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A.R. Packwood

Internal Report No. 270
March 1987

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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HYDRODYNAMIC PERFORMANCE OF BRIDON FIBRES HAIR/FRINGE FAIRING FOR OCEANOGRAPHIC ROPES

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INTRODUCTION

Marine ropes used for instrument moorings or towing underwater vehicles are very susceptible to vortex-induced vibrations commonly known as strumming. This is due in part to their great slenderness, flexibility and the relatively low tensions at which they are often used. Strumming in this application has a frequency range of 5 to 200 Hz with amplitudes of vibration up to 3 cable diameters. These unwanted vibrations reduce the fatigue life of the rope and fittings, generate noise and dramatically increase the effective drag of the rope. Griffin (1985) quotes drag amplification factors of up to 250% for strumming cables. Clearly this strongly influences the drift or knock-down of instrument moorings, surface or sub-surface, and reduces the operating depth of towed vehicles.

A large number of schemes attempting to suppress the vibrations have been tried with varying degrees of success. A number are catalogued in the review paper of Every et al (1982). Among the more successful is "hair fairing". In this design individual fibres are attached to the cable, or cable covering, at regular intervals on a line running the length of the cable on the downstream side when immersed in the flow. When tufts of fibres replace the individual "hairs" the fairings is sometimes referred to as "fringe fairing". Typical spacings of hairs or tufts are 0.5 to 1d with tuft lengths of 4 to 6d. Every et al. suggest that hair fairings probably have the best characteristics with reported drag coefficients similar to, or even lower than, bare stationary cables. Fringe fairings, while suppressing the vibrations, may actually substantially increase the drag coefficient above that of a strumming cable. The most effective strum suppression and drag reduction device is a rigid, streamlined aerofoil shape which encases the rope. However this solution presents considerable winching, handling and storage difficulties. A table drawn from the figures quoted in Every et al. for the ranges of drag coefficients of these various strum suppressions devices and for bare cable is given in Table 1.

TABLE 1

Drag coefficients for cables and fairings after Every et al (1982)

	Cd
bare cable stationary	0.5 - 1.2
bare cable strumming	1.5 - 3.5
hair fairing	0.7 - 1.5
fringe fairing	2 - 6
rigid streamlined fairing	0.1 - 0.9

Ranges of Cd values are quoted because Cd is a function of Reynolds number Re where

$$Re = \frac{Vd}{\nu} \qquad \text{and} \qquad Cd = \frac{D}{\frac{1}{2}\rho V^2 d}$$

Note that D = cable drag per unit length and Cd is based on d, the diameter of the cable. It is usual to quote the normal flow drag coefficient i.e. for a cable vertical in the water. A separate loading function is then used to describe how the forces normal and tangential to the cable vary with the cable angle. Here Cd will always refer to the drag coefficient for the flow at 90° to the cable axis.

The Bridon Fibres Ltd fairing evaluated in this trial is shown in fig 1. It is assumed that the combined weight and buoyancy of the polyester overbraid and the polypropylene strands does not significantly change the weight of the wire in water. The overbraiding, which is necessary for the strands to knot into, increases the cable diameter in this case by 29%. In calculating the drag coefficient the diameter of the outer overbraid 10.6mm will be used. As can be seen from fig 1 the polypropylene strands are made up of hundreds of twisted yarns. At the knot the twisted diameter of the strand is approximately 2mm. The cut ends fray readily to make the fairing more of the "fringe" type than the "hair" type, using Every et al's terminology. The purpose of the trial was to evaluate the cable normal drag coefficient for a range of Reynolds numbers covering the likely operating conditions.

