Modeling and Simulation of the Deep-sea Mining Vehicle’s Hydraulic Execution System

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Abstract. Take the deep-sea mining vehicle’s hydraulic execution system for research object. Establish its simulation model and simulate various extreme obstacle conditions in deep sea environment using software AMESim. Get the submarine vehicle’s hydraulic execution system dynamics simulation through setting the main parameters in the AMESim. The result shows that hydraulic execution system and the various hydraulic components are reliable in various deep sea extreme obstacle conditions, the whole system is stable, it provides a new way in evaluating the submarine vehicle’s hydraulic system performance and its optimization design.

Introduction

Cobalt-rich rusts and hydrothermal sulfide resource is going to be the new industry this century. In order to be in the good position in deep-sea field, many have engaged in the technological research and development of deep-sea technology. The ocean, after the moon and the Mars, has been the new hot highland worldwide. This paper designs a composite wheel submarine vehicle which has active-passive hybrid crossing mode and aims at the national deep-sea strategy development.

Figure 1. Deep-sea mining vehicle.  
Figure 2. Composite Wheeled Structure.
Structure of Deep-sea Mining Vehicle and the Hydraulic System

Basic Structure of the Deep-sea Mining Vehicle

The composite wheeled submarine vehicle is composed of four composite wheels structure (Figure 2) and hinge-style seal crush resistance overall tank frame. Three wheels W1, W2 and W3 composite wheel W3, executive components in oil cylinder 1 and cylinder 2 can be realized under the telescopic supporting role of a certain degree of spatial structure changes. The whole organization have obstacle mixture and passive mode.

Design of the Hydraulic System

The hydraulic system is composed of hydraulic driving system and execution system. The hydraulic driving system uses the static hydraulic system. Power equipment select plunger pump, Variable pump and quantitative motor. The hydraulic execution system includes all the obstacle-surmounting executive and steering cylinder, and used throttle valve to control flow. Fig 3 illustrates how the hydraulic system works.

![Hydraulic system diagram.](figure3.png)

The design of hydraulic system parameters is the key part of complete machine system design. The main parameters are listed in Table 1.

Table 1. The main parameters of hydraulic system for Deep-sea mining vehicle.

<table>
<thead>
<tr>
<th>The rated pressure</th>
<th>The highest pressure</th>
<th>The motor rated speed</th>
<th>The motor power</th>
<th>The hydraulic pump displacement</th>
<th>The motor displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>16MPa</td>
<td>25MPa</td>
<td>1500rev/min</td>
<td>37kw</td>
<td>160mL/rev</td>
<td>808mL/rev</td>
</tr>
</tbody>
</table>

Modeling and Simulation of Hydraulic Execution Based on AMESim

Modeling of the Hydraulic Execution System

According to the diagram of hydraulic execution system, the paper models the vehicle’s front wheel unit hydraulic execution system in AMESim as illustrated in Fig 4.
Simulation of the Hydraulic Execution System

The deep sea mining vehicle’s vertical crossing cylinder plays an important role of the performance when it is working deep in the complex environment. The impact force may significantly apply to the cylinder. Take the raising and dropping of front wheel crossing obstacle as an example.

In 3 seconds intervals, elongate the crossing cylinder for 3.5s by providing the solenoid valve with -40mA signal. Then the signal be changed to 0 for 2 seconds and increased to 40mA and at the same time the crossing cylinder begins retract. Fig 5 illustrates the signal given to the solenoid valve.

With the signal, the cylinder raises the front wheel in the first 3.5s so that the front wheel is above the obstacle and at the same time the vehicle moves forward. At the moment of 5.5s, the wheel moves top of the obstacle and the vehicle stops. Then the front wheel fall after rise until back to the surface of the obstacle. Fig 6 illustrates velocity curve along with the time. The displacement and the acceleration curves are illustrated in Fig 7 and Fig 8 respectively.
From the curves, there is vibration in the beginning of lifting. The crossing cylinder moves to the hypothetical points perfectly. From the speed diagram and the acceleration diagram, in the beginning of fall after rise namely the activating of the solenoid valve, there is relatively big shock which is expected. In the effect of the buffering cylinder, the shock quickly becomes steady and decrease. The falling speed is even less than the lifting speed.

Fig 9 illustrates the pressure of head port and the rod port in the crossing cylinder in the crossing process. And Fig 10 illustrates the pressure on piston rod.

The simulation result in Fig 9 and Fig 10 indicates that the pressure on the piston rod increase to the maximum in the stage of falling that is the gravity shock vertically. But it does not exceeds the shock load of the cylinder and it guarantees the cylinder’s motion. So the mining vehicle is able to realize the expected crossing movement.

Conclusion

(1)This paper models and simulates the hydraulic execution system of deep sea mining vehicle and gets the related parameters and curves.
(2) The result illustrates that the hydraulic execution system has good stationarity thus satisfying the real working condition need in the complex deep sea.

(3) The simulation results can provide the theoretical foundation to the optimization design and the control of the deep sea vehicle hydraulic system. It can also provide a new method for the hydraulic system evaluation performance.

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References


