COOPERATIVE MODELING AND DYNAMICS SIMULATION OF FLEXIBLE MULTI-BODY SYSTEM FOR PARALLEL ROBOT

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Abstract: Based on the cooperative thought, a method of modeling and simulation of multi-flexible-body dynamics for a kind of mechanism is proposed in this paper. A multi-flexible-body dynamics simulation model of 3-TPT parallel robot is created, and its multi-body dynamics simulation is implemented by using the multi-body dynamics simulation software ADAMS and finite element analysis software ANSYS. For more accurate explanation of the analysis, simulation results of rigid body are compared with those of flexible body. The simulation results have shown that forces applied on flexible bodies are highly nonlinear because of the flexible characteristics, which is consistent with the reality. Compared with other simulation method, the simulation proposed of the multi-flexible body system are more authentic, nicety and can reflect actual dynamics characteristic of parallel robot with more accuracy. Therefore this is an effective method of analysis for design and optimization of parallel robot.

1 INTRODUCTION

Flexible multi-body system generally consists of rigid body and flexible body which interact with each other the motion of these components unit may be translational or rotational under the effect of power. The traditional multi-body system dynamics research is carried out mainly in the multi-rigid-body field, however, because of the rigid assumption sometimes its result will lose certain precision, even can't be accepted (Shabana A. A, 1997). With development of modern mechanical system towards to high speed, heavy load, high-precision direction, designers pay more and more attention to dynamic stress of the component and the service life prediction of product, elastic dynamics issue resulting from the coupling between rigid motion and the deformation itself of the system has already become the common problems needed to be resolved and key technology in this field. Therefore considering the flexible of all the parts in order to improve the precision of the simulation analysis becomes an important direction of parallel robot research (Fattah et al., 1995; Gamarra, 1999).

Robot dynamics simulation analysis is an important content of robot design, the model established in the previous analysis, whose components belong to a rigid body, and don't have elastic deformation when making motion analysis. But in fact, on the condition of the larger load, or acceleration and deceleration, it will have larger deformation and displacement after the mechanism got forced, resulting in vibration. In order to solve these problems, we should establish the reasonable elastic dynamics model of the parallel robot, based on this research the impact of its dynamic performance and structure and geometrical parameters on dynamic properties, put forward the corresponding structure optimization design method (Chen, 2001).

ADAMS software is well-known mechanical system dynamics simulation software, its analysis object is basically the multi-rigid-body, but the ADAMS provides a flexible body module, the module can be used to achieve motion simulation analysis of flexible body and substitute elastic body for rigid body. ANSYS software is a universal finite element analysis software, with a friendly cross-section before and after the treatment, accurate and efficient solver, has been widely used in various fields, it can effectively integrated the finite element analysis with CAD, CAE organically. In this paper, combining advantages of two kinds of software, the flexible multi-body system is established to conduct

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dynamic simulation of mechanism the dynamic behavior of mechanism can be simulated more realistically.

2 THE ESTABLISHMENT OF FLEXIBLE MULTI-BODY DYNAMICS MODEL OF PARALLEL ROBOT

All the objects in the mechanical dynamics simulation software ADAMS are defined as rigid bodies, and its theoretical basis is multi-rigid body dynamics, so the impact of structural flexibility movement is ignored, which is not good enough for many system dynamics analysis (Wang et al., 2005). However the general finite element software can do nothing for dynamic analysis of the movement system containing large displacement. But in the ADAMS, combination of rigid and flexible body can be a more feasible solution which can simulate the dynamic behavior of the mechanism movement more realistically. The flow chart of multi-flexible-body system collaborative simulation is shown in Figure 1:

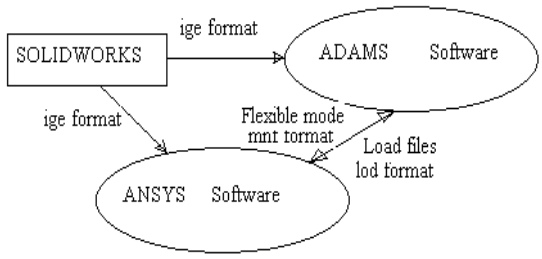


Figure 1: The flowchart of multi-flexible-body model cooperation simulation.

