Simulation research of RV Reducer bearing based on rigid-flexible coupling

ABSTRACT

In this paper, RV110-E reducer as the research object, using SolidWorks software to establish a three-dimensional model of RV110-E reducer, and interference check. The key parts were processed flexibly by Abaqus, and the processed flexible body was imported into Adams to establish the rigid-flexible coupling dynamics model of RV reducer. Through simulation analysis, the contact stress curve of key components is obtained, and the influencing factors of fatigue life of reducer are obtained, which lays a foundation for further calculation of fatigue life of reducer. The research method has certain guiding significance to the fatigue life of RV reducer.

Keywords: RV reducer; Rigid and flexible coupling; Load spectrum; Fatigue life

1. INTRODUCTION

Compared with the traditional reducer, RV reducer has a series of advantages, such as high transmission accuracy, large bearing capacity, smooth transmission and large transmission ratio, and has been widely used in robots, high-precision CNC machine tools and other industrial equipment, and also plays an indispensable role in the field of aerospace [1]. For RV reducer, fatigue life is an important index to judge whether it can work normally. In order to study the fatigue life of its work, it is necessary to find out the biggest factors affecting the fatigue life. Needle roller bearing, as the main transmission part of RV reducer[2], bears very large loads in the work of RV reducer, so it has important guiding significance to study its complex dynamic characteristics and carry out simulation analysis on it. Relevant scholars have conducted a series of dynamic virtual simulation research. Zhu Liangbin [3] established a rigid-flexible coupling dynamic model in ADAMS to obtain the load spectrum[4], studied the contact stress distribution and obtained the maximum stress contact area based on Abaqus finite element statics analysis, and analyzed and studied the dynamic characteristics and fatigue characteristics of the reducer. Xie Songcheng [5] completed the Structural statics analysis of the input mechanism and cycloidal gear mechanism by solving the structural Static stress and simulating the fatigue life of the input mechanism and the cycloidal gear gear mechanism with Static Structural module[6]. After defining the S-N curve of each component material and adding the load spectrum, the fatigue life of the input mechanism and the cycloidal gear gear was analyzed, and the fatigue life of the input mechanism was solved. Zhang Hong [7] used SolidWorks, a 3D modeling software, to establish the geometric model of RV reducer[8], and built a virtual prototype of RV reducer in Adams and carried out dynamic simulation calculation. Based on the finite element analysis results and the load spectrum obtained by dynamic simulation, the fatigue life prediction was carried out in the fatigue analysis software. Finally, aiming at the problem of fatigue life, the optimized design model was established, and the performance difference of the structure before and after optimization was compared to evaluate the results of parameter optimization.

In this paper, the geometric model of RV reducer is established in SolidWorks, and the assembly, interference inspection and appropriate simplification are carried out [9]. The virtual prototype of RV reducer was imported into Adams to construct and the dynamics simulation calculation was carried out. The key parts were flexible processed in Abaqus and replaced in Adams, thus the rigid-flexible coupling dynamics model of RV reducer was established[10], the contact stress curve of key parts was obtained, and the load spectrum was drawn. This will pave the way for the calculation of fatigue life. The research method has certain guiding significance to the precision design of RV reducer.

2. THE ESTABLISHMENT OF THREE DIMENSIONAL MODEL OF RV REDUCER

In this paper, the reducer model is RV110-E, and the precise modeling and assembly of the reducer is completed in SolidWorks, as shown in Figure 1.

Fig. 1. RV reducer parts explosion diagram

l. Input shaft 2. Rigid disc 3. Angular contact bearing 4. Cycloidal wheel 5. Tapered roller bearing 6. Crank shaft 7. Needle tooth 8. Needle roller bearing 9. Needle tooth housing 10. Planet rack 11. Planetary wheel

After the virtual prototype of RV110E reducer is assembled, interference test should be carried out on it, mainly to check whether the fit between the parts of the assembly and the modeling of the parts are correct[11]. After the test, there is no interference problem in the reducer, and the test results are shown in Figure 2. Finally, the model is saved as.xt format for further simulation calculation.

