Parametric Modeling of Double and Triple Helical Strands

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ABSTRACT

Cables and wire ropes frequently incorporate strands consisting of double and triple helical wires. Stranded conductors are helically wrapped into larger units that again are helically laid into cables. A structural analysis of such complex geometries requires knowledge of the net elongation, bending and twist of the individual wires in these strands. Equations that describe the centerlines of these wires and the wire surface areas are derived in this paper. These equations are useful in the development of structural models as well as three-dimensional plots of the cable geometry. Realistic graphical renderings of a wire rope and cable demonstrate the use of these equations.

Three equations in terms of one parameter are used to describe the centerline of the double and triple helical wires. A companion parametric equation, using two parameters, describes the double and triple helical wire surfaces. These equations are implemented in a computer program that produces plots of the three-dimensional shape of individual strands or the complete cable. Such plots are useful in designing cables where geometrical interrelationships are easily understood. Finite element meshes can be more accurately generated with the helical wire geometry completely defined.

KEY WORDS: Cable; wire rope.

INTRODUCTION

High strength wire ropes are highly efficient structures used to transmit tension along straight paths and around circular sheaves. They are widely used in mechanical and structural applications that require flexibility and strength. For Electrical-Optical-Mechanical (EOM) cables, helically-laid wires provide flexibility and provide external armor to protect electrical and optical core components. To model such cables for specific applications, computation of change of helical wire elongation, curvature and twist is needed to compute stress magnitudes in the helical wires and to produce deformed plots. In addition to using the helical equations for stress analysis, industry has expressed a need for realistic solid models of cable constructions to help in packaging components, use of color coding and to convey new concepts to design team members and customers. Moreover, such geometrical detail will help with calculation of cable weight and cost.

Single, double and triple helical cable geometries are developed as parametric equations that describe wire centerlines and their surfaces. Single, double and triple helical parameters, \( u, \alpha \) and \( \beta \) are used to formulate all three parametric relations.

DESCRIPTION OF CABLE STRUCTURES

A wire rope is an assembly of steel wires or other materials that are helically served around a core which results in a flexible metallic cord capable of resisting high tensile loads. A typical wire rope is composed of a helical strand that is helically laid along a straight core wire as shown in Fig. 1. The outer layer wires in this configuration form a double helix.

Geometrical Parameters

The geometrical parameters used to describe the helical structures presented in this paper follow.

1. **Pitch radius** (R): The perpendicular distance between the centroidal axis of the strand and the cable axis.
2. **Wire radius** (r): The radius of an individual wire in the strand.
3. **Strand lay angle** (\( \alpha \)): The lay angle of the strand about the cable axis (single helix).
4. **Substrand wire lay angle** (\( \beta \)): The lay angle of a substrand about the strand axis (double helix).
5. **Wire lay angle** (\( \gamma \)): The lay angle of a wire about the substrand axis (triple helix).
6. **Position angle along strand axis** (\( \theta_s \)): The angle measured from the global X-axis (Fig. 5) to a point on the strand axis.
7. **Position angle along substrand axis** (\( \theta_d \)): An angle similar to \( \theta_s \) to determine position of an individual substrand helically laid about the