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Characteristics of Locked Coil Strands Under Free Bending

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ABSTRACT

In published literature, the strand constructions dealt with have almost invariably involved only wires which are circular in cross-section. There are, however, instances when shaped wires are used in, for example, half-lock and full-lock coil constructions. There is currently a paucity of theoretical and/or experimental results for locked coil steel cables. Only recently, some large scale restrained bending fatigue test data related to locked coil ropes has been published. It is by using these data that it has been possible to propose a contact stress-slip versus fatigue life curve for these cables, which should be useful as a predictive tool in design applications.

INTRODUCTION

In offshore applications, platform drift and yaw and possible hydrodynamic effects such as vortex excitation will be responsible for a restrained bending action near the end fittings of, for example, tension legs in the inevitable presence of bearing friction at the terminations. This paper is particularly concerned with these bending effects in steel cables (spiral and/or locked coil strands) in the absence of sheaves, fairleads or other formers, so that the radius of curvature of the cable is not predetermined. These conditions will be referred to as free-bending.

Despite the efforts of research workers which date back to the early years of this century, little light had (until recently) been cast on the mechanisms of the free bending fatigue problems in steel cables, and traditional methods of design against restrained bending fatigue of cables at terminations suffered from significant shortcomings (Raoof, 1993a, b). Closely related free bending problems are a source of concern (and not infrequent failures) in other structures, ranging from suspension and cable-stayed bridge hangers and stays for guyed masts to electromechanical cables where fatigue failures near partially restrained terminations caused by aero or hydrodynamic loading are not uncommon.

For the free bending of long cables under an approximately steady axial load, it is common to introduce a mathematically convenient constant effective bending rigidity $(EI)_{eff}$ for the cable, from which the radii of curvature at the points of restraint are calculated (Raoof, 1993a, b). The maximum bending strains in individual wires are then found on the basis of a variety of, frankly, sweeping assumptions (Raoof, 1983; Raoof and Hobbs, 1984; Raoof, 1993a). These strains are further assumed to govern the strand bending fatigue life. However, this last assumption is not supported by the experimental evidence (Raoof, 1989, 1992b) where it is often found that the primary mode of wire fatigue failure is associated with interlayer or interwire fretting action very close to the usually partially restrained terminations of various types (Gabriel, 1993; Miki et al., 1992; Kopanakis, 1992).

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In a series of recent publications by the author and his associates (Raoof and Hobbs, 1984; Raoof, 1989, 1990a, 1992b, c; and Raoof and Huang, 1992), a theory backed by a number of large-scale and carefully conducted experimental checks has been developed for predicting the restrained bending fatigue of axially preloaded spiral strands (i.e., helical strands with only round wires) at terminations. The newly developed (alternative) contact stress-slip approach assumes (in line with laboratory and field observations) the interwire fretting between often counterlaid wires in various layers of steel strands to be the factor responsible for individual wire fractures.

The previously reported contact stress-slip parameter was developed in connection with spiral strands composed of a large number of round wires. There are, however, instances where shaped wires are used in, for example, half-lock and full-lock coil construction (Fig. 1). The three main shaped wires used in such constructions are the wedge, half-lock, and full-lock Z or S shaped types.

The purpose of the present paper is to present details of a theoretical model for obtaining values of contact stress-slip parameter for locked coil strands. Using such an approach, then, a contact

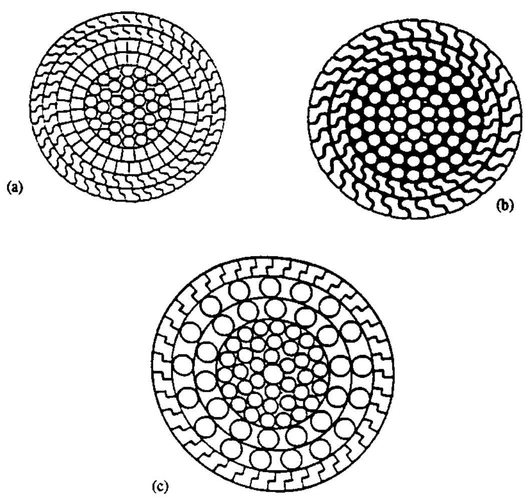

Fig. 1 Typical examples of lock coil cable constructions