Reduction of cable resistance by helical-ridge type fairing

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***Abstract*- A Karman Vortex commonly occurs when a cylinder is pulled through a fluid. Because of the vortex, the cylinder vibrates and the towed cable receives extra resistance. In MCS investigation, this is a big problem and cables are often damaged. Therefore, it is important to mitigate the cable resistance when towing objects. Vibration and resistance can be reduced by using various fairings, such as a helical ridge.**

The fluid resistance is cut down about 50% by the helical ridge type fairing.

***Index terms*- MCS, air gun, paravane, umbilical cable, helical ridge, and fairing**

Ⅰ. INTRODUCTION

In order to understand the deep structure of the earth's crust Japan Marine Science and Technology Center (JAMSTEC) has been conducting site surveys in the adjacent seas of Japan using a multi-channel seismic survey system (MCS).

Nippon Marine Enterprises Ltd. (NME) was established in 1980, operates four research vessels, a deep submersible Shinkai 2000 (out of service) and three deep ROVs owned by JAMSTEC. In 1997 JAMSTEC contracted NME to operate the MCS system and in 1999 one hundred ocean bottom seismometers (OBSs) were added.

The R/V Kairei has the largest on-board air-gun system in the world with 200 liters capacity, and a 5000-meter streamer cable to carry out the MCS reflection surveys. It fires 8 guns, each gun has a capacity of 15 liters and operating pressure of 140 kgf/cm2 .

The air gun array is spread apart by two paravanes, one paravane is towed from the starboard side and the other is towed from the port side.

In order to do a quasi-3D MCS survey by single-streamer cable we need to increase the horizontal spread of the air gun arrays, which are towed on both sides, to 100 m. The air guns on both sides will be shot in a flip-flop mode to run two gun arrays at a time. In 1999, we measured the towing width of the gun arrays, which was only 65 m. At that time we started a program to increase the width of the air gun arrays to 100m.

Paravanes are commonly used for remote-sensing systems, but it is not common to tow a paravane for scientific research in the sea. In general the technical data of a paravane is not made public. (e.g. see[1])

We have begun to collect data testing air-gun systems at sea, and are planning to test a 1/10-scale model paravane in a water tunnel. The value of this study is to better understand the operation of the paravane. It is hoped that the paravane can be used to improve the air gun system and allow us to operate in quasi-3D MCS survey mode. We will discuss towing techniques for decreasing drag and oscillation. The goal is the overall improvement of towed of observation and increased air gun array spread.

Ⅱ. EXPERIMENTAL

A. Method and equipment

Fig.1 shows the umbilical cable (color: orange, length: 140m, diameter: 66mm) with a spirally attached rope (diameter: 10mm), which is called a helical-ridge fairing. The fairing is used to decrease the oscillation and the resistance of a cable.

First, we towed the cable without the fairing. As expected, it experienced a lot of oscillation. Next, we twisted the rope around the cable as it was originally wrapped.

We measured the towing tension of the umbilical cable, which was about 600 kg at 4 knots. We needed to use some tools to hold up the cable when towing the system. If fairing tension decreases, we can reel out more cable to expand the air-gun array, and still operate the system safely. Implementing the fairing is good since it decreases the cable's resistance.

Fig.1. The umbilical cable on the port side of R/V KAIREI before the test.

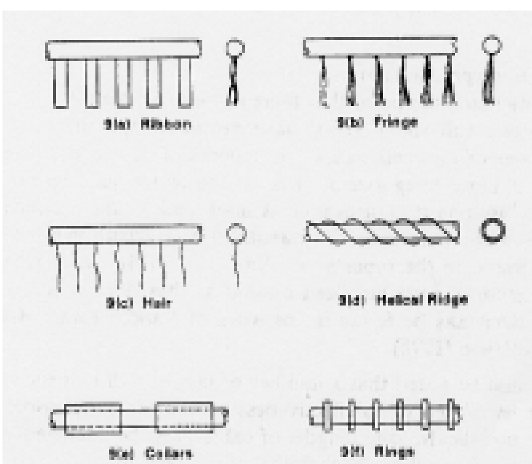

Fig.2 various cable fairings (after M.J.Every, 1982)

Fig. 2 shows various cable fairings. There are many fairings ribbon, hair, and helical ridge.... We adopted the helical ridge for our cable. One reason is that it has a proven oscillating-prevention effect. Our towed cable has always had a helical fairing, but its pitch was not optimized to reduce tow tension. Moreover, it is easy to obtain and attach. The fairing material is the Cremona rope made from cotton.

B. Water tunnel test

We experimented in a water tunnel to determine what was the optimal helical pitch for our cable. A picture of the experimental setup is shown in Fig.3 Our model is 1/2 diameter of helical-ridge type fairing. There were 7 types tested (included a bare cable).

Fig.3. A schematic diagram of the experimental

Fig.4. 7 kinds (included a bare cable) of 1/2 scale model

Fig.4 shows the 7 kinds (included a bare cable) of 1/2-scale models. Bare cable with a diameter of 30mm was used. A gain, the helical ridge is made of Cremona rope.