FAIRING TRIALS

The trials were carried out in Loch Linnhe using the NERC Research Vessel Calanus operating out of Dunstaffnage. After rigging on 2nd March the trials were conducted on 3-4 March which unfortunately was at a period of spring tides when tidal currents were quite strong. Loch Linnhe was chosen as the test site because the water depth there was greater than 100m for more than 4nm allowing a sufficiently long test run. Approximately 170m of the faired cable shown in fig 1 was overwound on one of the trawling winch drums on the after deck. From there the wire was passed over an 18in diameter polyurethane covered sheave suspended from the fixed stern gantry. The outboard end of the wire was attached to an upward looking side-scan sonar fish designed and built at IOS. The fish and transducer are shown diagramatically in fig 2 and are described in the paper by Thorpe et al (1985). At the inboard end the deck-unit electronics were connected to a Furuno colour video display which gave range data. In this experiment the side-scan sonar was used to give an accurate depth of the towed fish. This information was directly available from the Furuno display to an accuracy of ± 0.1 m.

By measuring the depth of the fish at known ship speed through the water and with a known length of wire in the water, it is possible to deduce a Cd value for the faired cable, provided the weight and drag of the fish are known. The assumptions involved in this procedure will be discussed later. Having a means of determining the depth of the fish the next important measurement is ship speed. Unfortunately the ship did not have an accurate speed log so an indirect method had to be employed. An IOS 10 kHz, shallow water, acoustic transponder was deployed on a 20m length of rope buoyed to the surface and free to drift in the tidal currents. A ceramic ring interogating transducer was then deployed from the ship in a small 'Dolphin' fish to a depth between 10 and 15m. Details of the transducers used and their operation are given in Phillips (1981). On setting a course to run past the drifting transponder sound travel times were recorded on a Mufax machine and ranges were calculated at regular intervals from which the ship speed relative to the transponder was estimated. Provided the ship and transponder were in the same current stream this would correspond to the ship speed through the water. The range accuracy of the system was approximately 2m. The ship speed was held by maintaining constant engine revolution and propellor pitch on any given run. The wire was marked at 50m, 75m and 100m. Runs measuring the depth of the fish were made for each of these lengths of wire in the water, for ship speeds ranging from 2 to 6 kts. On changing speed it was necessary to adjust the length of wire out in order to maintain the required length of wire in the water. At the end of the trial a conductivity, temperature and depth (CTD) cast was made in the centre of the trials area, using an NBA CTD, in order to determine the sound speed in water.

TABLE 2

Averaged results for each run and calculated cable drag coefficient

wire out (m)	ave speed (kts)	ave depth of fish (m)	Cd	Re
100	2.27	66.4	1.83	8300
100	3.45	40.7	1.91	12500
100	3.98	48.6	1.05	14500
100	5.30	29.2	1.28	19300
70	4.72	29.8	1.23	17200
75	2.45	53.0	1.70	8900
75	5.62	23.0	1.34	20400
50	2.29	41.6	1.69	8300
50	5.10	20.1	1.55	18500
51	5.83	25.6	0.77	21200
53	2.17	45.0	1.63	7900
54	2.15	45.6	1.69	7800

RESULTS AND ANALYSIS METHOD

The CTD cast revealed that the water column down to 50m deep was well mixed at a temperature of 7°C with salinity of 33.4‰. This gave the sound speed to be 1480 m/s and the kinematic viscosity of the water was taken to be $\nu = 1.5 \times 10^{-6}$ m^2/s. Each run past the transponder lasted between 10 to 20 min in which time fish depths and ranges were recorded every 1 or 2 mins. From the slant range information distance along track was calculated once the nearest approach distance to the transponder was known. Simply differencing these values and dividing by the time between measurements gave the ship speed. For each run the measured speeds and fish depths were averaged to reduce the errors. The averaged results are shown in Table 2. Typically over the length of a run the standard deviation in depth was 1 to 2m and in speed 0.2 to 0.26 kts. In other words the variability was around ± 10% at the slower speeds or the shallower depths.

The normal drag coefficient was derived using the IOS catenary analysis program known as SHAPE which is after the code of Mihoff (1966). The program uses the cable loading functions due to Eames (1968). These were developed to cater for both bare and faired cables and incorporate a parameter μ, known as the 'friction ratio', which is the ratio of friction drag to pressure drag for any given cable or fairing profile. Although some empirical data exists for determining μ for bare cables and for rigid streamlined fairings, there is none available for hair or fringe fairings. It was assumed that the fringe would add considerably to the friction drag while possibly reducing pressure drag therefore, based on Eames' figures for faired cable, a value of $\mu = 0.8$ was assumed. The resulting Cd values were found to be rather insensitive to the actual value of μ, as is shown later.

