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GEOMETRIC MODELING OF WIRE ROPE

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ABSTRACT— Independent wire rope cores are constructed by helically wrapping the a wire strands over a straight wire and then following it by more strands depending on required wire rope construction i.e. application of wire rope. The locations of single and nested wires are created for a given design and the meshed model is constructed for analysis. The outer wires of the IWRC wire ropes are of double helical shape which can be modeled using special technique. Aim of this paper is to presents a more realistic approach of generating wire rope model using CAD software SolidWork™. Correctness of the profile of the generated rope model is controlled by visualizations. This modeling technique is found quite easy and effective.

KEYWORDS— Wire strand; wire rope; double helical geometry; Wire rope modeling; independent wire rope core

I. INTRODUCTION

Wire strands and ropes are used in a variety of engineering applications due to their high strength-to-weight ratio and very efficient use of the material. These characteristics are of particular significance in the design of lightweight suspended structures and large-span cable-stayed bridges. Wire ropes are used in elevators, cranes, mine hoisting, bridges, aerial ropeways system and several other applications involving safety of human life. An IWRC is the main component of wire ropes. On the design of IWRC wire ropes, a simple straight strand as a core strand is wound by a number of layers of outer strands depending on the application **[1]**. There have been various design of IWRC wire ropes e.g. Warrington IWRC, Seale IWRC, Combined IWRC. Rope ropes are meant for application under large tensile load with small bending and torsional loads**.** Due to complex geometry of wire ropes, it is difficult to analyze the wire rope by using numerical methods. So, finite element method is used for analysis purposes **[3]**. Computer-aided design together with the finite element method creates a powerful tool for the modeling and analysis of wire strands and ropes. In the design and analysis of wire strands and ropes three fundamental phases can be identified as follows:

- Creation of the geometric model,
- Generation of the engineering cable model using the CAD system
- Application of the finite element method for an analysis under the required loading.

The geometric model is most important phase and plays a key role in all further phases of the design and analysis process. The three dimensional shape of the single and double helixes can be defined by the mathematical geometric equations. Several authors have developed geometrical and analytical models of strands and ropes to predict their behaviour under various loads. The wire strands and ropes are treated either as a discrete set of concentric orthotropic cylinders (the individual layer of wires is replaced by an equivalent cylindrical orthotropic sheet) or as a configuration of helically curved rods, with different assumptions about the cable geometry or the inter-wire contacts, according to the authors **[4]**. Utting and Jones' analysis **[5, 6]** based on the classical twisted rod theories for the behaviour of helical laid wires takes the contact deformation and friction effects into account whereas Costello's approaches neglect these effects of friction **[7]**. The orthotropic sheet model was first applied to cable modeling by Hobbs and Raoof **[8]** and then extended by Raoof and his associates over two decades. Velinsky **[9]** presented the closed-form analysis for elastic deformations of multi-layered strands and the design of wire ropes **[10]**. Lee **[11]** presented the geometrical analysis applicable to any rope with axisymmetric strands and derived the Cartesian coordinate equations, which describe the helix geometry of wire within a rope. Through the application of differential geometry and the use of engineering drawing development approach, problems associated with the three-dimensional helix geometry of wire rope could be solved. The derived geometric equations were used for an analysis of the geometrical properties of cables. Hobbs and Nabijou **[12]** studied the changes in curvature in single and double helixes as they are bent into circular arcs. This analysis was applied to wire ropes to examine the bending strains in the wires of a frictionless rope as it is bent over a sheave. Jolicoeur and Cardou **[13]** proposed semi-continuous mathematical model for the analysis of multilayered wire strands under bending, tensile and torsion loads. Each layer of a strand is mathematically represented by an orthotropic cylinder whose mechanical properties are chosen to match the behaviour of its corresponding layer of wires. Raoof and

