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Design of Spiral Strands Against Axial Fatigue

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ABSTRACT

The author has fairly recently reported details of theoretical predictions for the axial fatigue life of large-diameter (e.g. 127 mm O.D.) spiral strands based on first principles. The predictions have been verified against a very extensive set of test data for spiral strands with diameters ranging from 25 to 164 mm. The paper presents newly developed S-N curves which, unlike the previously available design S-N curves, take variations in the lay angles of large-diameter (i.e., realistic) spiral strands into account, and also cater for the effects of end terminations. The proposed S-N curves are based on extensive theoretical parametric studies using the newly proposed model. In addition, the question of size effects as regards the axial fatigue performance of spiral strands will be addressed in some detail. Finally, the proposed S-N curves are compared with those recommended by others.

INTRODUCTION

The safety of the many deep-water platform concepts is, among other considerations, strongly dependent on the reliability of the anchoring systems which should have a high level of integrity and whose costs of installation and replacement are very high. Steel cables are used for mooring certain types of offshore platforms such as semi-submersibles, guyed towers, etc., and are proposed as elements of mooring systems of wave energy devices. The loading spectrum on the individual mooring lines is obviously very complex: It depends mainly upon the type of structure, its location and type of mooring system adopted. The most significant aspects of the service conditions are long lives (in excess of perhaps 20 years) and the random nature of imposed loading. Permanent immersion of most of the cable in seawater is another important consideration.

Cable design and manufacture are often considered to be an art rather than a science. The limits of validity of present design and calculating routines, largely based on commercial experience, are far from clear and it is an area where the rule of thumb reigns supreme. Simply scaling up cable diameters to meet the ever-growing demands for stronger elements, via extrapolation of the orthodox designs, is a risky process. Model tests of the designs in the present state of understanding of cable (i.e., spiral strand and/or wire rope) behaviour can (despite very encouraging progress in the last 15 years) still prove to be unacceptable for investigating certain characteristics of cables (such as their axial fatigue performance), while full-scale testing is very time-consuming and expensive.

In the past, the only reliable source of information on steel-cable axial fatigue characteristic has been laboratory tests on cable specimens, the results of which often exhibit large degrees of scatter, and the number of variables involved makes the interpretation of the extensive work by manufacturers and technical societies rather difficult. Divergence of opinion on various aspects of cable behaviour under even closely controlled laboratory conditions is not uncommon. Even for the same diameter and loading, different cable constructions may exhibit significantly different fatigue lives. In published work, there seems to be an undue amount of repetition and imprecise conclusions. The conflicting desires for publicity and commercial secrecy are also evident.

With the availability of increasing numbers of test results for a wide variety of cable constructions, design S-N curves for steel cables have been included in some recent codes of practice in the field of structural engineering. One example is API (1992); another is the design S-N curves prepared for the Health and Safety Executive by the Transport Research Laboratories, U.K. Work is also in progress for Eurocode 3. The API and HSE attempts at codifying the S-N curves have taken the form of suggesting lower bound curves to published S-N data, although, as discussed by Raoof (1992), the API recommendations may prove to be unconservative in certain cases.

Fairly recently, a theoretical model was reported for predicting axial fatigue life under uniform cyclic loading of multilayered spiral strands from first principles (Raoof, 1990a,b, 1991). The theoretical predictions were based on an extension of a previously reported orthotropic sheet model (Raoof and Hobbs, 1988), and the theory could predict the spiral-strand axial fatigue life to first wire fractures both at the fixed end and away from the terminations (i.e., in the free field). Some extensive large-scale experimental data from other sources provided very encouraging support for the theoretical predictions for strands with outer diameters ranging from 25 to 127 mm (Raoof, 1990a, b, 1996; Alani and Raoof, 1995; and Raoof and Alani, 1997).

Based on Raoof's theoretical model, the lay angle of the helical wires in different layers has been shown to be the primary geometrical parameter influencing the axial fatigue life. In other words, spiral strands with different lay angles (within current manufacturing limits) have widely different axial fatigue characteristics: This important point has been ignored in the codes of practice such as API (1992), which propose a single S-N curve irrespective of the type of cable (spiral strand and/or wire rope) construction. Moreover, the theory is capable of quantifying the important effects of end terminations, which have also previously been ignored in the proposed codified S-N curves. Such S-N curves do not differentiate between the occurrence of individual wire breakages in the vicinity of end terminations and wire fractures away from the ends (i.e., in the free field).

This paper presents newly developed S-N curves for large-

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