2.1 The Establishment of Solid Model of Parallel Robot

Because of this low-DOF parallel robot having complex structure, while in the ADAMS modeling of complex shape parts is not powerful enough, when establishing robot models, in this paper, three-dimensional CAD software SOLIDWORKS is applied, because it has a seamless connection between ADAMS and SOLIDWORKS. Therefore, the function of model conversion between them is used in this paper, in that the robot's three-dimensional model is first imported into the ADAMS, creating a virtual prototype model of the robot. Obtained multi-body dynamics model of the parallel robot in ADAMS through proper handling is shown in Figure 2:

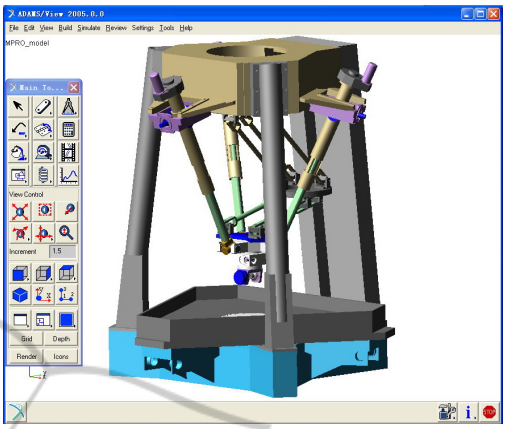


Figure 2: The multi-body model of parallel robot in ADAMS.

2.2 Generation of Modal Neutral File

The principle of creating flexible multi-body dynamics is applied for components for slender and with lower stiffness generate flexible body parts, while for large rigidity parts rigid body model can be used. Therefore, only three flexible telescopic arms were processed with flexibility and the other components are rigid body. After the multi-body dynamic model of the parallel robot is established in the ADAMS, the telescopic arms of parallel robot is needed to make discretization processing of finite element in finite element software ANSYS, in order to generate modal neutral document for multi-flexible-body dynamics analysis purposes.

First, the telescopic arms parts of parallel robot in three-dimensional solid software is saved solely to generate Parasolid model neutral file, and then ANSYS through a dedicated interface to read the neutral file, the definition of units, real constant, and materials etc. is completed. The divided cell grid, the definition of the external nodes, before outputting MNF-neutral file, must carry out quality, and load etc. inspection operation to ensure that the reliability of data is contained by the file of modal neutral file of flexible telescopic arms in the ANSYS. After meshing, finite element model of telescopic arms is generated, which is shown in the following figure 3.

2.3 The Establishment of Flexible Multi-body Dynamic Model

After parallel robot modal neutral file is established, ADAMS / Flex Module is embedded in the ADAMS. Through the Flex body to rigid dialog box

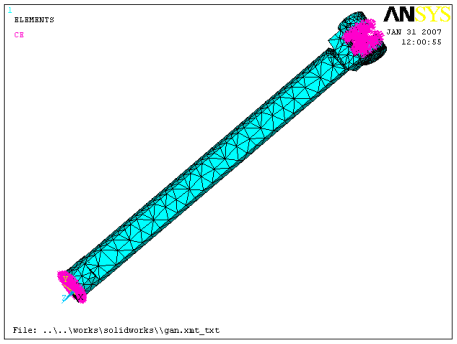
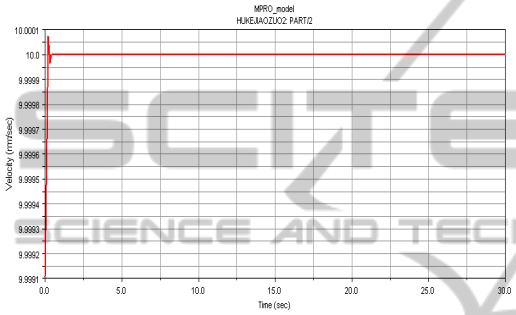
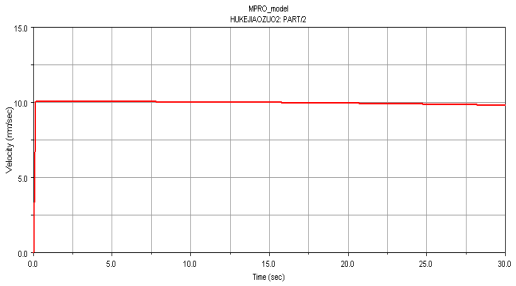


