Structural Analysis of Composite Umbilical Cables

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ABSTRACT

Numerous submarine cable applications require sophisticated designs that satisfy a combination of strength, communication and power transmission functions. These cables often have highly complex constructions that require structural analysis beyond simple, idealized mathematical models. In general, manufacturing industries have realized greatly increased productivity and product quality gains through the implementation of general purpose, computer-aided design tools. The cable industry, however, has not benefited from these tools to the same extent because of the difficulty of modeling the helical wire geometries found in cables. A finite-element code developed specifically for modeling the structural properties of cables, rope and flexible pipe is described in this paper. Examples presented illustrate the validity of the code.

KEY WORDS: Cable; wire rope; umbilical; flexible pipe.

INTRODUCTION

Figure 1 illustrates a typical umbilical cable that challenges engineers in designing modern cables with composite constructions of helically-laid strength, conducting and transmitting components with materials ranging from nonlinear plastic and elastomeric to metallic and synthetic fiber materials. Single, double and triple helical geometries (Huang and Knapp, 2006) further complicate structural analysis.

The computer code, CableCAD, has been developed for geometrical and finite element modeling of cables. Fig. 1 is a solid model of a composite umbilical cable generated with this code. A finite element mesh is generated automatically by the program, and nodes are coincident with lines and points of contact between adjacent helical-helical and helical-tubular components. This latter function greatly simplifies creation of a finite element model. Upon solving, plots of cable strain, torque or rotation, deformations and stress contours are produced by the code to assess cable performance.

The purpose of this paper is to discuss the effectiveness of the cable model in modeling composite umbilical cables, and to validate the model with comparisons of model and physical test results. A brief description of the model is given, and pertinent structural and finite element equations are described in the references cited.

GEOMETRIC MODEL

An accurate geometrical description of a cable is needed to define the exact locations where components make contact. Since the shape of a circular component viewed in the cross-section is not circular, and varies with radial distance from the cable axis and lay length, an automated geometric modeler is employed.

For contra-helical adjacent layers, contact occurs on a cylindrical surface between the layers (two outer armor wire layers in Fig. 1); for meshed layers having the same lay length and direction (tubular layers in Fig. 1), the modeler automatically fits components into the interstices of a subjacent layer using a drag and drop operation. For example, the core components of the ROV cable shown in Fig. 2 are assembled by this operation. Shown is a filler component being dragged between a...