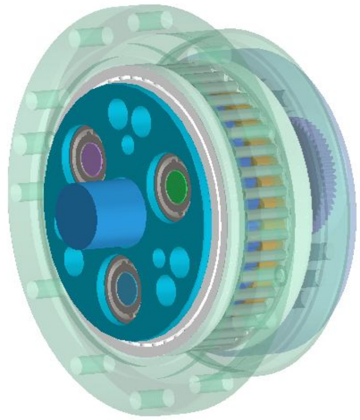


Fig.2. RV reducer interference test

3. THE ESTABLISHMENT OF RIGID-FLEXIBLE COUPLING MODEL

3.1 Fuzzy control scheme

Since Adams can only solve the change of the contact force of the object and cannot solve the change of the contact stress during the simulation analysis, it is necessary to make the key parts flexible before the simulation analysis. Finite element analysis software Abaqus was used to generate modal neutral files of elastic deformation of flexible body, and then the rigid body was replaced by flexible body files in Adams [6]. Follow these steps to generate the appropriate modal neutral file in abaqus:

1.Save the parts that need flexibility in.xt format and import them into Abaqus.

2. Create an analysis step, create a frequency extraction analysis step of a linear perturbation step, extract natural frequency and a substructure generation step, and generate a submodel. The first 12 order natural frequency and mode information were extracted.

3. Grid division.

4. Define the constraint relation, and adopt the form of beam element and MPC coupling for bearings, so that their rigid nodes are connected with the surrounding nodes.

5. Define boundary conditions that apply full constraints to rigid nodes in two analysis steps.

6. Keyword file.

7. Generate flexible body: Submit job analysis and complete calculation.

8. Part of the natural vibration modes corresponding to the generated modal file are shown in Figure 3.

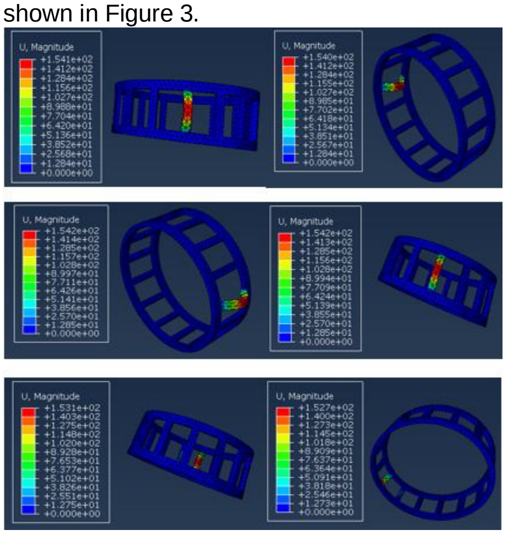


Fig. 3. The first six natural modes of the flexible body

3.2 The establishment of Adams dynamic simulation model

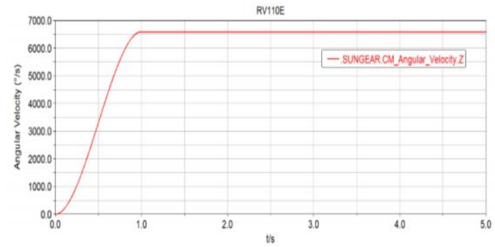
The main steps of establishing the rigid-flexible coupling dynamics model of RV reducer in Adams are as follows [12]:

1. Guide the 3D model saved before to Adams in.x_t format, unify units and set material properties.
2. Import the flexible body modal neutral file (.mnf) generated in abaqus into Adams to replace the corresponding rigid parts.
3. According to the kinematic relation of parts, define the corresponding kinematic pairs.
4. Contact parameter setting: IMPACT-FOUNCTION is used in Adams to define contact relationships between parts.
5. Set drive and load: apply Step function slowly to avoid excessive stress at the beginning of simulation. Within 0-1 s increased from 0 to 1665 r/min, the load torque within 1-2 s increased from 0 slow to 1078 N □ m rated load.

