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RESEARCH ARTICLE

WIRE STRAND WITH COMPLEX SHAPED ELLIPTIC OUTER WIRES

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ABSTRACT

The main advantage of wire ropes is their ability to operate under high tensile load and in this way to resist large axial loads. Different types of wire ropes are produced according to increase their strength over the traditional ones. For example compacted wire ropes are low stretch wire rigging which increase the breaking strength and stretch of the wire ropes compared to the traditional wire ropes. Outer wires are formed using a special process called compacting. In this article, a three-dimensional model of different external wire cross-section is examined. For this purpose, a (1+6) wire strand model designed by using elliptical cross-sectional outer wires are designed. Then finite element analysis results for stress, displacement and contact pressure are presented.

Keywords: *Wire Strand, Elliptical Wire Strand, Modeling Wire Rope, Elliptical Outer Wire Composition, Wire Strand Finite Element Analysis*

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KOMPLEKS ŞEKİLLİ ELİPTİK DIŞ TELLER İLE TEL DEMET

ÖZ

Tel halatların ana avantajı, yüksek gerilme yükü altında çalışabilmeleri ve bu şekilde büyük eksenel yüklere karşı dayanıklılıklarıdır. Geleneksel olanlara göre mukavemetini arttırmak için farklı tel halat türleri üretilmektedir. Örneğin, sıkıştırılmış tel halatlar, geleneksel tel halatlara kıyasla tel halatların kopma mukavemetini ve gerilmesini arttıran düşük gerilimli tel halatlardır. Dış kablolar sıkıştırma denen özel bir işlem kullanılarak oluşturulur. Bu yazıda farklı bir dış tel kesitinin üç boyutlu modeli incelenmiştir. Bu amaçla eliptik kesitli dış teller kullanılarak tasarlanan bir (1 + 6) tel demet modeli tasarlanmıştır. Daha sonra sonlu elemanlar yöntemiyle elde edilen stres, uzama ve temas basıncına ait analiz sonuçları sunulmuştur.

Anahtar Kelimeler: *Tel Demet, Eliptik Tel Demet, Tel Halat Modelleme, Eliptik Dış Tel Kompozisyonu, Tel Demet Sonlu Eleman Analizi*

1. INTRODUCTION

Due to wire ropes capability to carry large tensile loads, wire ropes find different usage area in the industry and daily life such as lifting, mining, bridges, cranes, etc. Different configurations of the material, wire, and strand structure provide different benefits for the specific lifting application, including such as strength, flexibility, abrasion resistance, crushing resistance, fatigue resistance, corrosion resistance and rotation resistance. In the literature there are a number of studies on wire rope theory and its numerical analysis. Costello et.al. studied various aspects of wire ropes under specific conditions in his study [1]. Velinsky et.al. developed a theory to predict the static response of a wire rope with complex cross sections in [2]. A finite element model of a simple straight wire rope strand is presented by Nawrocki and Labrosse [3] which allows for the study of all the possible interwire motions. An accurate and general strand model using the FEM is presented by Jiang et.al. which accounts combined effects of tension, shear, bending, torsion, contact, friction and possible local plastic yielding when loaded in [4].

3-D wire rope modeling gives ability to conduct Finite Element Analysis over a wire rope under certain loading conditions. Thus, one can have deep information about the behavior of the wire rope under different scenarios. In the literature search there exists a number of paper about modeling wire ropes. A wire rope with an independent wire rope core (IWRC) model, which fully considers the double-helix configuration of individual wires considered by Elata et.al. in [5]. Parametric mathematical equations of single and double helical wires within an IWRC is represented in [6]. Modeling issues of nested helical structure based geometry for numerical analysis and the encountered problems and solution techniques are mentioned in [7]. Lately a geometric model of spiral one or two-layered oval nested wire strands (WS) are proposed by Stanova et.al. in [8].

