

The Effect of Wire Indentation on Cable Rotation

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ABSTRACT

The importance of selecting lay angles to achieve torque balance in cables with contrahelically wound wire layers is well-known. This paper explores a second mechanism, frequently overlooked in cable design, which can greatly affect cable torque/rotation performance. Radial deformations that occur due to indentation of helical wires into adjacent plastic cylindrical layers must be considered in computing cable torque. This paper describes a procedure based on a standard mechanical test to determine wire indentation. This procedure is demonstrated by predicting the permanent "constructional stretch" and attendant change of end rotation of an electrical-optical cable. Model and test results are in good agreement.

INTRODUCTION

Electrical, optical and fluid power and communication cables frequently employ plastic cylindrical layers that serve as electrical or mechanical insulation. As the cable is loaded in tension, radial compressive pressure is produced between helical wire and cylindrical layers (Knapp, 1979). This results in radial indentation of the relatively rigid round wires into the softer plastic cylindrical layers. The amount of indentation depends on the layer pressure and elastic-plastic properties of the cylindrical layers.

This paper introduces a procedure based on a simple plane-strain compression test to estimate wire indentation for any wire diameter and layer thickness. This procedure has been implemented in the SAC computer program for the stress analysis of cables (Knapp, 1989). The effect of wire indentation on cable rotation is examined for an electrical-optical test cable.

Torque developed in a cable is due to the circumferential component of wire tension about the cable axis at a pitch radius, R . A change in R , such as produced by wire indentation, results in a change of torque. Although R changes by only a small amount, the effect on torque may be significant, particularly for a low-torque cable design.

Cable torque-balance is achieved by alternating the lay directions of helical wire layers so that the sum of torques in one lay direction equals the sum of torques in the other direction. The simplest case would be a cable with two outer contrahelically-wound wire layers. The lay angle for each layer is selected to yield a net zero torque for the cable, assuming that the pitch radius of each wire layer remains constant. For wires made from the same material, this condition (Knapp, 1981) is satisfied approximately by:

$$\sin \alpha_2 = - \frac{n_1 A_1 R_1}{n_2 A_2 R_2} \sin \alpha_1 \quad (1)$$

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Received January 17, 1994; revised manuscript received by the editors June 29, 1994. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.

KEY WORDS: Cable, torque, wire indentation.

where α = lay angle; n = number of wires in a layer; A = wire area; and the subscripts refer to the inner and outer layers 1 and 2. Eq. 1 is an approximate condition for torque balance that can be used to examine the effect of a changing radius, R_2 , on the lay angle, α_2 . For example, assume that the two layers are identical except for the direction of the lay angle. For $\alpha_2 = 20$ degrees and the pitch radius, $R_2 = 10$ mm, a wire indentation of only 1 mm would require approximately a 2.5 degree adjustment of the lay angle to preserve torque balance.

This simple example provides the motivation for this study. As a torque-balanced, contrahelical construction is very sensitive to radial deformations in the cable cross-section, a means of predicting the change of pitch radius due to wire indentation is needed. In the following sections, a procedure for predicting this indentation is described.

WIRE INDENTATION EXPERIMENTS

To characterize the indentation mechanism, two experiments were conducted. First, the compressive yield stress of the indented material was measured. From this test, a true-stress, true-strain curve and yield point were obtained. Second, experiments were performed to measure indentation of several sizes of round wires. These data are used to verify the indentation model discussed in the subsequent section.

The material used in the test cable examined later and selected

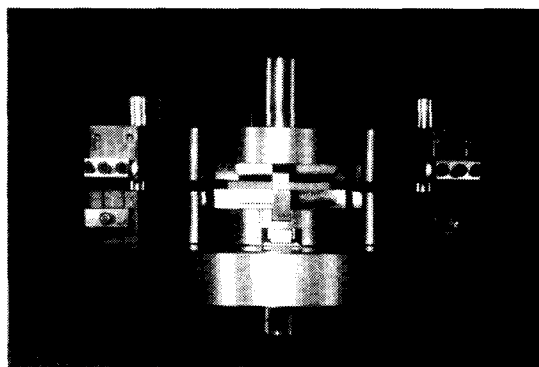


Fig. 1a Plane strain compression die