Dynamic Analysis of Gearbox Transmission System Based on ADAMS Traction Locomotive

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Abstract: In order to verify the rationality of the design of the gearbox transmission system of the traction locomotive, based on the ADAMS software, the 3D model of the gearbox transmission system is established in CREO 3.0, and the dynamic model of the gearbox transmission system is built into the ADAMS for simulation. Analysis, the dynamic meshing force between the gears, the force of the bearing on the box, etc., and the obtained simulation values are compared with the theoretical values. The results show that the results obtained by ADAMS simulation fluctuate around the theoretical value, which verifies the reasonable design of the traction locomotive gearbox transmission system.

1. Preface
The gearbox is a component that changes the torque in the traction locomotive. The gearbox transmission system [1] plays an important role in the vibration of the gearbox and the operation of the traction locomotive. Therefore, the dynamic performance of the gearbox transmission system is studied [2] is of great significance. Based on CREO3.0 and ADAMS software, this paper establishes the dynamic model of the gearbox transmission system, and analyzes the dynamics of the transmission system, which provides important guidance for the further vibration and noise analysis of the gearbox [3].

2. How the gearbox drive system works
The gearbox transmission system is mainly composed of a traction motor, a gear box, a driving gear, a driven gear, a large-capacity cover and the like. The traction motor, the gear box and the axle box form a rigid structure. One end is supported on the axle by two rolling bearings respectively installed in the axle box and in the gearbox, and the other end is suspended by the motor hanger on the bogie frame [4]. The rotating shaft drives the gear rotation in the gear box to transmit the force vertically to the other rotating shaft, that is, a driving wheel drives the driven wheel to rotate, and the gearbox transmission system is as shown in FIG.
3. Establishment of dynamic model of gearbox transmission system

System dynamics modeling first analyzes and studies the logical relationship of each element, obtains the corresponding flow graph, then writes the mathematical formula in the corresponding part of the flow graph, and then uses the computer to simulate these mathematical equations, and these data were modified and improved based on the simulation results.

3.1 Establishment of 3D solid model

Before the modeling, the structural characteristics and motion characteristics of the gearbox transmission system are first analyzed. The gearbox transmission system is mainly composed of the box body, the bearing, the input mechanism and the output mechanism, and the necessary simplification is needed before modeling:

1. Omit parts that are not involved in the transmission: Fasteners such as bolts only play a fixed role in the model, and are replaced by fixed pairs during simulation.
2. Omit the structural features such as chamfers that are not related to system analysis.

3.2 Importing ADAMS

The default units in Adams are mm, kg, and s. Unit conversion is required before the virtual prototype is imported into Adams to ensure accurate analysis results. This article uses the latest Adams2014 for simulation analysis. This version of the ADAMS software has added interfaces to modeling software such as Pro/E, CATIA, and UG. It can directly read .asm files to achieve no between Pro/E and Adams. Splicing and docking avoids the trouble of converting through neutral files or third-party software, and also ensures the integrity and accuracy of the model, and avoids problems such as model deformation caused by common interface files. The model can be further manipulated after importing the model into ADAMS.

3.3 Defining the material properties of individual components

The model imported from CAMMS into ADAMS has no information on material properties [5], so material properties must be assigned to each component. Among them, the gear box housing material is ALSi7Mg, $\rho=2650 \text{kg/m}^3$, elastic modulus $E=7.4 \times 10^{10} \text{Pa}$, Poisson's ratio $\mu=0.3$. The pair of helical gears and the main driven shaft material are 45 steel, $\rho=7.85 \times 10^3 \text{ kg/m}^3$, the elastic modulus $E=2.07 \times 10^1 \text{ Pa}$, and the Poisson's ratio $\mu=0.31$.

3.4 Constraint relationship added between components

After defining the material properties, you need to define constraints and motion pairs for the motion relationships between the components. The constraint relationships that need to be added are:

1. Adding a fixed pair of gearboxes
(2) Input shaft and box add rotary pair
(3) Adding rotary pair to output shaft and box
(4) Adding contact pairs to the driving gear and the driven gear
(5) Adding rotary pair to the driven gear and the output shaft
(6) Adding rotary pair to the drive gear and input shaft

3.5 Adding contact force
There are two methods for calculating the contact force in ADAMS, one is the Restitution method, and the other is the impact function method. The contact force of the compensation method is the product of the penalty coefficient and the insertion depth, due to the penalty coefficient. The size is difficult to determine, so it is cumbersome to calculate or not to converge. The impact function method is based on the impact function to calculate the contact force between two members. The contact force consists of two parts, one is the elastic force generated when the two members are cut into each other; the other part is between the two entities. The damping force generated by the relative speed.