We used h=2mm diameter (h/D=1/15; h=Cremona rope diameter; D=bare cable diameter) and h=5 mm diameter (h/D=1/6). All test were done with a right-handed coil wrap. Three pitches were tested L=300mm (L/D=10; L=wrap interval), L=150mm(L/D=5) and L=60mm(L/D=2).

Flow direction of α=-60,-30,0,30,60 degrees were tested; α is the angle between the flow direction and the perpendicular direction to the cylindrical axis in the horizontal plane. Flow velocities of 1.0, 1.5 and 2.0 m/s were tested.

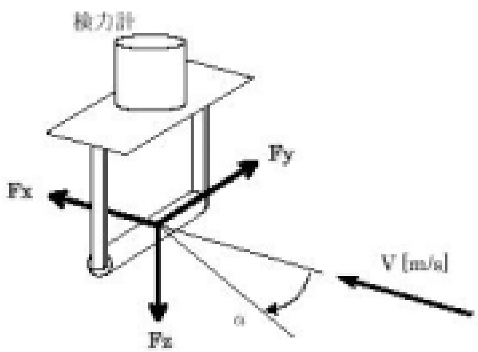

Fig.5. A component figures of 3-dimensional forces.

Fig.5 is a figure of the 3-dimensional forces, which operate on a cable. Fx is resistance, Fy (the deployment direction), and Fz (lift-force) exerted on a cable subject to flow V of water. The cable forces can be adjusted with the goal of improving the deployment width of the air gun array.

Considerations for each force are as follows; (e. g.see [3])

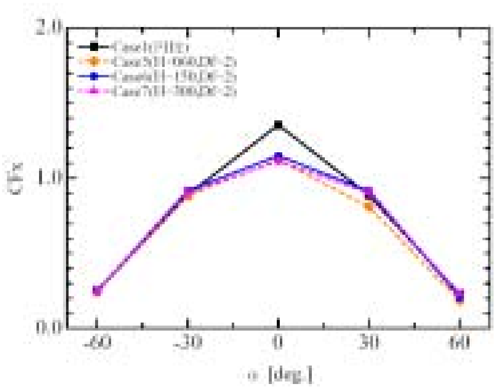

Fig.5-a. Fx-direction

This figure shows that for α=0, every tested pitch of helical cable reduces drag over bare cable. Bare cable's drag coefficient (Cdx) is 1.355 for an angle of 0 deg and 1.5m/s flow rate. All fairing's drag coefficient are 1.114〜1.177 for the same flow conditions.

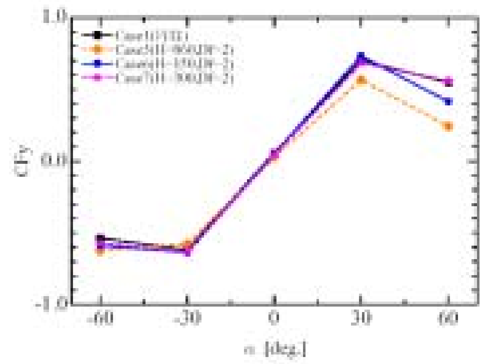

Fig.5-b. Fy-direction

α> 0 , a helical pitch of L/D=10 gives the big Fy component, allowing maximum spread. The bare cable's Cdy is 0.549 at an angle of 60 deg and 1.5m/s flow rate. All fairing's Cdy are 0.244〜0.560 for the same flow conditions.

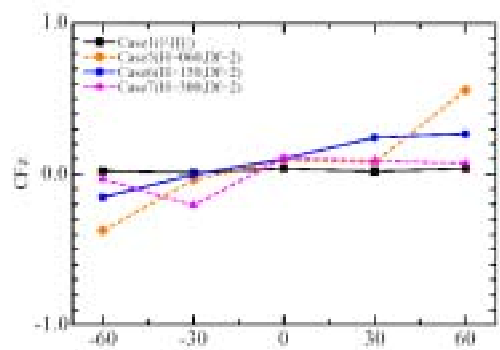

Fig.5-c. Fz-direction

Fz is the lift force and for right-hand-lay(**α**> 0), Fz is positive and a lift is achieved. Bare cable's Cdz is 0.021 for an angle of -60 deg and 1.5m/s of flow. The fairing's Cdz is -0.034〜-0.525 for this flow condition. The bare cable's Cdz is 0.031 for an angle of 60 deg and 1.5m/s of the flow. The fairing's Cdz is 0.071〜0.688 for this flow condition.

C. Sea trials

Since it is difficult and expensive to perform engineering experiments at sea, we used the result from the tank experiment to rebuild the helical-faring with the optimized pitch to reduce drag and vibration. Based on our tests, it was decided to attach a fairing with a diameter of 4mm to our cable. Fig.6 is showed the towed cable with this smaller helical-fairing. We also changed the sense of the pitch from right-handed to left-handed approximately every 10m to prevent the cable from sinking too low or rising to the surface.

$\alpha > 0$ is R, and $\alpha < 0$ is L in Fig.5-c.