During this literature search, it is observed that all kind of wire ropes are composed using circular cross sectional wires. Only the compacted forms are different because of the special process used to build them to reduce the gaps between wires. In this paper this procedure will be investigated and the reductions of gaps between wires are done using elliptic cross sectional wires.

2. WIRE ROPE MODELS

There are number of traditional type wire ropes are produced widely such as WS, IWRC, Warrington IWRC, Seale IWRC with different wire compositions are given in Figure 1. From this figure it can be seen that these traditional wire ropes are composed by using circular shaped wires.

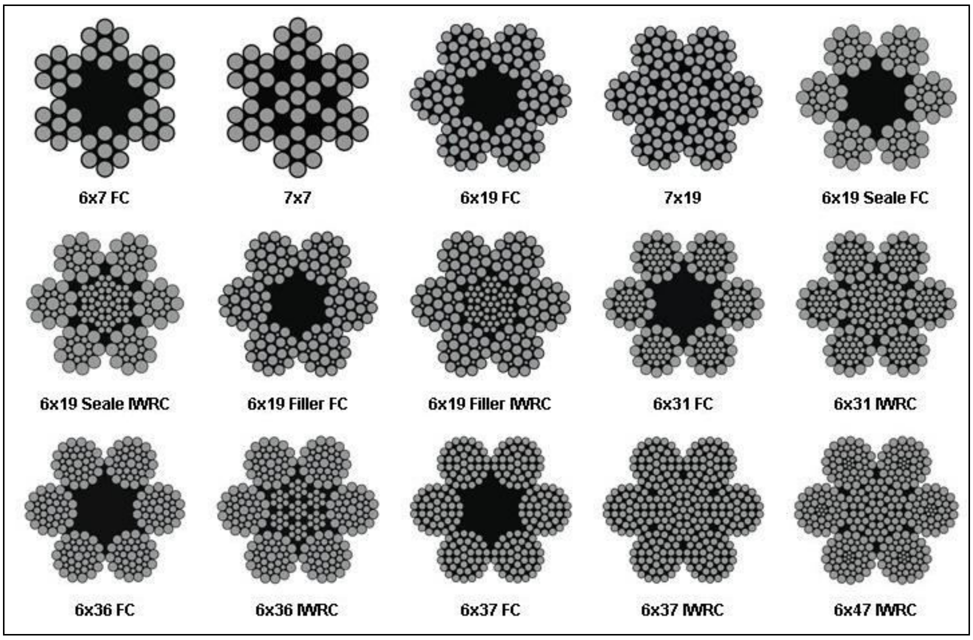

Figure 1. Different Types of Wire Ropes

But this issue is started to change with newborn wire rope compositions like compacted wire ropes. According to the producers of these type of wire ropes, compacted form is low stretch wire rigging, which features more than a 30% increase in breaking strength over traditional 1×19 wire, and 25% less stretch. A cross section of this kind of compacted wire rope is presented in Figure 2.

It is observed from the Figure 2 that these wires fill more space between wires by leaving fewer gaps. Compacted wire ropes are built by swaging process. Swaging is a metal forming process of reducing diameter of a rod or tube by forcing it into a die with the help of reciprocating blow. This process plastically deforms the metal and forces it to flow into die and acquire die cavity shape.

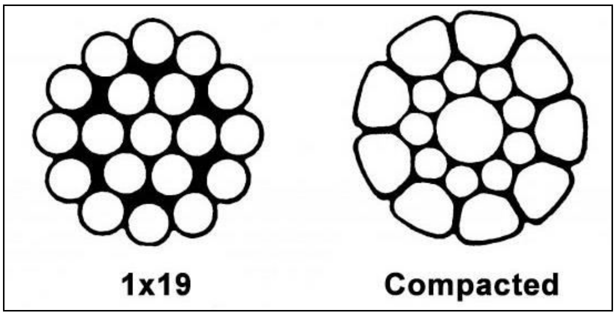

Figure 2. Traditional and Compacted Form of a 1x19 Wire Strand

There are some benefits of compacting on wire ropes such as cutting force is higher compared to the same rope diameter and have a long life. Since the outer shape of the rope is rectangular and extend the life inclusive of the drum reduces the frictional force.

