



SOME STUDY OF DYNAMIC AND ACOUSTIC CHARACTER OF STEERABLE STREAMERS FOR OCEAN EXPLORATION

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Abstract

The steerable streamers are used to control the orientation and depth of sonar hydrophone array in plotting a course for ocean exploration. The dynamic strength of the streamer steering device under impact is related with its reliability and life cycle. The acoustic noise radiated from its hull is a part of environment noise of the hydrophone in the cable banded streamer steering devices. Therefore, the dynamic character and flow noise of steerable device are key factors for ocean exploration, which are investigated in numeric simulation and experiment research respectively in this presentation. The hull of streamer steering device is made of polyurethane elastomer with a carbon-glass-fibre bush tube. The hyperelastic material model is used to simulate the polyurethane elastomer in finite element analysis of the steerable device hull. The material property parameters of the carbon-glass-fibre tube are identified by the experimental mode analysis. The impact of between the steerable device and shipboard in different velocity is simulated, and the results from numeric analysis suggest the impact limitation of steerable device. On the other hand, the acoustic noise due to flow induced by steerable device is measured in the tube with flow, in which the self noise under water of steerable device with different angle of steering wing as well as flow rates are investigated. The results show that the steerable devices would result in very low acoustic noise in ocean exploration at the cruising speed lower than 5 Kn.

1. INTRODUCTION

The steerable streamers are used to control the orientation of sensor array in plotting a course for ocean exploration. The steerable streamers consist of the exploring cables containing sonar hydrophone array, and steerable devices are bond on the exploring cable to keep its orientation and depth [1-2]. The static strength, dynamic strength and acoustic characters play key parts for the reliability of steerable devices which work in the ocean at the depth from 5 to 100 meter.

The capability of enduring the shock between the shipboard and the streamer steering device while enlacing back is evaluated by simulation in this presentation. Then, the underwater acoustic noise of steerable device in different flow velocities is investigated in a water flow tube.

2. SHOCK OF STEERABLE DEVICES WHILE ENLACING BACK

The hull of streamer steering device is made of polyurethane elastomer with an inside bush tube of carbon-glass-fibre. Some early research on the shock of composite material and hyperelastic material were presented [3-5], from which some procedures are used for the simulation of this case.

The inside tube of the hull of steering device can be model as an orthotropic cylindrical shell which physical parameters, such as E_1 , E_2 , E_3 , v_{12} , v_{23} , v_{31} , G_{12} , G_{23} , G_{31} and ρ , are identified by experimental mode analyzing, where E_1 , E_2 , and E_3 express the Yang's modulus in tangential, axis and radius direction respectively, v_{12} , v_{23} and v_{31} express three main Poisson's ratio respectively, G_{12} , G_{23} and G_{31} express three shear modulus respectively, ρ means density.

The body of hull of steering device is made of polyurethane which physical parameters and strength limitation can easily be test by extending limitation experiment, in which Mooney-Rivilin's model for rubber is introduced for modeling the constitutive equation of polyurethane of hull.

Two steering wings on the both sides near middle island on steering device hull are used for keeping depth and orientation. The wings are not included into analyzing model, since they are strong enough as the solid wings linked with hull by steel pins. The finite element model of the hull of steering device is shown in Figure 1, which is used for numeric simulation of the shock between the hull and shipboard while streamer steering device is enlacing back to the boat.



Figure 1. The finite element model of the hull of steering device

The glue of carbon-glass-fibre bush tube and polyurethane hull body should be processed carefully, in order to confirm the nodes on the interface can work well. The orientation of orthotropic inside tube material should be consistent with the element orientation. The shipboard is modelled as a rigid cylinder, since the stiffness of steel is much higher than polyurethane. The hull body is free from any restriction, and gravity of streamer steering device is neglected in simulation.

The initial distance between shipboard and hull of streamer steering device is 10mm in simulation, and the initial velocity is in the normal direction of cylindrical shipboard. The initial velocity is 2.5m/sec which is a little bit higher than practical enlacing speed which is near 4Kn.

The time history of all stresses of inside tube and polyurethane hull can be calculated. Some data are shown in Figure 2~ Figure 4, in which distribution of stress are shown at the time with largest stress in overall shocking history. The results from simulation show that the largest extension normal stress of inside tube in radius, tangential and axis direction are 4.6MPa, 63MPa and 95MPa respectively, and are much smaller than their extension strength limitation as 30MPa, 1000MPa and 550Pa respectively. The largest compression normal stress of inside tube in radius, tangential and axis direction are -5.6MPa, -37MPa and -92MPa respectively, and

safe from their compress strength limitation as -120MPa, -600MPa and -400Pa respectively. The largest shear stresses are 43MPa, 16MPa and 8MPa, and smaller than their shear compress strength limitation as 85MPa, 100MPa and 120Pa respectively. The Von Mises's stress of hull is much smaller than strength limitation of polyurethane. It can be concludes that the steering device is safe for usual enlacing operation, in which the relative velocity between the streamer and shipboard is near 2.5m/sec.

