A General Formulation of the Theory of Wire Ropes

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The author claims to have developed a simple and well-organized approach towards the formulation of wire strand and rope problems. He considers both the geometric nonlinearity as well as the linearized theory, and while stating the case in programming his theory, no numerical results are presented. The continued interest in wire strand and rope behavior exemplifies the importance of these elements. However, the author has missed a whole body of literature over the last ten years which has previously provided generalized theories for wire strands and ropes, and has done so in a much more usable form. In general, the theory of wire rope has been well developed by Costello and his associates, whose references are too numerous to mention, and they have examined a wide variety of problems from linear and nonlinear response of wire strands and ropes under static and dynamics loads to the response of viscoelastic ropes to the response of strands and ropes comprised of wires with various types of cross-sectional geometry. Typical of these works are the development of the basic theory and their use in the examination of specific wire rope problems. A few of the papers will be discussed to follow which have already accomplished far more than the paper under discussion.

First, as noted above, Jiang (1995) presents both the geometrically nonlinear and linear theories. Velinsky (1985) has already presented a general nonlinear theory for wire ropes and additionally, and of principal importance, through examination of a wide variety of complex configurations, he has shown that the geometrically nonlinear theory provides no value over the linear theory for the normal load range of wire ropes. This paper (Velinsky, 1985), thus further verified the linear theory. It might be added that the deviation from the linear theory is only of significance for strains that would be well beyond the linear elastic region for the rope material, and thus the material model would fail at loads far lower than that in which the linear geometric theory is no longer valid. As such, the first part of the Jiang paper provides no valuable contribution.

Costello and his associates use the wire rope axial and rotational strain to describe the deformation behavior of the total rope. Jiang in Eq. (18) of his paper also uses these parameters. One aspect should be noted, however, and that is that Jiang's rotational strain, φ, is not dimensionless.

Jiang states as one of his primary contributions is his showing that the strand structure can be characterized by seven stiffness and deformation constants. This is not a new idea. Velinsky (1988) stated, "We note that the global behavior of a strand can be completely described by the following strand quantities: the stiffness constants, $S_1$, $S_2$, $S_3$, and $S_4$, the effective strand radius, $R^*$, the strand effective Poisson's ratios, $\nu_{IS}$ and $\nu_{OS}$, and the strand bending stiffness, $A^*$." Velinsky has eight constants, and the reason is that the strand size is necessary which Jiang has omitted. It should also be noted that Jiang uses a different notation which is much less intuitive, but represents essentially the same parameters. It should also be stressed that these strand describing coefficients are all constants only for the linear theory (e.g., the stiffness varies with load for the nonlinear theory).

The Velinsky (1988) paper not only generalizes the analysis of strands of both Seale (close packed) and resting lay types, but also: examines the detailed geometry of these configurations, develops a design methodology for the configurations including methods for selecting the appropriate wire sizes, and examines the sensitivities of various strand properties to the design parameters. Velinsky's generalization recognizes that three independent variables, the wire axial strain, the change in helix radius and the change in helix angle, exist for each wire lay and requires the solution of three simultaneous linear equations for each lay. His formulation is performed in a dimensionless manner in order to quantify a class of strand configurations rather than a specific size and geometry. Furthermore, he examines parameters that describe global strand behavior which support the fact that optimal designs must exist.

Velinsky (1989) later extended the generalized approach of his 1988 paper to examine complex wire rope design. The Velinsky 1989 paper develops the general analysis for wire strand core, independent wire rope core, and fiber core types of wire ropes. The total rope analysis requires only the eight parameters for each strand, and a similar set of three linear equations are necessary for the deformations of each strand lay. Furthermore, as in the earlier paper, the theory is exercised in examining the sensitivities of various total rope properties to numerous strand and rope design parameters. In addition to total rope properties, Velinsky also examines the sensitivities of rope design parameters on individual wire stresses. The Velinsky formulation is easily programmed in a general manner (and has been), and is easily exercised as exhibited by the large amount of results that have been presented.

References


Author's Closure

Dr. Velinsky first criticizes that the paper presented "no numerical results" and "missed a whole body of literature over