Using the idea of reducing the gaps between wires in a wire strand for 3-D modeling, elliptical outer wires are taken into account in this paper. First of all the general model for the wire strand is created using elliptical helical wires around a single straight center wire. Then its finite element analysis is done.

3. CONSTRUCTION AND FINITE ELEMENT ANALYSIS OF THE ELLIPTICAL WIRE STRAND MODEL

Classical structure of wire strand consists of a (1+6) wire where outer circular wires are wound helically around the core circular wire. The proposed model is built using elliptical cross sectional wires instead of circular outer wires. This structure is modeled and meshed using parametrical mathematical equations using Matlab code. A circular cross section of a wire strand is shown in Figure 3-a, while Elliptical Wire Strands (EWS) cross-section is shown in Figure 3-b and EWS meshed model is given in Figure 3-c. Due to the shape of the EWS gap between the outer wires and the center wire is more closer than the circular wire strand. Finite Element Analysis (FEA) is done using the EWS model and the von-misses stress distribution over the strand is shown in Figure 4. During the analysis one end of the EWS is constraint with encastre boundary condition while the other end displaced in the z direction. The stress distribution along the wire strand shows the general characteristics of wire strand. Displacement distribution and contact pressure distribution over center and two outer elliptic wires are shown in Figure 5-a and Figure 5-b respectively. The contact pressure shows contact area along outer wires in Figure 5-b.

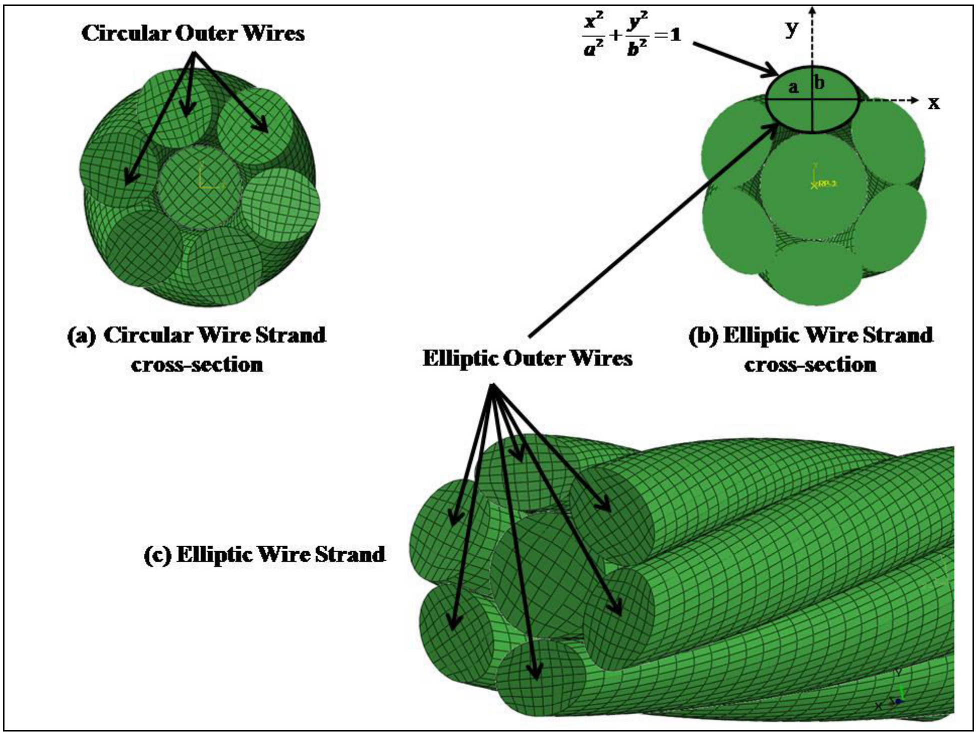

Figure 3. (a) (1+6) Circular Wire Strand, (b) (1+6) Elliptical Wire Strand Cross-Section, (c) (1+6) Elliptical Wire Strand Meshed Model