Figure 3: The finite element model of mechanical arm in ANSYS.



(a) The end effector velocity diagram of multi-rigid-body.



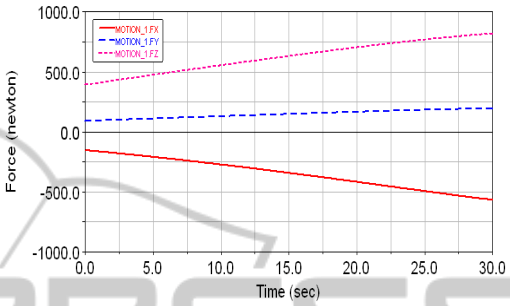
(b) The end effector velocity diagram of multi-flexible-body.

Figure 4: The end effector velocity comparison of multi-rigid-body and multi-flexible-body.

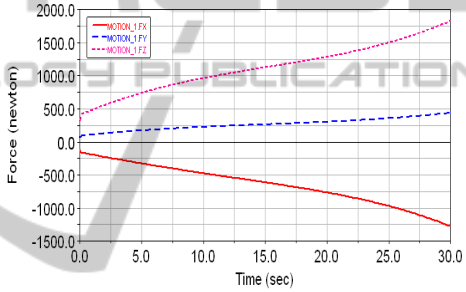
under this module, the flexible body model is imported into the ADAMS to replace the original rigid body, thus parallel robot flexible multi-body simulation model is obtained, and then through model checking, multi-flexible-body dynamic analysis can be carried out.

3 SIMULATION RESULTS AND ANALYSIS

In order to carry out parallel robot dynamics simulation analysis, 1000N acting force is applied on the end effecter of built parallel robot along the X negative direction, and dynamic characteristic curve of multi-rigid-body model is compared with dynamic characteristic curve of multi-flexible-body in this paper. The comparison of end effector velocity of multi-rigid-body and multi-flexible-body is shown in figure 4. The contrast between force curves of rigid and flexible driven link is shown in Fig. 5.



(a) The rigid body.



(b) The flexible body.

Figure 5: The component force contrast between rigid and flexible driven link along three direction.

From the above figures of the simulation results we can see that: (1) Due to the existence of mechanism clearance, Multi-rigid-body model has vibration phenomenon before movement speed is constant, while multi-flexible-body model reduces the vibration due to the deformation of flexible body, making the change of the speed more smooth.; (2) The stress variation amplitude of rigid arm is smaller and with good linearity, while the stress variation amplitude of flexible arm is larger and shows a highly nonlinear.

4 CONCLUSIONS

The motion characteristics of parallel robot flexible multi-body system is studied based on co-modeling ideas. In this paper, the combination of the finite element software ANSYS and multi-body analysis software ADAMS are successfully utilized for

simulation. analysis of the parallel robot flexible multi-body system. We have found that using ADAMS and ANSYS co-simulation analysis of the flexible system, the actual motion characteristics of flexible system can be more realistically and accurately. Since simulation model is easy to learn with component flexibility, it is easy to observe the deformation of the components, predict system performance with more accuracy, and therefore this method offers reference for improving and optimizing the structure of parallel robot. Some components of the system considered as flexible body and assembled together with other components to build dynamic analysis model of rigid-flexible coupling is a worthful method for the field of parallel robot research.

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