RATING SUBSEA CABLES FOR RESISTANCE TO EXTERNAL AGRESSION

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Abstract: Apparatus to extend the existing ITU G976 impact test for subsea cables to failure is described and test results for several cable types are presented. The tests relevance as a method to measure a cables resistance to external aggression is discussed and compared with existing fault data.

1 INTRODUCTION

Since the introduction of optical fibre cables there have been large improvements in route engineering and plough technology that help to protect these valuable assets from acts of external aggression. However there are still unavoidable areas of the sea bed which offer poor or no burial and where the only means of providing protection is the selection of a correctly armoured robust cable design. At the current time there is no widely accepted method of determining a subsea cable's resistance to external aggression. Several methods to do so have been discussed, and at the last SubOptic the author jointly published a paper suggesting a new test and also extending the existing ITU G976 [1] impact test to the point of failure. The intention was to allow prospective purchasers to compare cable designs and for cable manufacturers to have the information to improve their products resistance to external aggression where required. Since then, BT have developed an impact tester capable of delivering the high energy loads required to fail most armoured cables.

2 APPARATUS

A picture of the impact tester can be seen in figure 1.

It consists of a substantial metal framework, bolted firmly to a concrete reinforced floor. A metal cradle, the weight of which can be adjusted between 115kg and 416.6kg in increments of 20.1kg by the addition of metal plates, is allowed to drop freely between greased uprights. The cradle can be raised to any desired height within the range 0 to 1.4m by an electric winch. The maximum impact energy the apparatus can therefore deliver is given by the formula

Energy=Mass x Height x acceleration due to gravity (g)

=416.6 x 1.4 x 9.81

=5721.6 J

The cradle is released by a cord activated mechanical quick release mechanism. This is a commercially available over-centre toggle linkage which allows for a safe, smooth load release. A prepared cable sample is secured on the base plate by means of a V-clamp, with additional horizontal clamping to ensure the cable is held straight across the impact area. The impact tool is bolted to the base of the cradle to allow for different profiles to be used and profiles to be changed if wear or damage occurs. For the tests detailed in this report a solid 50mm diameter profile, as specified in ITU G976, was used perpendicular to the cables axis.

4m cable sample were prepared by stripping the ends back so that there was enough loose fibre to be able to loop back a large proportion of the cables fibres. These were then connected to a light source and power meter so that the overall attenuation at 1550nm could be measured throughout the test allowing any microbending or optical failure to be observed. In addition a Megohmeter T2900 was used to measure the insulation resistance of the sample, before and after each impact at 500 V and 1000V, with 1000V being applied whilst the test took place.

Each cable sample was subjected to a range of impacts until both optical and electrical failures were observed or the limit of the machine was reached. The cable sample was then dissected, the lightweight core sectioned, and the Impact energy value where the insulation thickness was reduced to zero was recorded.

As the resolution of the results is determined by the weight and height interval chosen for each series of tests, the weight was kept constant for each cable, and normally for each armour type (RA, DA, SA). The height was altered so that a good spread of results was obtained, with increments of 0.1m being used when near the estimated failure point. Generally the resolution of the results for failures given in this report is 370J.

3 RESULTS OF IMPACT TESTS

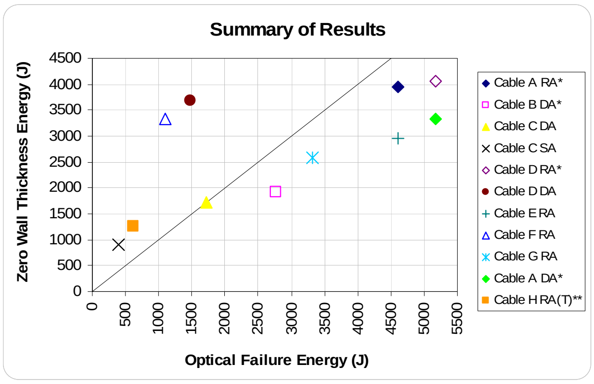


Figure 2 plots the energy recorded for optical failure and the energy value where the insulation thickness reached zero for each of the ten cables so far tested. A diagonal line has been drawn to show where the two energy levels are equal. Theoretically, a cable plotted above the diagonal line would fail optically before failing electrically, and cables plotted below the line would suffer a shunt fault before failing optically. In real life the voltage on a cable is likely to break down the insulation before the point of zero insulation wall thickness is reached and a shunt fault would occur. Therefore the position of cables above or below this line is only an indication of the type of failure to be expected.

It should be noted that cables marked * did not fail optically during the test so the energy used for optical failure is the highest value tested. It should be noted that as the insulation thickness had already been reduced to zero before this energy level was reached, theses cable would have failed electrically before this. The Cable marked ** did not reach a level of zero insulation thickness during the test so the highest energy tested at is used, however it had already failed optically before this point and is an unrepeated design.