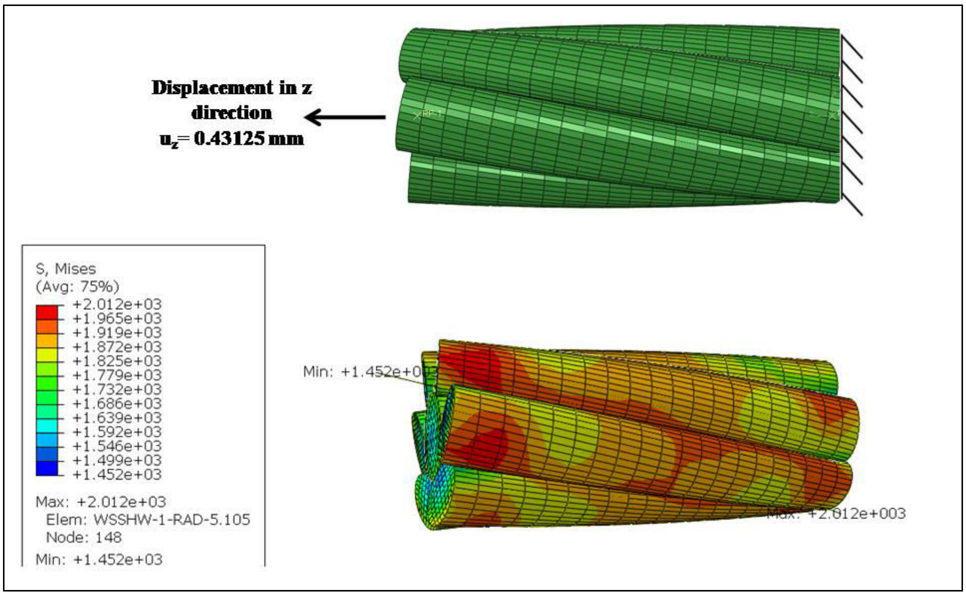

Figure 4. Von-Misses Stress Distribution over an Elliptical Wire Strand

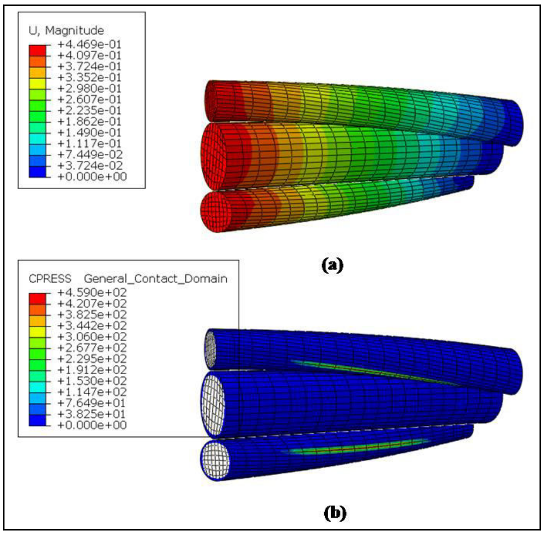

Figure 5. (a) Displacement Distribution on EWS, (b) Contact Force Along the EWS

4. CONCLUSION

Wire strands are modeled with using circular wires around a single straight wire in general. To build more compact wire strands with reduced gaps between center wire and outer wires, elliptical outer wires are used in this study. This structure is named as elliptic wire strand (EWS) and it is modeled and meshed using parametrical mathematical equations using Matlab code. The finite element analysis (FEA) of the proposed model is run and the results show the general behavior of the wire strands. The proposed study is going to be the generation for the other complex forms as future works.

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