Analysis of Multi-rigid-body Dynamic Characteristics of Chain Drive System

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Abstract. *Based on the theory of multi-rigid-body dynamics, the dynamic analysis of chain transmission components is carried out by using ADAMS software. Mech/pro is used to build the model, and the parametric transformation of the model is realized. The kinematic characteristics of target chain and the changing trend of contact force are analyzed, and the dynamic load conditions in transmission are obtained, which provides an important basis for reducing impact load.*

Keywords: *dynamic characteristics; chain; ADAMS; contact force*

I. Introduction

The dynamic characteristics of chain drive have a key influence on the stable movement of mechanical equipment. Generally, the multi-body dynamics calculation of transmission system includes two basic processes: the establishment of control model and the solution of dynamic parameters. The control model can be divided into physical model and mathematical model according to different categories. The two models are basically reciprocal in principle. Geometric models are usually imported by digital software, and they contain various loads and constraints, such as force, degree of freedom, motion and other physical constraints, forming a physical model that can express specific dynamic problems. Essentially, physical model and mathematical model are different. The establishment of physical model depends on the boundary conditions of mechanism, and the establishment of mathematical model is based on the coefficient matrix of motion equation. When solving the mathematical model, kinematics, inverse dynamics or static equilibrium or other analytical algorithms can be used synthetically. During the whole iteration process, it is necessary to feed back the results of the analysis to the design objective, and then make a new calculation again according to the feedback value, so as to repeat until the optimal design result is obtained.

The transmission dynamics analysis of multi-body motion must be based on the differential relationship between rigid body position and velocity. Based on the constrained multi-body mechanical system, the algebraic equation of the equivalent position constraints of the pair of motion is first required, and then the velocity and acceleration constraints are derived from the equation, and the generalized position coordinates, corresponding velocity and acceleration coordinates are obtained. Finally, the position, velocity and acceleration of each point are obtained according to coordinates. ADAMS is one of the best dynamic analysis software at present. After many years of updating and improvement, it has become widely used prototype analysis software. ADAMS has been applied in various fields, which accounts for a large part of the global software usage and has achieved great success in technology and economy.

II. Establishment of Dynamic Model

2.1. Characteristics of ADAMS Model

The main functions of ADAMS are: (1) it can be used for dynamic analysis; (2) it can simulate the whole hydraulic system; (3) it can simulate the vibration model. The data processing ability of ADAMS is also very strong. Different characteristic curves can be obtained according to different needs. The post-processing module can ensure the clarity and accuracy of the analysis results. In dynamic analysis, Lagrange equation method is the core of the whole dynamic analysis. Using ADAMS simulation software, the user defines the working load of the model according to the actual working conditions of the machine. Different types of analysis can be realized by virtual prototyping system, including kinematics. Based on the basic analysis results, the second analysis of the research object can be completed through the internal integration of relevant algorithms and techniques. Optimize. ADAMS is very open and has many interfaces, which makes it a multi-functional analysis platform. The analysis results are credible, especially for the dynamic characteristics analysis of multi-degree-of-freedom systems.

Mech/pro is a connection software developed by MSC Company to realize seamless data access for

ADAMS. The parametric model of hydraulic support in this paper can be connected with ADAMS and PRO/E through this software to realize the parametric transformation of system dynamics model, which makes the dynamic and kinematic calculation of virtual prototype model more efficient. The advantage of Mech/pro is that it can be integrated into Pro/E software, and the boundary characteristics such as rigid body load and constraint can be defined directly in the assembled model. It can output the model and boundary characteristics to ADAMS completely and finally complete the required dynamic analysis or optimization.

2.2. Model derivation

In this paper, the assembly drawing model is built by Pro/E three-dimensional software, and then imported into ADAMS after the completion of parameterization through mech/pro interface software. In dynamic analysis, different types of constraints and connection forms need to be set according to actual working conditions to realize virtual assembly and motion simulation. Through the analysis of Mech/pro software, the similarity of the model has been improved, and the work efficiency has also been improved. When constraints are imposed on the interface software, the features of the parts can be directly selected. All data in the interface software can be included in the exported data, and the parameter information will not be lost because of the complexity of the model or the tedious definition of the boundary. In practical analysis, ADAMS has the problem of inconvenience in defining some boundary conditions, which can be well solved by mech/pro. Therefore, these boundary conditions can be added to Mech/pro. When all parts are rigidized in Mech/proe, corresponding motion pairs can be added. Selecting mech/pro-set up mechanism-constraints-joint-create can add motion pairs and rotation pairs. After adding motion pairs and constraints, the unit of the system is set to mm/kg/sec/C, and then click mech/pro-interface-only write files-yes to export the CMD file. Finally, the analysis model is obtained as shown in Fig.1.