A version of the SHAPE program was modified to include a convergent iterative procedure which found the Cd value that gave the catenary solution which matched the measured ship speed and fish depth. The iterations were continued until the calculated catenary depth was within 10cm of the measured fish depth. Apart from details of cable diameter and cable and fish weights in water, the program requires a drag coefficient for the towed fish. As can be seen from fig 2 the towed side-scan fish is not well streamlined and undoubtedly the flow separates where the electronics tube enters the steel tube that comprises the main body of the fish. From Hoerner (1965) it was estimated that the drag coefficient for the fish, based on forward projected area and allowing for tow point and transducer drag, lay between 0.6 and 0.8. The more pessimistic value of 0.8 was used in the calculations but Cd was found to be relatively insensitive to the fish drag. The calculated values of Cd for each run are tabulated in Table 2 together with the Reynolds number, which is based on the outer diameter of the cable. Also Cd is plotted against Re in fig 3 where the degree of scatter becomes more apparent.

SOURCES OF ERROR

An error analysis was carried out varying the uncertain parameters, such as fish drag and the friction ratio, and evaluating the change in the calculated Cd value. Also changes in the measured parameters were made, commensurate with their observed variability, and the resulting Cd values noted. The findings are summarized in Table 3. From this it can be seen that the precision of the fish drag and friction ratio have very little influence on the deduced Cd. Errors in ship speed and fish depth however have a large effect and these probably account for the high degree of scatter observed in fig 3. Of these the most likely errors lie in the ship speed calculations. The area in which the experiments took place was subject to quite strong tidal currents and the transponder was observed to meander in the tidal stream quite considerably. It is probable that the transponder and ship were not always in the same part of the tidal stream. Consequently errors in ship speed are the most likely source of error that will not be reduced by averaging, unlike the measured depths. From this, with reference to Table 3 and fig 3, we might conclude that the best accuracy that may be quoted for the estimated Cd values is ± 25%. This covers most of the observed scatter band.

TABLE 3

Sources of error

error source and size	resulting change in Cd
3% in immersed length of wire	5%
10% in speed	18%
25% in fish drag	2%
37% in friction ratio μ	3%
2m in depth of fish	18%

CONCLUSIONS

Operationally no problems were encountered in using the Bridon Fibres fringe fairing. As far as could be observed from the ship all signs of cable strumming were suppressed. The polypropylene tufts showed no tendancy to pull out or suffer adverse damage when handled on the winch or over sheaves.

The effect of the fairing, through suppressing the strumming, is to substantially reduce the drag of the cable. In April 1984 the same side-scan fish was towed on the bare wire rope under similar operating conditions. The wire was observed to strum and the depth that the fish attained, for given wire out and ship speed, corresponded closely to a wire Cd value of 2.5. At a ship speed of 5 kts the fringe fairing reduced the overall normal drag of the bare strumming cable by 35%. The drag coefficient was actually reduced by 50% but the cable diameter was increased 29% by the polyester overbraid. The Cd values for the fringe fairing shown in fig 3 exhibit considerable scatter. It is thought that this was due to difficulties in accurately measuring the ship speed through the water in a region of complex tidal flows. Despite the scatter there is evidence that Cd decreases with increasing speed. This is probably a Reynolds number effect and maybe due to better streamlining of the tufts at higher Re values or changes in the friction drag on the tuft fibres. The drag coefficient is very much better than those reported by Every et al for fringe fairings, shown here in Table 1. However it is not quite as good as that quoted for hair fairing so there may be scope for improvement. It should be borne in mind that manufacturers performance predictions are notoriously optimistic. It therefore remains to be seen whether the low Cd values of 0.7 to 0.8, quoted for some hair fairings, are realistic in the operational environment.

The present Bridon Fibres fringe fairing successfully eliminates the strumming phenomenon and gives a useful drag reduction compared to a strumming rope in the Reynolds number range 10,000 to 25,000.

