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MODELLING AND SOLUTION OF THE BENDING PROBLEM OVER THE HELICAL WIRE STRAND

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ABSTRACT

Theory of wire rope is starts with the constructions of the nonlinear equilibrium equations in 1944 by Love. Governing equilibrium equations are taken as a starting point in most of the analytical analysis.

The six governing differential equations are presented below. Using the direction cosines and summing the forces $N + dN$, $N' + dN'$ and $T + dT$ along the element length ds respectively for x, y and z axis gives [1],

$$\frac{dN}{ds} - N'\tau + T\kappa' + X = 0\,, \frac{dN'}{ds} - T\kappa + N\tau + Y = 0\,, \frac{dT}{ds} - N\kappa' + N'\kappa + Z = 0\,. \qquad (1)$$

Similarly the couples $G + dG$, $G' + dG'$ and $H + dH$ for the moments in x, y and z axes will give,

$$\frac{dG}{ds} - G'\tau + H\kappa' - N' + K = 0, \frac{dG'}{ds} - H\kappa + G\tau + N + K' = 0, \frac{dH}{ds} - G\kappa' + G'\kappa + \Theta = 0\,. \qquad (2)$$

A loaded thin wire, with the force distribution over it, is shown in Figure (1-a) and a wire strand model is given in Figure (1-b). The arc length is described by the variable s over the thin wire. The general behavior of the wire ropes in different aspects in his papers and, gathered his works is presented by Costello in [2]. A simple straight strand with a center wire surrounded by six outer wires are modeled and solved for an applied force and twisting moment in [3] with the aid of Maple®. In this paper a simple straight strand subjected to a bending moment m_s will be investigated. First of all the equilibrium equations for the bending moment will be solved then the bending moment m_s will be derived. As a starting point, the spring was subjected to bending moment only shown in Figure (2-a). Considering this the following result occurs,

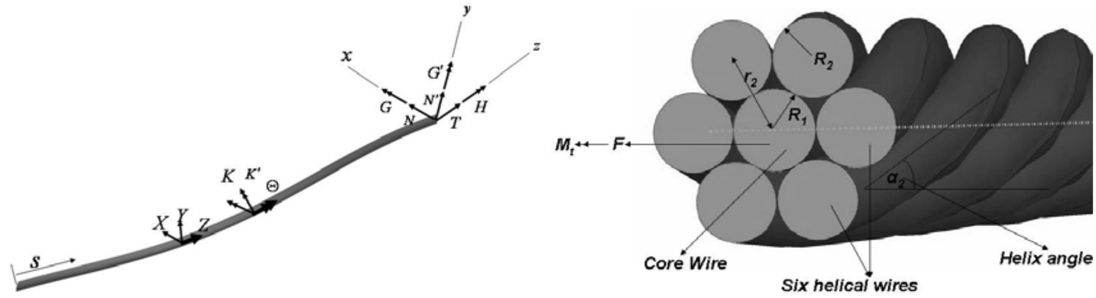
$$X = Y = Z = K = K' = \Theta = N = N' = T = 0. \qquad (3)$$

The equations of the equilibrium given in equations (1)-(2), while only the bending applied to a simple straight strand, becomes to the following form,

$$\frac{dG(s)}{ds} - G'(s)\tau_1 + H(s)\kappa_1' = 0, \frac{dG'(s)}{ds} - \kappa_1 H(s) + \tau_1 G(s) = 0, \frac{dH(s)}{ds} - \kappa_1' G(s) + \kappa_1 G'(s) = 0\,. \qquad (4)$$

Equation given in (4) is solved by using Maple® and the results are found harmonious with the

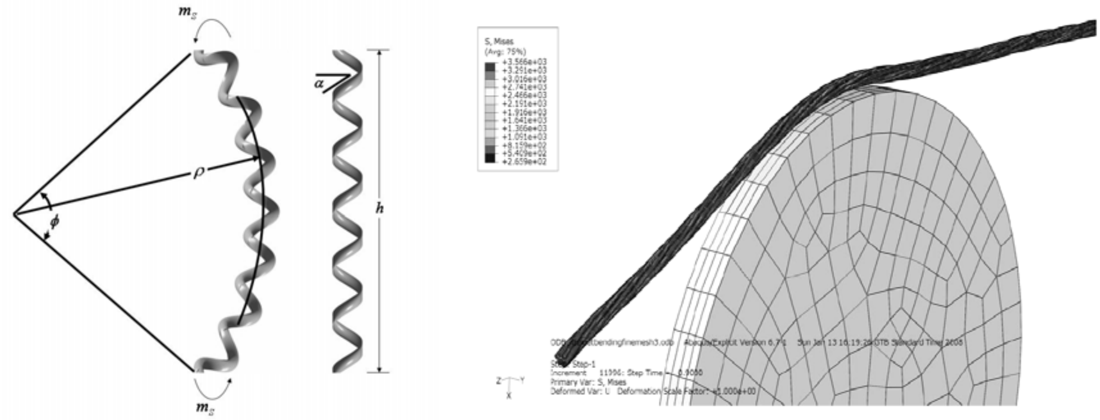
solutions of Costello [2].



(a) Loads acting on a thin wire, **(b)** (1+6) wire straight strand model

FIGURE 1. Loads on a thin wire and 7 wire strand model

The complex nature of the wire rope strand geometry is considered (Figure (1-b), Figure (2-b)) and a more realistic full model of the wire strand is created using commercial computer-aided engineering packages. Bending problem construction includes more difficult wire interactions as shown in Figure (2-b). Applying bending moment over the straight wire strand over a sheave is modeled in Figure (2-b) and the strain/displacement distribution over the loaded strand is also analyzed. It is concluded that the strain/displacement distribution over the wire strand is found to be acceptable and harmonious with the analytical solutions.



(a) Bending applied to a helical spring, **(b)** Wire strand bent over a sheave.

FIGURE 2. Bending problem of a wire strand

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