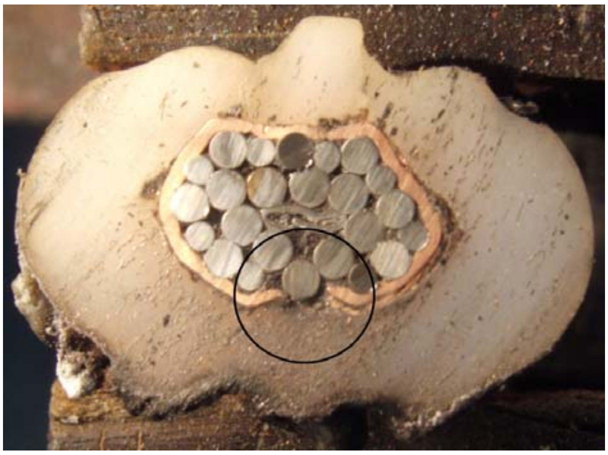
The repeatability of the results was examined by retesting Cable C DA using a different drop weight. Failure both optically and by wall thickness were found to be within 20J of each other.

Looking at the results so far obtained the following points are observed:

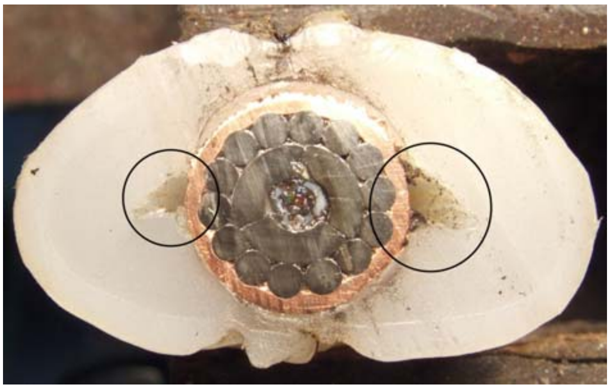
- Rock armoured cables perform better than double armoured variants of the same design
- Double and Rock armoured cables, designed for repeated systems, with an insulation thickness of 21mm or more require an impact energy of at least 3000J for their insulation to reach zero thickness
- The results indicate that generally embedded fibre packages performed better than loose tube or slotted core packages although other factors such as insulation thickness may effect this
- Slotted core packages require relatively low energy levels before microbending and optical failure are observed.
- Most of the repeated system cable designs examined have a higher optical failure energy than zero wall thickness, indicating that the predominant failure mechanism for these systems should be a shunt fault.

From the dissection of the failed cables two interesting observations were seen that are considered worth noting;

1) On one cable type, the copper tube which among other things forms the hydrogen barrier for the cable was found to be non-continuous thus forming a point at which hydrogen to enter the cable and cause high losses



2) On several other cable types, especially those with high density polyethylene insulation, cracks and voids were seen at the higher energy levels. These would encourage electrical failure.

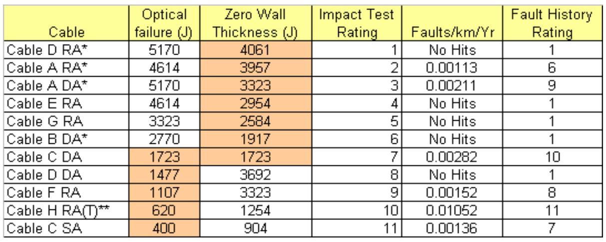


4 COMPARISON OF RESULTS WITH FAULT HISTORY

Due to the complex and varied nature of external aggression, the results of impact testing alone cannot be taken to show a cables ability to withstand an attack. When fishing gear, an anchor or other objects impact a cable, it will be subjected to a combination of impact, tension, abrasion, penetration and torsion. The degree of any particular component will depend upon the type of object, the sea bed conditions, angle of attack, cable tension and height above or below the seabed. In order to assess the suitability of impact testing to rating cables against external aggression some correlation between the test results and actual fault records must be carried out.

The ideal way to look at this would be to examine the fault history of cable systems where cables of consistent armour variants but of different types run closely parallel to each other for some distance. This would give a direct comparison of performance. In real life this is something that route engineers try to avoid to improve diversity, and in respect to the cable types examined in this paper, BT has only one instant involving two closely parallel cables. Their fault history shows that over a 50km section, where the cables run approximately 10km apart, Cable H RA (T) has suffered 6 failures whilst Cable A RA has had none. This reflects the findings of the impact testing as theses cables are at opposing ends of the graph shown in figure 1. It is however only a very small sample and at best indicates that general suitable/not suitable decisions could be made on the basis of impact testing.

In order to improve the confidence in impact testing to failure and see if the results are reflected in "real life", the overall fault history, for the tested cables, in BT managed systems in Western Europe were calculated on a faults per km per year in service basis. Table 1 shows the results of this along with the energy failure values obtained from the impact testing used to plot figure 1.