Combining right-handed and left-handed fairings averaged out rising and sinking of the cable. The helical-pitch sense is illustrated in Fig.7.

Fig.6. The cable with an exchanged helical-faring of diameter of 4mm.

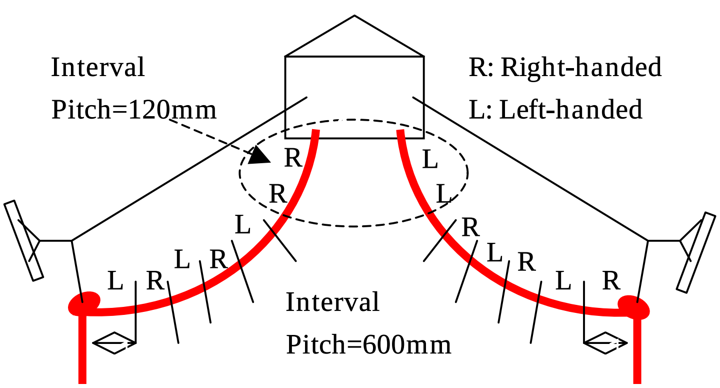

Fig.7. Helical ridge type at the ship

D. Results and discussion

We simulated MCS towing in the real ocean by examining the performance of various fairings in a flow tank. At sea the air gun deployment width was measured towing with the original and optimized fairing windings. Fig.8 is a photograph of the original towed cable before an improvement. The cable enters the water at as steep angle about 5m past the ship stern. This indicates that Fz is too big.

Fig.9 shows the towed cable after the fairing improvement. The cable enters the water at a relatively shallow angle.Also, as shown Fig.10 between trail number 10 (which corresponds to Fig.8 before fairing improvement) and trail number 11 (which corresponds to Fig.9 after fairing improvement) the cable tension dropped by more than 1/2 from over 600 to under 300kg.This drop in tension allowed increased delivery spread.

The last trail number 12 used the same helical fairing with an increased paravane angle to increase deployment spread at the cost of increased cable tension.

Fig.8. Photograph before an improvement

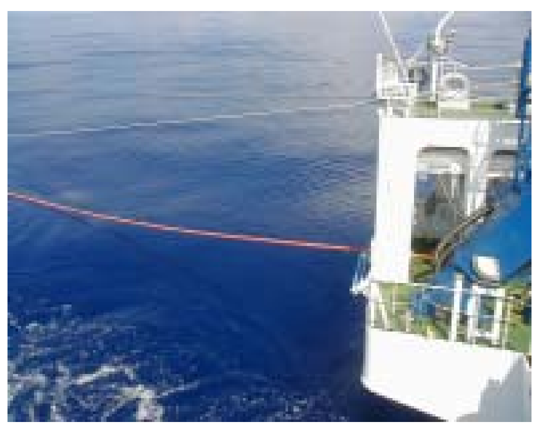

Fig.9. Photograph after an improvement

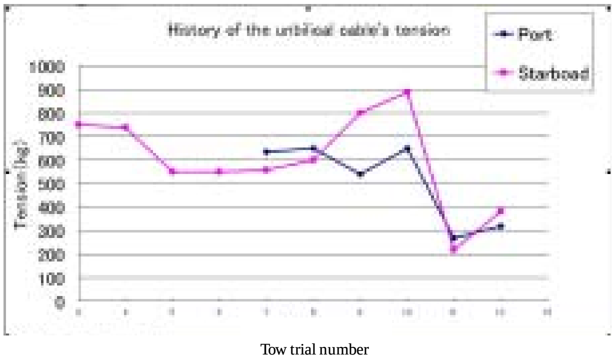

Fig.10. History of the umbilical cable's tension
Trial 10 corresponds to Fig.8
Trial 11 corresponds to Fig.9

Fig.12. Photograph when air gun deployment width is set to 90-100m

III. CONCLUSION

The purpose of this research was to increase the air gun deployment width beyond 65m.

Fig.11 shows that we were able to increase the width by 30% to over 90m.

We demonstrated an improved towing configuration, which used more of the paravane's capability. This year we measured the effect of flow on different fairing geometries. These design tank experiments have shown it is instructive to measure the 3 separate components of force on a helical cable. We hope these results prove useful for other applications, as well.

Fig.12 is a photograph when air-guns deployment width is set to 90-100m.The white portion of the water surface is the bubble of the high-pressure air oscillated from air-guns.

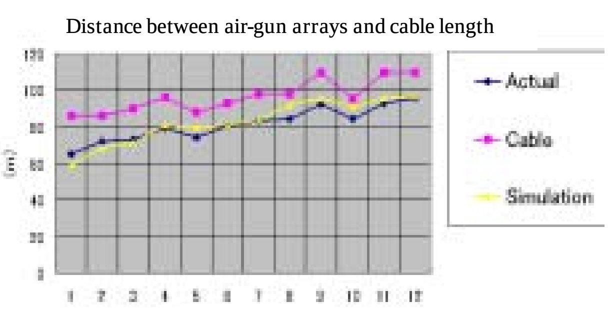

Fig.11. History of the distance between two air gun arrays and cable length

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