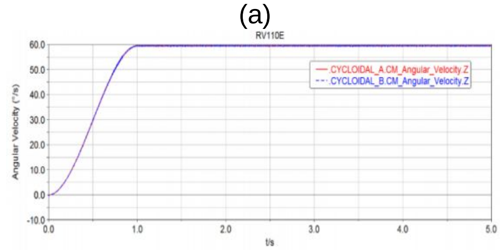
4. ANALYSIS OF DYNAMIC SIMULATION RESULTS

4.1 Verify the accuracy of virtual prototype motion simulation

It can be seen from FIG. 4 that within 0-1s, according to the setting conditions of STEP function, the angular velocities of the planetary wheel, cycloidal pin wheel and output flange increase with the increase of the angular velocity of the input shaft, and the rotational speed of the planetary wheel is opposite to the rotational speed of the input shaft, which is consistent with the actual motion situation.



(a)



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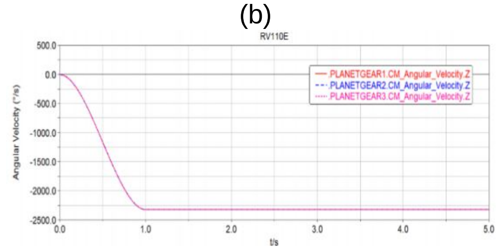
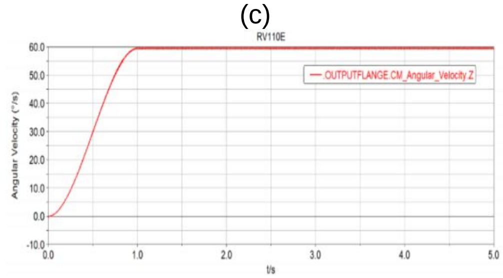


(c)



(d)

Fig. 4. Speed curve of each part

(a): Input axis angular velocity curve; (b): Cycloidal pin wheel angular velocity curve; (c): Angular velocity curve of planetary wheel; (d): Output flange angular velocity curve.

Through the simulation calculation of the angular velocity of the input shaft, the angular velocity of the planetary wheel and the angular velocity of the output flange, the results show that they are basically consistent with the theoretical calculation results, indicating that the motion simulation has a high accuracy, which verifies the correctness of the setting of constraint pairs and contact forces of the virtual prototype model.

4.2 Simulation result analysis

In Adams post-processing, the result set was set as the current result [13], the solution object was set as each contact, the contact pair between needle roller bearing and cycloidal wheel was selected, and the plotting was added to obtain the change of stress on the contact with time, which laid the foundation for solving the fatigue life of the mechanism later. The contact stress curve is shown in Figure 5.

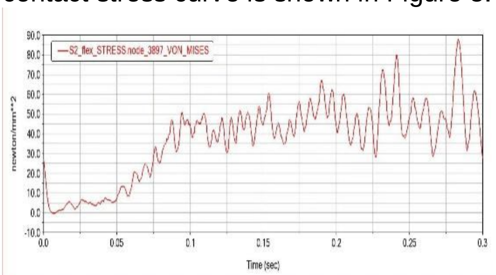


Fig. 5. Time domain diagram of contact stress of needle roller bearing

5. CONCLUSION

The 3D modeling of RV reducer was carried out in SolidWorks, and then the key parts were flexible in abaqus. Finally, the rigid-flexible coupling dynamics model was established in Adams, which provided the preparation for the next dynamic analysis.

Through the analysis in Adams, the rigid-flexible coupling model is verified, and the dynamic response curves of key components such as speed, meshing force and contact stress are obtained, which prepares for the later fatigue life span analysis.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

'Author Hongwei Wang' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. 'Author Linshan Han, Jiaying Wang, Jiangyu Zhao' managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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