ACKNOWLEDGEMENTS

I would like to thank Alan Hall and Greg Phillips of IOS for their assistance in operating the side-scan and acoustic transducers with their associated electronics, the master and crew of the R.V. Calanus for their co-operation and Brian Short of Bridon Fibres for supplying the fairing.

NOTATION

Cd	cable or fairing normal flow drag coefficient
d	cable diameter or outer diameter of cable covering
D	cable drag force per unit length
Re	Reynolds number
V	velocity through the water
μ	Eames' friction ratio
ν	kinematic viscosity of sea water
ρ	density of sea water
mwo	metres-wire-out

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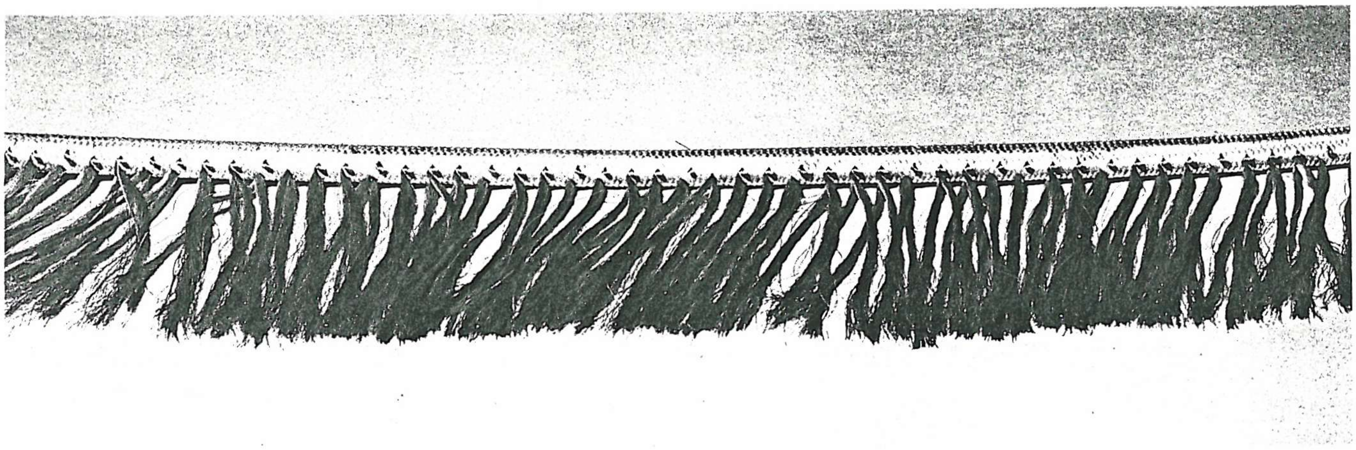
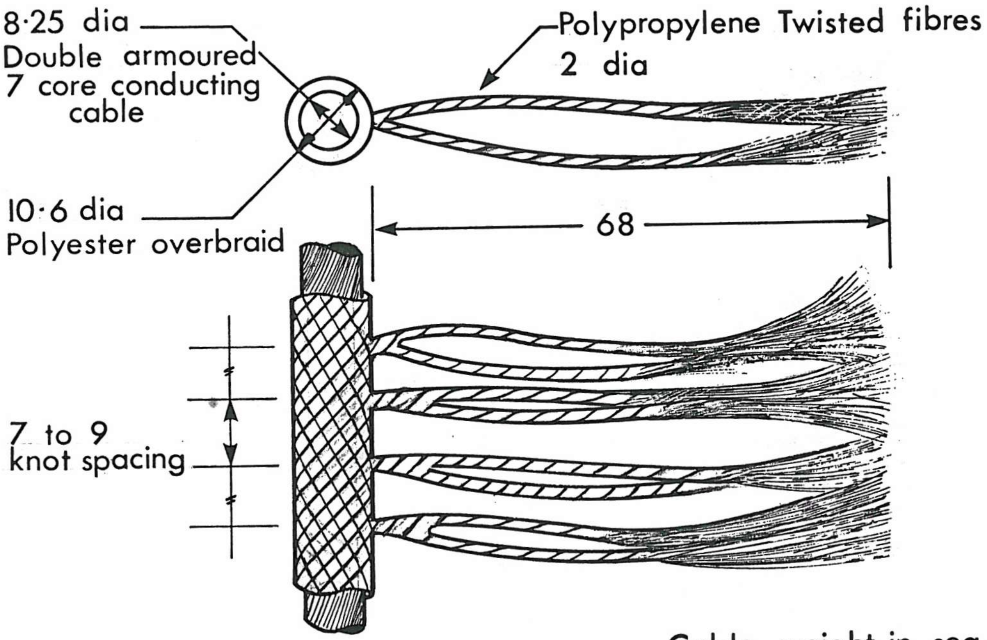
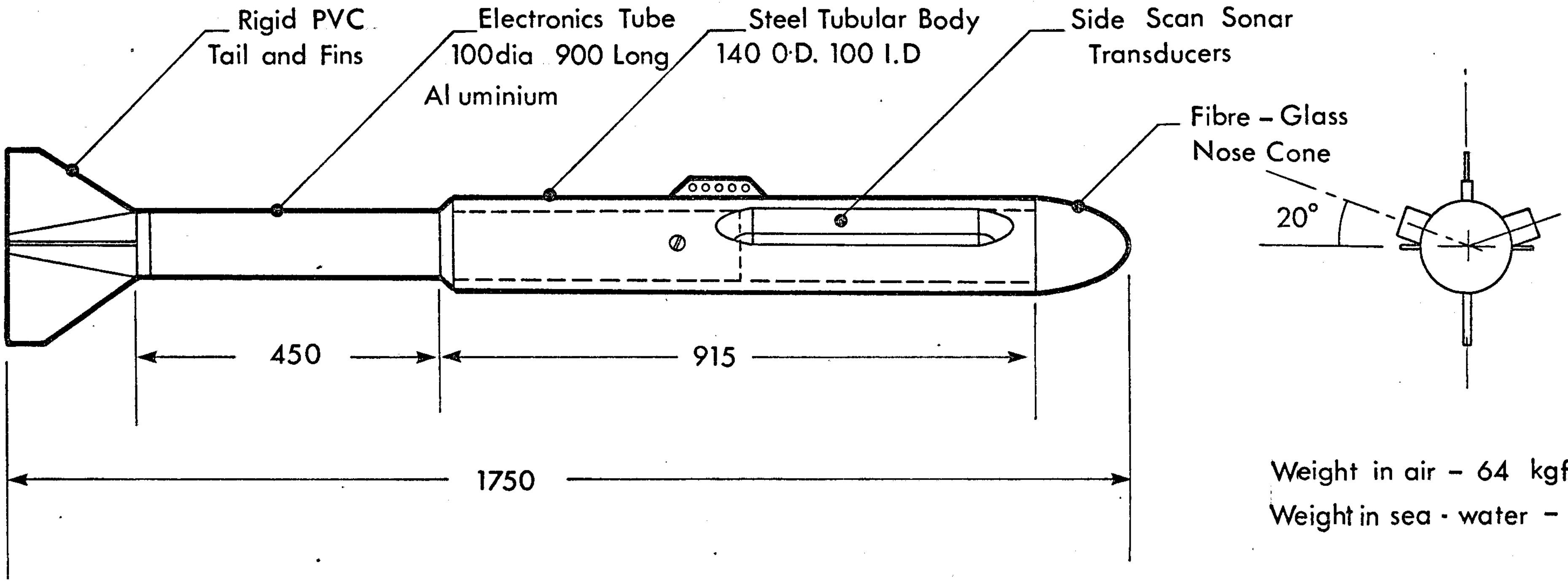




DIM Millimetres

Cable weight in sea-water: 2·06 N/m

Fig. 1 Bridon Fibres Fringe Faired Cable.



