summary, numerical analysis has been fully applied in mechanical system dynamics, and mechanical system dynamics have been developed faster on the basis of numerical analysis.

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