Kraincanic **[14]** presented the model for the theoretical analysis of a large-diameter wire rope, using results from a derived orthotropic sheet model, for analyzing the behaviour of its constituent helical strands. Knapp et al. **[15]** developed the CableCAD software code for the geometric modelling and finite element analysis of cables. Elata et al. **[16]** presented a new model for simulating the mechanical response of a wire rope with an independent wire rope core. In contrast with previous models that consider the effective response of wound strands, the present model fully considers the double-helix configuration of individual wires within the wound strand. This enables to directly relate the wire level stress to the overall load applied at the rope level. The double-helix geometry is modelled with the parametric equations because of its complex nature. A review of previous studies on the geometric modelling and analysis of steel and synthetic cables can be found in **[17,18].** Synthetic fibre ropes are characterized by a very complex architecture and hierarchical structure. Leech et al. **[19]** presented a more complex analysis of fibre ropes and included it in the commercial software Fiber Rope Modeller (FRM). Usabiaga and Pagalday **[20]** derived the parametric equations of the double helical wires for the undeformed configuration of the rope. In this paper, the improved geometric model of wire strands and ropes in computer-aided design software SolidWorks**™** is presented. The right (left) hand lay strand is a strand in which the cover wires are laid in a helix having a right (left) hand pitch. The right (left) hand lay rope is a rope in which the strands are laid in a helix having a right (left) hand pitch. The Lang's lay rope is a rope in which the wires in the strands are laid in the same direction that the strands in the rope are laid. The regular (ordinary) lay rope is a rope in which the wires in the strands and the strands in the rope are laid in opposite directions. A steel wire as the basic structural member of strands and ropes can be laid in the strand or in the rope as:

- a core of the strand (the centreline of a core wire forms a straight line)
- a wire in a layer of the strand (the centreline of a wire in a layer forms a single helical curve)
- a strand core of the multi-strand rope (the centreline of a core wire forms a single helix),
- a wire in a strand layer of the multi-strand rope (the centerline of a wire in a strand layer forms a double helical curve).

Consequently, at the mentioned cases the centreline of a wire forms from geometric aspect two types of helical curves (single and double helixes) depending on its location in the strand or in the rope. Direction is positive when the helix is right handed.

II. MODELING DOUBLE HELICAL GEOMETRY

Geometric model generation needs geometric data i.e. wire diameter, length, lay angle are illustrated in figure 1.

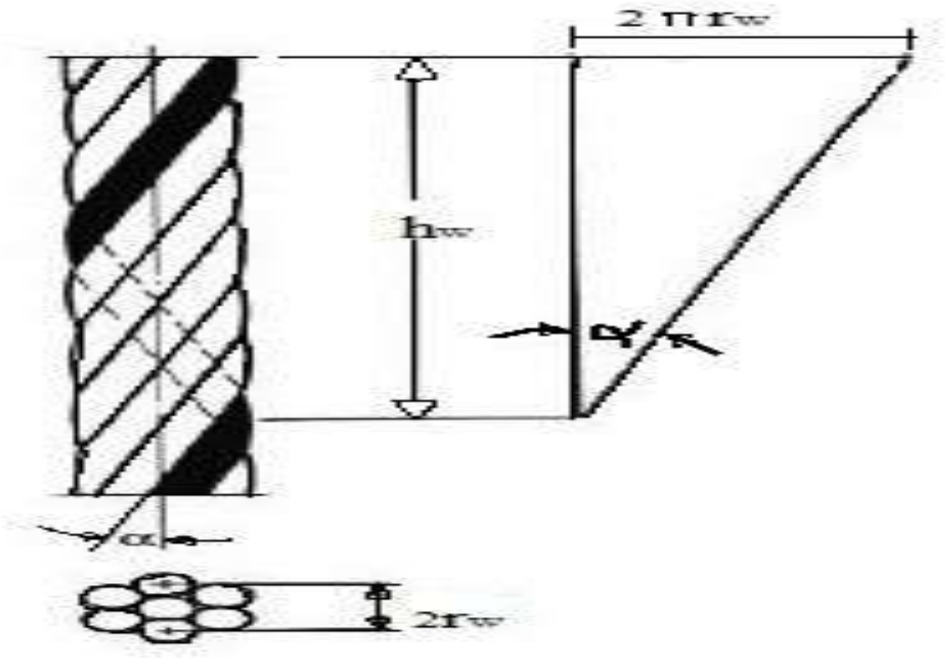

Figure 1 Wire Rope Parameters

Relation between diameter, length and lay angle can be given by following relation: -

$$\tan\alpha = \frac{2\times\prod\times r_w}{h_w}$$

Where, r_w = Wire winding Radius e.g. Core wire radius, Strand radius, wire rope radius

h_w = Wire Lay length i.e. length of strand in which lay wire makes one complete turn

Wire rope parameters for a particular geometry for computer model are tabulated in Table 1.