Some cases with higher initial velocity and different fibre compositing way of inside tube are studied. The results show that the inside tube of streamer steering device can not endure the shock with initial relative velocity higher than 5m/sec between hull and shipboard, in which the shear stress σ_{12} will close to its stress limitation firstly.



Figure 2. The distribution of normal stress of inside tube, time =4.14ms



Figure 3. The distribution of shear stress of inside tube, time =4.14ms



Figure 4. The distribution of Von Mises's stress of polyurethane hull, time =4.14ms

3. UNDERWATER ACOUSTIC NOISE OF STEERING DEVICE

3.1 Test rig for underwater acoustic noise measurement

The steering device is bond on the exploring cable array to keep its orientation and depth. Because the sonar in the exploring cable is used for detecting the echo signal, the underwater acoustic noise of steering device should be as lower as possible. The noise can be considered as from two sources, in which one is from steering machineries installed the inside of bush tube, and the other is flow noise. The water flow has the dominated contribution to overall noise level.

In order to investigate the underwater acoustic noise, a yellow steering device is set in the flow water tube shown in Figure 5, in which a B&K 8103 hydrophone is set in the exploring cable shown as the white cylinder in Figure 5. Amplified by B&K 2636 amplifier, the underwater acoustic signal is analyzed by Müller-BBM MKII Vibacoustic System.



(a) The specimen bond on a cable in flow tube

(b) The survey of test rig

Figure 5. The test rig for investigating the flow noise of steering device in flow tube

3.2 Measurement and analysis

First of all, the base noise in the cable in flow tube is measured before the steering device is installed on the cable. Turning on pump, the velocity of water in tube is kept at 2m/sec, 2.5m/sec, 3m/sec, 3.5m/sec and 4m/sec respectively. The one third octave spectrum of sound level and auto-power spectrum are analyzed at different flow velocity. Only the frequency components lower than 2000Hz are studied, since the operation frequency of sonar in the cable array cruising in ocean is lower than 1600Hz.

Then, the steering device is set up in the flow tube, and the cleaned water is filled into the flow tube again. The air bubble should be driven out completely by changing the water pressure several times. The one third octave spectrum of sound level and auto-power spectrum are analyzed in the same different flow velocity as the cases without steering device. The steering wings on the streamer steering device are set at the horizontal angle, extreme angle and minus extreme angle, respectively.

Some one third spectrums of sound level are shown in Figure 6, from which some characteristic of underwater acoustic noise of streamer steering device can be understood.

For the noise component of frequency lower than 100Hz, the streamer steering device increase the noise near 2~5dB, and noise in the case of wings at their minus extreme angle is a little bit larger than other angle.

For the noise component of frequency band from100Hz to 1000Hz, the underwater acoustic noise level difference between with and without steering device is only 0~2dB, and noise in the case of wings at their extreme angle is a little bit larger than other angle.

For the noise component of frequency higher than 100Hz, the steering device increase the noise near $1\sim 2dB$. The noise in the case of wings at their minus extreme angle is $2\sim 10dB$ larger than other angle. The higher the frequency is, the much the high frequency noise components increase.

The auto power spectrums of sound pressure at the flow velocity 3m/sec are shown in Figure 7 as instances, in which the spectrums have been time-averaged. These spectrums suggest the main difference of underwater sound signal in the cable installing the streamer steering device with different wing angle. Comparing the four spectrums each other, only a few of peaks increasing near 350Hz and 500Hz can be observed. The noise in the case of wing angle minus extreme angle is a little bit larger than horizontal angle and extreme angle. However, the largest spectrum difference with and without steering device is smaller than 5dB, so that it can be said that the flow noise from streamer steering device has no effect to the sonar in the cable.



Figure 6. One third octave frequency spectrum of sound level, v=3m/sec



Figure 7(a), (b). Auto power spectrum of sound pressure, v=3m/sec



Figure 7(c), (d). Auto power spectrum of sound pressure, v=3m/sec

4. SUMMARY

It is necessary that evaluating the capability of enduring the shock between the shipboard and steering device while enlacing back. The simulation shows that the hull of the steering device can endure the shock with the initial velocity lower than 3m/sec, which is made of polyurethane elastomer with a bush tube of carbon-glass-fibre. The underwater noise of steering device under different velocities is investigation in a water flow tube, that shows the flow noise due to steering device is only at a few of individual frequencies with some 2~5dB increasing. It can be concluded that the flow noise from steering device has no effect to the sonar in the cable.

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