Cable	Optical failure (J)	Zero Wall Thickness (J)	Impact Test Rating	Faults/km/Yr	Fault History Rating
Cable D RA*	5170	4061	1	No Hits	1
Cable A RA*	4614	3957	2	0.00113	6
Cable A DA*	5170	3323	3	0.00211	9
Cable E RA	4614	2954	4	No Hits	1
Cable G RA	3323	2584	5	No Hits	1
Cable B DA*	2770	1917	6	No Hits	1
Cable C DA	1723	1723	7	0.00282	10
Cable D DA	1477	3692	8	No Hits	1
Cable F RA	1107	3323	9	0.00152	8
Cable H RA(T)**	620	1254	10	0.01052	11
Cable C SA	400	904	11	0.00136	7

The first column of the table shows the cable type, the second and third the values the cables failed at during the impact tests. The lowest failure energy, either optical or zero wall thickness, is highlighted and the cables are ranked in order highest to lowest (Column 4). If the impact test is a good indication of cable robustness this order should be reflected in the cable fault history. This is listed in column five and the cables ranking according to this is given in column six.

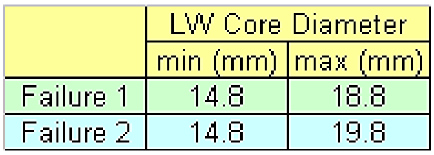
As can be seen, the two different rankings do not exactly correspond although it can be said that generally, cables which perform well in the impact test do have a good fault history. It is believed that the main reason for the discrepancies seen are in the age of the cable system in which the types of cable looked at are found: Firstly several of the cable types have experienced no failure in service. These are all in systems installed since 1998. As already stated route engineering and plough technology have improved dramatically, and it is these later systems that benefit the most from this. Secondly it is two armour variants from the oldest cable design present that are rated well in the impact test but have a higher than expected rating from their fault history. For a cable to experience external aggression it must be on or very near the seabed surface Older systems which were installed when ploughing was still being developed, and the installation ships used had limited bollard pull will not be as well buried and thus it would be expected that their fault record be worse.

Another point of interest is if the type of failure identified by impact testing is reflected in real life. Unfortunately a hit on the cable may be large enough to cause both types of failure, so that having a lower optical failure energy may not mean that all failures on that cable type are exclusively optical. As already stated, for repeated system designs, impact testing indicates that electrical failure should occur more frequently than optical failure and from experience most system operators would state that this is indeed the case. However cable types with the fibres held in a central slotted core arrangement are known to suffer more from optical faults, either high losses or complete optical failure. The one example of a repeated design of this type, Cable F tested so far also failed optically at approximately 1/3rd of the energy it failed electrically. Examination of the fault history show that 75% of the faults in this cable type were identified as optical failures, corresponding well with the impact test results.

5 ESTIMATING IMPACT VALUES OF ACTUAL FAULTS

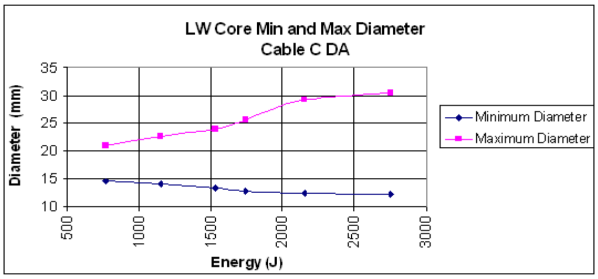
In a previous SubOptic paper [2], the likely maximum impact energy from a fishing vessel on a cable was estimated to be approximately 3600J. By measuring the maximum and minimum diameters at the point of impact from actual faults that have been recovered, and comparing these with those recorded during impact testing, BT hopes to be able to build up a picture of what actual impact value a cable needs to be able to survive.

To date only two examples are available, all of Cable C DA. The measurements of the dissected light weight core (LW) of these faults are given below in table 1



	LW Core Diameter	
	min (mm)	max (mm)
Failure 1	14.8	18.8
Failure 2	14.8	19.8

Theses figures can then be compared with the diameters of the LW core obtained from the dissected Cable C DA impact tested cable from the graph given below in figure 5 to obtain a predicted energy of the hit which caused the failure.



By doing so, it can be seen that the predicted impact energy level which caused the failure in these cases was approximately 750J or less. Electrical failure, or zero insulation thickness, was predicted by impact testing at 1723J. So the use of impact testing to predict actual energy levels for failure may not be appropriate, although with only two instances examined, more work needs to be carried out in this area.

6 CONCLUSION

From comparison of actual fault records to the experimental data, it can be seen that impact testing to destruction could be developed as a valid method of ranking a cables resistance to external aggression. More work needs to be carried out on different cable types and variants to build up a more complete picture, and BT intend to use the results to aid in their selection of cable where, due to lack of guaranteed burial or other considerations, resistance to external aggression is identified as a requirement.

7 REFERENCES

1. ITU G976, Test methods Applicable to Optical fibre Submarine Cable Systems

2. Lynsey Swatton, Purchaser's Request to Suppliers: The Design of a New Qualification Test, Suboptic 2001