Table 1 Input parameters for generating computer geometric model of Wire Rope

Sr. No.	**Wire Rope Component**	**Diameter (mm)**	**Lay Angle (Degree/mm)**
1	Core 1. Core Wire 2. Core strand Wire 3. Core Strand 4. No. of wires in strand	 0.65 0.65 2.01 7(1-6)	 0 7.5(ACW)* 0
2	First Outer Layer 1. Core Wire 2. Strand Wires 3. No. of wires in strand 4. Strand 5. No. of Strands in Layer	 0.65 0.65 7(1-6) 6.44 6 6	 0 5.75(ACW) 5.75(ACW)
3	Second Outer Layer 1. Core Wire 2. First Layer Wire 3. No. of Wire in First Layer 4. Second Layer Wire 5. No. of Wires in Second Layer 6. Strand 7. No. of Wires in Strand	 0.85 0.75 6 0.85 8 15.6 15(1-6-8)	 0 4.33(CW)** 4.33(CW) 3(ACW)

* ACW- Anticlockwise Twist
**CW- Clockwise Twist

The generation of a computer geometric model of a 1-6-8 Stranded Wire Rope with defined input parameters consist of the following main steps: -

1. Draw 2D sketch of cross-section of wire rope with dimensions as shown in figure 2.

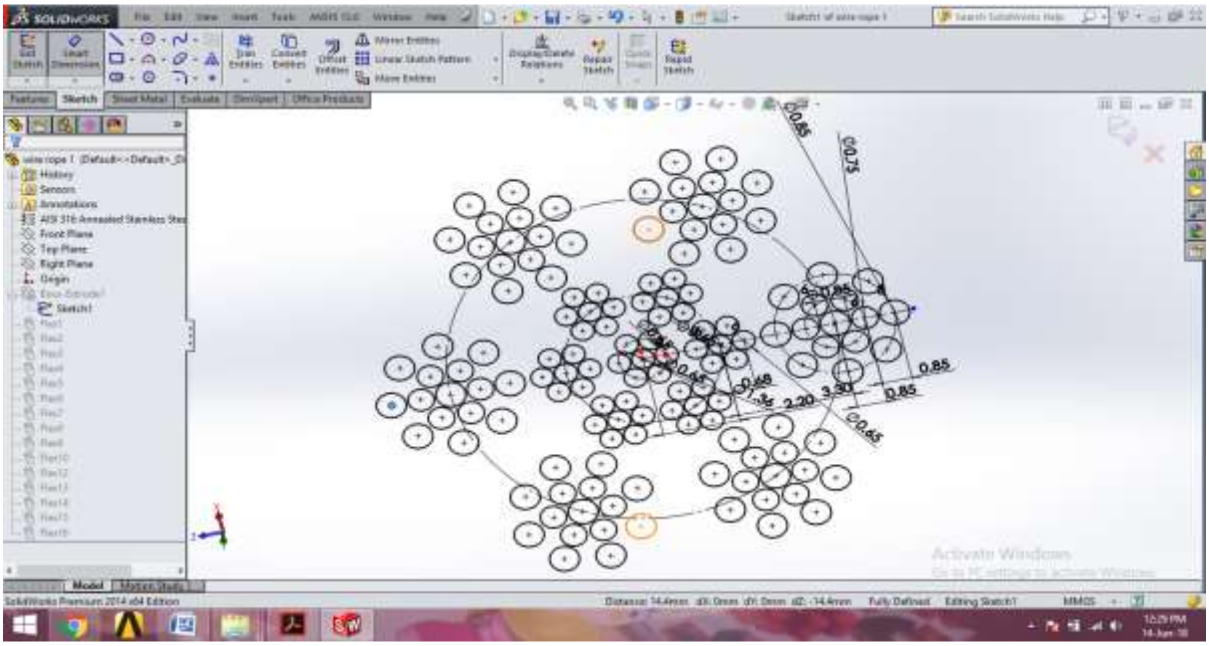