The impact function is:
\[
F = \begin{cases} 
0 & p \geq p_0 \\
F_1 + F_2 & p < p_0 
\end{cases}
\]

F1 is the elastic force, F2 is the damping force, K is the stiffness coefficient; p0 is the reference distance that the two objects are to contact; p is the actual distance between the two objects; e is the rigid force index; C is the damping coefficient; step is the step function ;d is the plunging depth.

3.6 Selection of contact parameters
Contact parameter description:
(1) Stiffness refers to material stiffness. In general, the greater the stiffness value, the more difficult it is to solve the integral.
(2) Force Exponent is used to calculate the index of the material stiffness term contribution in the instantaneous normal force [7]. For metals, 1.3 to 1.5 are commonly used, and this article is 1.5.
(3) Damping defines the damping properties of the contact material. This article selects 50.
(4) The friction force needs to be considered in the contact process [8]. According to the theoretical situation, the static friction coefficient is 0.1 and the dynamic friction coefficient is 0.05.

The static resistance slip speed is 0.0001 m/sec, and the dynamic resistance conversion speed is 0.01 m/sec.

3.7 Adding drivers and loads
For the actual working condition of the gearbox, it is necessary to add loads to the corresponding components of the box according to the speed and torque under the rated power of the work. For the parameters of other sports pairs, the default parameters are selected. Considering the actual working condition of the box, the rated speed needs to be loaded on the input shaft, and the load torque needs to be added to the output mechanism.

1. Add input speed:
   In the actual work, the speed of the prototype is slowly increased from zero to the rated speed, and then maintains a constant speed. Here, in order to simulate the actual working conditions, the step function (time, t0, w0, t1, w1) is used to add the input speed, that is, at t0. During the time of ~t1, the speed is smoothed by w0 according to a certain rule to w1. After t1 time, the speed keeps w1 constant, so as to avoid the discontinuity of the differential value caused by the sudden change of the rotation speed. The unit of angular velocity in Adams is degrees/s (d/s), and the rated speed of the prototype is 602r/min, which is 3612d/s. Define the step function as w=step(time, 0, 0, 0.5, 3612, 0), and time is a time variable.

2. Define the load
   Define the prototype as a rigid body model, simulate the working condition of the prototype under rated conditions, and add load torque to the output mechanism of the prototype. The load torque can
be calculated.

\[ T = 9550 \frac{P}{\eta n} \]

Among them, the rated power is the transmission efficiency, which is the rotational speed of the corresponding component.

By calculation, it is necessary to add 8700 torque to the output mechanism. In order to prevent the sudden change of the rotation speed, add the opposite load to the output gear in the output gear, and set the torque to \( \text{STEP (TIME, 0, 0, 0.1, 1, 8700)} \) (The negative sign indicates the opposite direction), the simulation time is 0.05 seconds, and the simulation step is 50.

4. Dynamics simulation and verification
According to the dynamics simulation, the dynamic meshing force of the meshing gear pair can be compared with the theoretical value [10] to verify the accuracy of the dynamic simulation, and the acceleration of the transmission system can also be obtained.

![Figure 2. Dynamic meshing force between meshing gear pairs](image1.jpg)

![Figure 3. The force of a shaft front end bearing](image2.jpg)

![Figure 4. The force of the front end bearing of the other shaft](image3.jpg)
In order to verify the accuracy of the simulation results, the verification is based on the mechanical design gear force formula.
\[ F_n = F_d / \cos \dot{\omega} \cos \beta = 2T / d \cos \dot{\omega} \cos \beta = 26897.474N \]

The dynamic meshing force of the meshing gear pair obtained by simulation changes around the theoretical value, which verifies the rationality of the gearbox transmission system design.

5. Conclusion

Through the dynamic analysis of the gearbox transmission system, the following conclusions are obtained:

(1) Establish a three-dimensional model of the gearbox transmission system in CREO3.0, introduce the dynamic model of the gearbox transmission system into ADAMS, and perform dynamic simulation in ADAMS.

(2) The dynamic meshing force of the meshing gear pair obtained by simulation fluctuates around the theoretical value, which verifies the accuracy of the simulation.

(3) The obtained results can provide an important reference for further lightweight design, fault diagnosis and vibration and noise analysis.

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