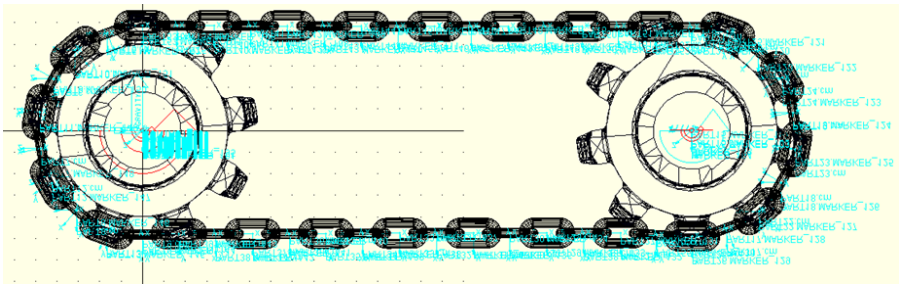

Fig.1 Dynamic Model

III. Dynamics Simulation

3.1. Setting of Solving Conditions

Before dynamic simulation, it is necessary to define the load and boundary conditions of the model, such as motion parameters, friction properties and contact conditions. In the aspect of setting the analysis step time, the total time is set to 5 seconds and the analysis step is 50. The solver adopts GSTIFF integration mode, ignores the constraints of the maximum integration step, and takes the default iteration error of the system as the precision deviation condition. In the dynamic analysis of transmission mechanism, the kinematics characteristics and contact force change process of a certain chain-ring part P_t are taken as the research object in this paper.

3.2. Result analysis

The displacement characteristics of the center of mass in the Z axis (horizontal to right) direction are shown in Fig. 2. The longitudinal coordinates are the distance between P_t and the center of driven sprocket, and the abscissa is the time. The two coordinates are approximately sinusoidal and have obvious periodic characteristics.

From the kinematic characteristics of target chain P_t , it can be seen that since the sprocket rotates counter-clockwise, the direction of movement of upper chain (side of tight chain) is - Z. The distance between the centroid position of P_t and the Z axis direction of driven sprocket is 0.25m at the initial time. With the rotation of sprockets, the initial state of sprockets shows certain fluctuation characteristics, which is due to the effect of gravity, the motion appears fluctuation and reciprocity, but the amplitude is small and can be ignored by myopia. When the time step of the model is 1.2s, the minimum value of longitudinal coordinates appears in the model as the farthest horizontal meshing end with the driving wheel; when the time step of the model is 3.3s, the longest longitudinal coordinates appear, that is, the P_t motion to the farthest horizontal meshing end of the driven wheel. The analysis of the displacement characteristics of the center of mass of the ring chain can provide a reference for the following dynamic characteristics.

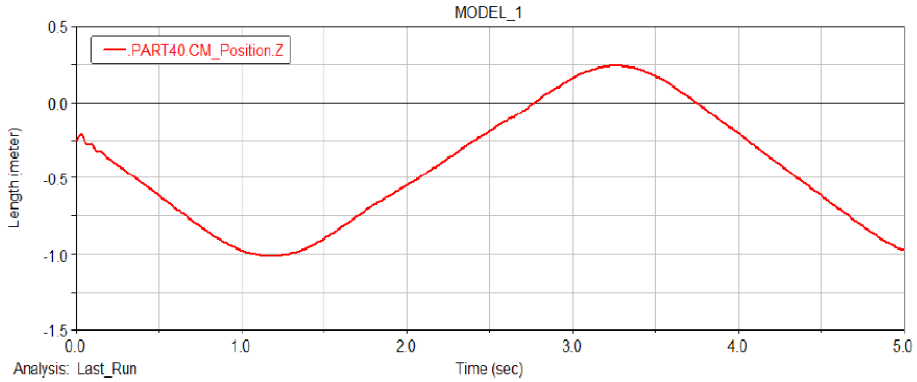

Fig.2 Z-direction displacement

The change of contact force between chain ring parts and sprocket is shown in Fig.3. From the figure, it can be seen that when the analysis step time is 0.7s, the contact force between chain ring parts and active sprocket starts to contact, i.e. meshing transmission. At this time, the contact force between the two parts instantaneously increases to the peak value, and the chain ring bears the main pulling force. With the rotation of sprocket, when the flat ring enters the meshing state, the pulling force acting on it will decrease rapidly, so the contact force between the chain ring and the sprocket will decrease accordingly, and the transition of the state occurs at 1.3s. When the analysis step time is 1.8 seconds, the contact force between the chain part and the sprocket changes again, and the rate of contact force changes decreases. At this time, the chain part bears the pulling force of the loose chain.