Weight in air - 64 kgf
Weight in sea - water - 44·5kgf

DIM --- Millimetres

Fig. 2 Upward Looking Side - Scan Sonar Fish

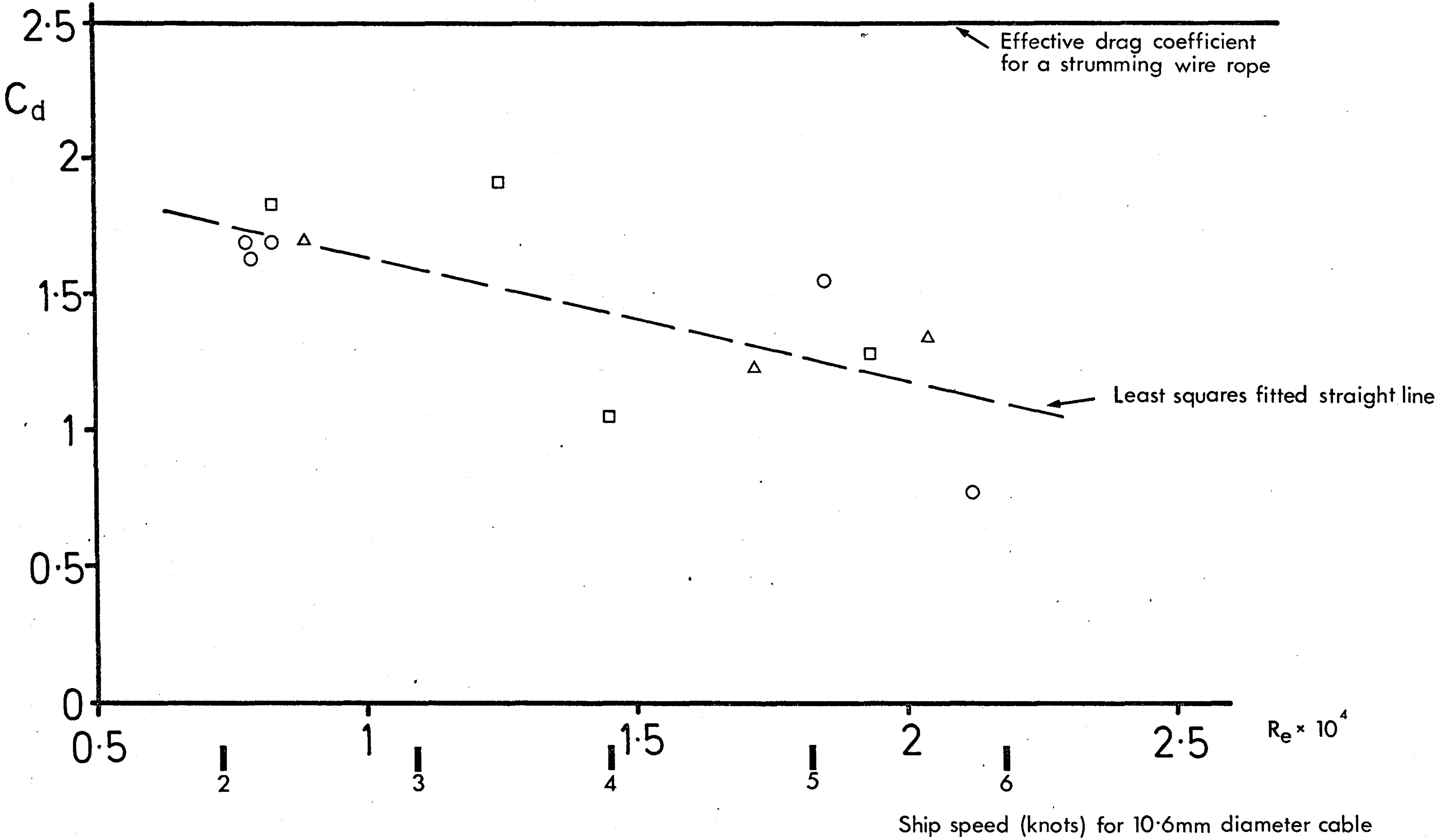


Fig.3 Normal flow drag coefficient for the Bridon fibres fringe fairing plotted against Reynolds Number.