

Fatigue, Internal Stresses and Deformation of Electrical Umbilicals: Experimental Work

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ABSTRACT

This paper reports the experimental part of a development project on the design and fatigue performance of composite umbilicals. A series of tests have been carried out, both fullscale tests on complete umbilicals and more fundamental tests, to improve the understanding of the internal behaviour of an umbilical, to verify the theoretical analysis and to gather physical data necessary for the development of an analytical theory for calculating internal stresses in an umbilical being bent over a sheave.

INTRODUCTION

Over recent years, umbilicals have been increasingly used in many off-shore applications worldwide for subsea control, chemical injection, etc. The failure of these components in a remote subsea installation can be extremely expensive both in lost production and rectification.

Unfortunately, insufficient knowledge of the complex behaviour of umbilicals has often led to defective design, manufacture, installation and operation. A U.K. Department of Energy report, dated July 1990, states a high percentage of failures for umbilicals (Knight et al., 1990). Following the failures, fault analyses were of course carried out. However, it became obvious that some form of planned R&D was necessary.

Since 1985, BP, ABB Norsk Kabel and EFI, which is a part of the SINTEF Group, Norway, have run a project with the objective of acquiring a better understanding of the behaviour of umbilicals and to identify factors having a significant influence on the life of umbilicals.

It was decided, as a start, to concentrate on electrical umbilicals, both unarmoured and armoured, and to try to determine the stresses and the fatigue life of an axially loaded umbilical running back and forth over a sheave. If this problem is amenable to analysis, it is expected that more complex umbilicals and other types

of bending problems can be included in later phases.

The objective of experimental work, which will be presented in this paper, was mainly to provide backup data and confirmation of the assumed theoretical parameters, and to verify the results produced by the mathematical model.

The development of an analytical theory for calculating internal stresses is described in an accompanying paper (Waloen et al., 1992).

OBJECTIVES AND TYPES OF TESTING

A number of experimental tests have been carried out parallel to the development of the analytical theory.

The main objectives for the experimental work have been:

- 1) To improve the understanding of the internal behaviour of an umbilical as it is loaded and bent over a sheave.
- 2) To perform tests to verify and, if necessary, modify the theoretical analysis as it was developed.
- 3) To gather necessary physical data that is used as inputs to the theoretical model: Tensile tests, friction tests, fatigue tests of single conductors, etc.

Tests to improve the understanding of the internal behaviour of an umbilical and to verify analytical calculations include:

- Cyclic bending fatigue tests to investigate the influence of factors affecting fatigue life of an umbilical, i.e., lubrication (coefficient of friction), sheave diameter, axial load, conductor type (solid or stranded), armour type etc. A study of factors affecting kink formation was included.
- Bend stiffness tests to measure the force required to bend umbilical samples over a range of sheaves, in order to evaluate the bend stiffness of the umbilicals.

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