Multi-body Dynamics Simulation and Analysis of Inertia Release Mechanism

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Abstract. For multiple work sections and complicated work conditions, Inertia Release Mechanism contains complicated contact surfaces of parts, it is hard to design and analyze with traditional methods. In this paper, the detailed structure model of Inertia Release Mechanism was designed with UG, and its virtual prototype model was established with LMS Virtual. Lab Motion. Based on the model, system kinematics and dynamics were simulated and analyzed. The simulation results revealed that with virtual prototype technology, the design level and efficiency of Inertia Release Mechanism can be enhanced. The model can also be used for structure optimum design.

Introduction

Inertia Release Mechanism (IRM) is an important part of torpedo recycling system. It undertakes the important missions of secure connection between products and recovery system under high impact load in high air and the missions of reliable release between products and recovery system under the high impact when it enters into water. The characteristics of IRM are that the structure is compact, the links of the working process are so much, the forces of each link are complicated, the contacts involved are very much, etc. Because of the complexity of IRM, there are no general design models or equations to use to fully reflect the dynamic characteristics of the real working process. In the past, the design was done according to the work principle, and used the existing data and appearance requirements to roughly determine the basic size of the structure at first, and then carried on the detail design and sample test, and ultimately determined the structure, size and the processing technology of various parts. The paper used the virtual prototype technology, did multi-body dynamics simulation of IRM, improved and optimized the design. Research will be conducive to realize comprehensive optimization design of IRM and improve design efficiency, reduce development costs and shorten the development cycle.

The 3D Model of IRM

Structure and Working Principle of IRM

The structure of IRM is shown as figure1(a), mainly composed of the inertia block, connecting body, reset spring, release spring, steel balls and the elastic ring. The back-end of the connecting body connects with the recycling system, and the front-end connects with the connecting block of the product. Steel balls are installed in the sockets of the connecting body and the connecting block, and the inertia block provides radial constraints for the steel balls, then the connection between product and recovery system is realized. When IRM enters into water, it is overloaded, and the inertia block overcome the reset spring and thrust forward under the effect of inertia force, so the radial constraints of steel balls are removed and the balls fall into the slot of the inertia block, the products and recycling system is separated.
The 3D Solid Model

According to the actual situation, 3D model of IRM is established with UG4.0 software, the model is shown as figure 1(b).

Figure 1. Schematic Diagram and 3D Model of IRM.

Multi-body System Dynamics Simulation Analysis of IRM

Dynamics Analysis Model

The virtual prototype technology includes multi-rigid-body and multi-flexible-body dynamics analysis[1-3]. Dynamics research of IRM used multi-rigid-body dynamics analysis model to get the release process of IRM when it entry into water with high-speed under the impact force of recovery system, to get the pull force of the recovery system when release and to get the contact pressure between parts, to provide the basis data for the design and the input load for strength analysis.

The elastic ring has no effect on analysis, it was ignored when established dynamics modeling. Three springs are replaced with spring force TSDA. Kinematic pairs are shown in table 1.

UG 3D model of IRM was imported into LMS Virtual. Lab Motion software. According to the constraints between components in table 1, CATIA dynamics simulation analysis model established.

<table>
<thead>
<tr>
<th>components</th>
<th>connecting block</th>
<th>steel ball</th>
<th>connecting body</th>
<th>inertia block</th>
<th>limiting pin</th>
<th>fastening nail</th>
<th>spring ring</th>
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<tbody>
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<td>contact pair</td>
<td>sliding pair, spring force</td>
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<td>sliding pair, contact pair</td>
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<td>Fixed Joints spring force</td>
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The Simulation and Results

In order to get the load IRM bears when it enters into water and realizes release, air flight tests had been done for three times. Overload sensor measured overload acceleration as figure 2.
The connecting block was connected with the earth and the overload acceleration measured was applied on the kinematics model, the pulling force value of the recovery system was calculated preliminary. The contact parameters of contact parts were adjusted to debug the model. When the simulate pulling force value of the recovery system reached about 2000N and the water velocity was about 40 m/s, IRM completed release, and the movement process was reasonable.

The release process of IRM is as figure 3.

Using post-processing function of dynamics analysis, the maximum normal contact force between the ball and socket got and has been shown in figure 4, the maximum normal contact force between the steel ball and inertia block shown in figure 5, the velocity and the acceleration of the inertial block shown in figure 6 and figure 7.
Figure 4. Maximum Normal Contact Force Curve Between the Ball and the Socket.

Figure 5. Maximum Normal Contact Force Curve Between the Ball and the Inertia Block.
Figure 6. Velocity Curve of the Inertia Block.

(a) The First Test
(b) The Second Test
(c) The Third Test

Figure 7. Acceleration Curve of the Inertia Block.

(a) The First Test
(b) The Second Test
(c) The Third Test
The analysis of Simulation Results

(1) It can be seen from the curve of figure 4 and figure 5 that maximum normal contact force between steel ball and socket of connecting block is from 1400N to 1600N, the maximum normal contact force between steel ball and inertia block is 1400N.

(2) It can be seen from the curve of figure 4 and figure 5 that with the movement of inertia block forward, contact force decreases, the constraints of connection block is removed from the IRM in about 0.02 seconds, product and recycling system is separated and release is completed.

(3) It can be seen from the curve of figure 6 and figure 7 that the movement of the inertia block is oscillatory motion, the velocity and the acceleration of the first test and the second test is close, the velocity of the third test is slightly larger and the acceleration is slightly smaller, the difference of test data value of three times is not so much, therefore, the overload acceleration has little effect on the inertia block.

Summary

In this article, IRM was simplified, the format of UG model was converted and CATIA model was established. Boundary conditions and kinematic pairs (such as spring force and damping, kinematic pairs and contact pairs, etc.) were set and multiple rigid body kinematics model was established.

By doing dynamics simulation analysis and calculation of three test working conditions, the release processes of IRM were shown directly. The related parameters of the interaction force between the components and the pulling force of recovery system were concluded, which provide the input load for the strength calculation of parts and components (such as the steel ball, the connecting block and inertia block). Those also provide theoretical support for the development of such release mechanism. In a word, the results show that the virtual prototype technology can improve the design level and the design efficiency of IRM, and has certain reference significance to improve structure design.

Because there are so many contacts in the model and contact problem is a highly nonlinear problem, the contact setting of the model remains to be further perfect. The deformation of ball sockets of the connecting block is very large, if look the connecting block as a flexible body, the calculation results will be more reasonable.

References