Figure 2 Cross- section of wire rope

1. Extrude the drawn cross-section to desired length or at least for lay length of outermost layer.
2. Twist the core strand's wires around core wire for prescribed angle of twist as given in Table 1.
3. Repeat the step 3 for strands in outer layers.

4. Twist the first and second layer around core strand for prescribed angle of twist as given in Table 1. Then, the geometric wire rope construction is completed and its geometric model can be illustrated as in figure 3.

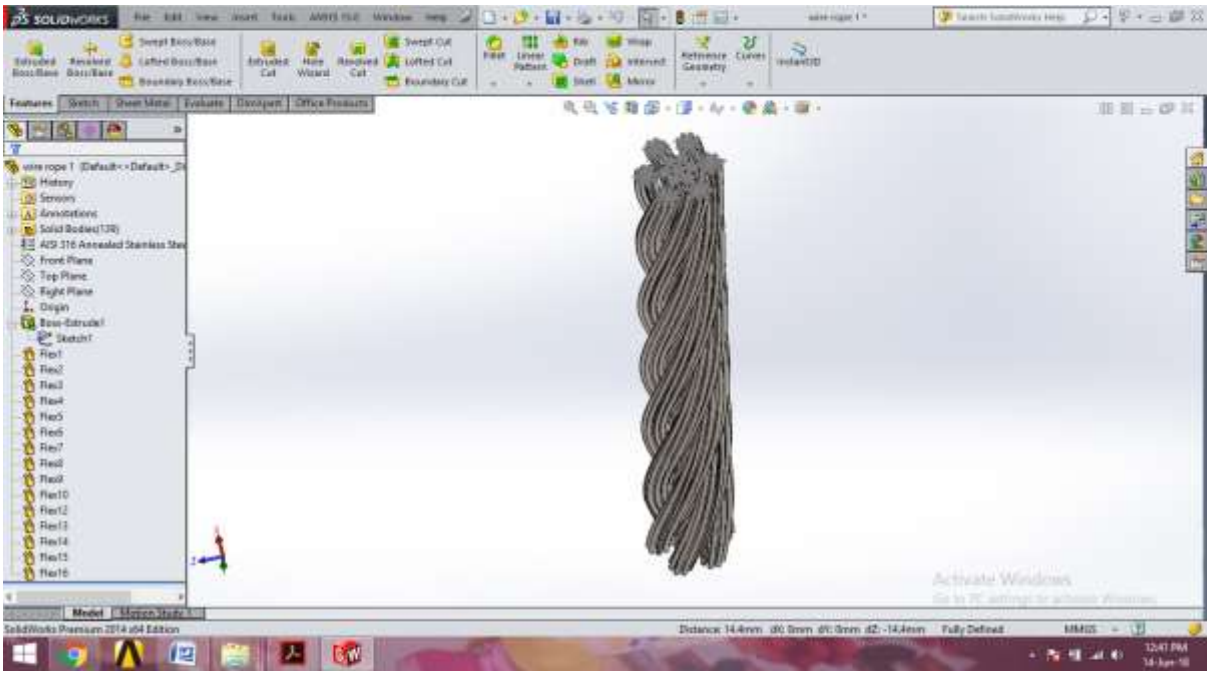

Figure 3 Geometric Model of Wire Rope

III. CONCLUDING REMARKS

Due to its complex geometry nested helical wires in an IWRC needs special handling while solid modeling. In this paper an IWRC is modeled taking into account the complex nature of the outer nested helical wires within the outer strand of the IWRC. This paper presents a easy and effective way of generating 3D model of wire rope.

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