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Effect of Lay Angle on Various Characteristics of Spiral Strands

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ABSTRACT

In a series of publications over the last 14 years, a number of theoretical models (backed by large-scale experimental data) based on a treatment of the layers of wires in a spiral strand as a series of orthotropic sheets have been reported by the author and his associates. Axial, torsional and free bending load cases have all been addressed with the effects of interwire/interlayer friction and contact deformations fully accounted for. The final results enable one to obtain reliable estimates of the no-slip and full-slip axial, torsional and bending stiffnesses, with their associated hysteresis for an axially preloaded spiral strand experiencing superimposed (external) uniform cyclic load perturbations, and axial or restrained bending fatigue life. Using a series of theoretical parametric studies on a large number of spiral strands with widely varying strand (and wire) diameters and lay angles, the lay angle has been shown to be the primary first order parameter (with the other geometrical parameters being of secondary importance) affecting the values of various strand stiffness coefficients and hysteresis. It, then, follows that (at least in principle) by varying the lay angle of the wires, a cable designer should be able to significantly change various overall characteristics of a strand to suit the demands made by the practising engineers in charge of designing the structures supported by the cables. However, it must be noted that although reductions in lay angle may, for example, increase the strand axial stiffness to the designer's benefit, they may (at the same time) significantly reduce the sometimes very desirable levels of structural damping in the strands, etc. It, then, follows that in the course of the strand design process, the choice of the magnitudes of the lay angles in various layers should take into account their influence on a number of overall cable characteristics, and one should work towards optimizing the constructional details of strands to fulfil a number of diverse (and sometimes conflicting) demands on their overall structural characteristics. Using the newly developed theoretical models, it is now possible to estimate a wide range of overall strand characteristics for any type of strand construction. Obviously, this will enable one to optimize the strand construction details to meet such a task. Recently, a major rope company designed three 127-mm O.D. spiral strands for use by the author with lay angles of 12°, 18° and 24° in their various layers (covering the manufacturing limits of lay angles) while the other geometrical parameters were kept nominally identical. The purpose of the present paper is to provide numerical results for certain overall characteristics of these strands as estimated by the models based on the orthotropic sheet approach and, hence, show the influence of changes in the lay angles on, say, the stiffness coefficients and hysteresis under various modes of loading. Using such results, then, a designer will be in a better position to gauge the manner in which lay angles are likely to influence a number of overall strand characteristics.

INTRODUCTION

Back in 1979, a survey of previous work on spiral strands (Raoof, 1983) showed that on both the experimental and the theoretical sides, reliable information of direct practical use was very scarce. The impression gained was that the analyses and techniques had paid too little attention to the effects of interwire contacts on overall strand behaviour, and rather too much attention to small (6 or 7 wire) strands. In published work, there seemed to be an undue amount of prejudice, repetition and imprecise conclusion. It became clear that the physical behaviour of even the apparently simple spiral strand (much less a rope) was not well understood, and the then available analytical methods had considerable shortcomings.

The safety of the many deep-water floating platform concepts is, among other considerations, strongly dependent on the reliability of the anchoring systems. During the operational life of the platform, the mooring lines will experience significant axial and free bending stress perturbations (the latter in the vicinity of the end terminations) with a consequent danger of fatigue failure. The loading spectrum on the individual mooring lines is obviously very complex; it depends mainly upon the type of platform, its location, and the type of mooring system adopted. The most significant aspects of the service conditions are long lives (in excess of maybe 20 years) and the random nature of the imposed loading. A collection of examples which demonstrate the level of loads and their frequency of occurrence was given in a report for the U.K. Department of Energy (Webster et al., 1982). This report was concerned with a feasibility study for the three primary types of tether design (wire strands of parallel or spiral lay, thin-wall tubular steel, and thick-wall tubular steel and shaped forgings) which were, at that time, believed to be the strongest candidates for Tension Leg Platform applications, with the Hutton TLP being the first of its kind to be built. Among other priorities, this report identified an urgent need for a better understanding of the axial and free bending performance of large-diameter (e.g. 127-mm O.D. or greater) strands, for which (at that time) there seemed to be very little available information of direct practical relevance. It was noted that although steel cable design and manufacture dated back to the 19th century, it was still an area where the rule of thumb reigned supreme with the commercial experience limited to the performance of cables with diameters not exceeding, say, 75 mm. Although cable manufacturers were able to manufacture steel cables with diameters well in excess of 100 mm (based on orthodox designs), they were the first to admit their lack

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