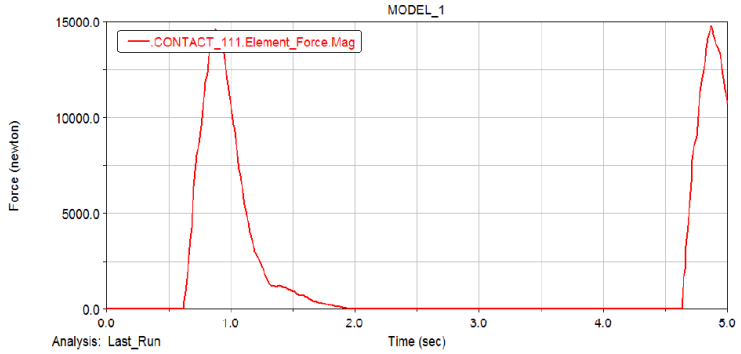

Fig.3 Contact force curve between chain ring and sprocket

The acceleration characteristics of the chain parts are shown in Fig. 4. Generally speaking, even if the dynamic load is small, the long-term damage to the transmission components is no less than the static load, and the polygon effect of chain drive will continue to generate dynamic load, so the study of acceleration characteristics is very important. Before meshing (0-0.7s), the acceleration of the chain has two obvious peaks, which are caused by the starting pull at the initial time and the contact force at the 0.7s time respectively. These two peaks will result in the greater impulse of the chain and also the key moment to test the strength of the chain. The meshing time between the active sprocket and the chain ring parts is 0.7-3.7 s. From the calculation results during this time, it can be seen that the acceleration fluctuates continuously in a very small range, which indicates that the transmission stability of the active sprocket is good. Load during meshing is formed by many factors, such as dimension accuracy, loose edge state of chain, etc. From 3.7s, the link parts and driven sprockets begin to mesh. In the time range of 3.7-5s, the acceleration of the chain-ring part forms two obvious peaks again, and the peak value is larger than that of 0-0.7s. The peak acceleration of this stage is caused by the contact between the chain and the driven wheel. At this time, the motion fluctuation is very large, and the load of the chain is large. The change of centroid acceleration is the result of the interaction of load and polygon effect.

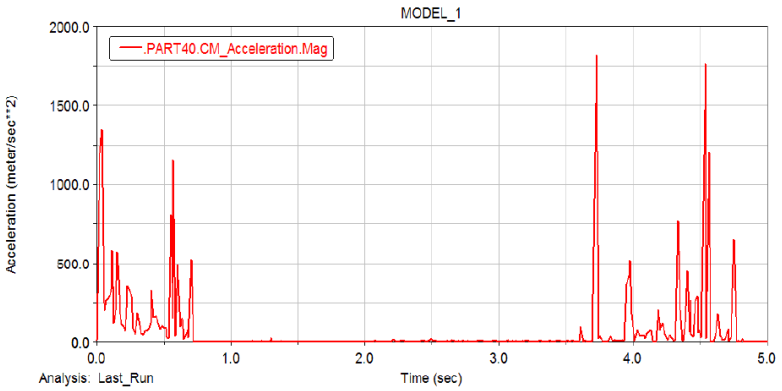

Fig.5 Acceleration Curve of Centroid of Chain Ring

The contact force curve between the chain parts and the adjacent chains is shown in Fig. 5. At the start-up time, the cyclic load on the chain parts is very large, and the maximum amplitude of the fluctuation is 2.75 times that of the conventional load. With the meshing of sprocket and chain-ring parts, the contact force between chain-ring parts and adjacent chain-ring parts is affected by polygon effect, and gradually reaches stability, and maintains in a specific range. Before entering the meshing of driven wheels, the loose-edged transmission between the chain part Pt and the adjacent chain links, so the contact force is very small, mainly due to gravity.

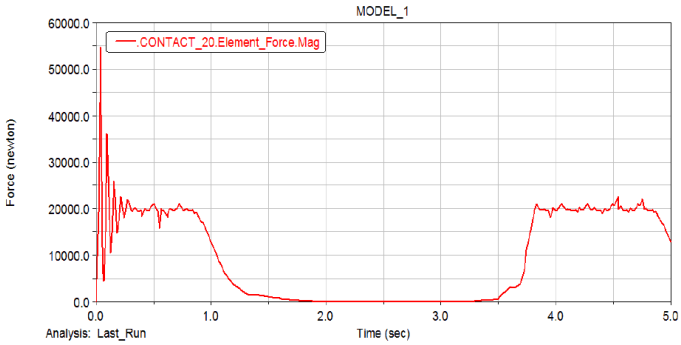

Fig.6 Contact force curve of adjacent chain rings

IV. Conclusions

In terms of design and development, CAE-based structural simulation and analysis has been widely used. In the chain drive part, if reliable dynamic characteristics are simulated by preset boundary parameters, the deficiency of empirical calculation will be effectively compensated. In the aspect of dynamics analysis, the multi-rigid-body dynamics theory and software ADAMS are used to calculate the motion characteristics and contact force characteristics of transmission components, and the transmission characteristics under dynamic loads are obtained.

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