Review of Wire Rope Analysis, Construction and Testing

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Abstract - The applications of wire ropes are growing in industries, mechanical power and many areas. In this review, we are discussing various methods used to calculate the most significant rope quantities such as rope geometry, wire stresses under tension, bending and twist, rope elasticity module, rope efficiency, torque, bending cycles and the discard number of wire breaks. Now, continuous research is going on the improvement of wire rope physical characteristics. This paper presents theoretical stresses calculation in straight wire ropes as well as elasticity module calculation of strands and spiral ropes. This review concludes with the future direction of further enhancement and some improvement into the manufacturing of wire ropes.

Keywords: Wire Rope, Reliability, Bending Fatigue Analysis, Tensile Analysis.

I. INTRODUCTION

Wire rope is various filament of twisted metal wire into a spiral structured “rope”. Wire ropes have diameter larger than 3/8 inch (9.52 mm), with smaller cords. Today, wire ropes are constructed using steel as main material. The wire ropes are extremely used in harbours, ships and various industrial fields. The safety of a wire rope is nearly related to the life safety and equipment safety. The wearing degree and quality of wire ropes significantly affect safety and reliability of elevators, cranes, mining hoists and air transportation [1].

Wire ropes were made for mining hoist applications in the 1830s. Wire ropes are applied dynamically for transmission of mechanical power, hoisting and lifting in cranes and elevators. It is also used for transmitting force in mechanisms, like a Bowden cable and the control surfaces of an airplane joined at levers and pedals in the cockpit. Wire strand core (WSC) are used mainly as aircraft cables. Also, these wires are available in thinner diameters than wire rope [2].

Wire ropes aggregate two very effective attributes: high axial strength and flexibility in bending. For many industrial applications, these attributes convert wire ropes into critical load transmission elements. Wire ropes are frequently used for load transmission. Compared with textile ropes (normally textile fibres or synthetic material), wire ropes have the advantage of greater strength and longer life [2]. There are, however, also special structures [3]. Wire ropes are used in combination with a chain. A chain can be (not only component parts but also a principal tension element for raising or lowering mooring components. It is essential to know the condition of the wire rope in order to provide timely replacement [4].

A. Steel Wire Rope

Steel wire is very high strength of the wire rope which enables wire rope to tolerate large tensile forces and to run over sheaves with relative small diameters [5]. Very high-strength steel wires had already been existence for more than a hundred years when patenting – a special heating process – was introduced and the drawing process perfected. Since then further improvements have only occurred in relatively small steps [6].

B. Non-Alloy Steel Wire Rope

Steel wires for wire ropes are normally made of high-strength non-alloy carbon steel. The steel rods from which the wires are drawn or cold-rolled as an excerpt of a great number of different steels from the Standard. The rods for rope wires have a high carbon content of 0.4–0.95 %. Carbon steels only contain small quantities of other elements [7].

II. LITERATURE REVIEW

Zhang et al. [8] studied the issue of the bending fatigue behaviour and failure mechanisms of wire ropes. In their research were used non-destructive quantitative detection and artificial detection methods.

Prier et al. [9] dealt with the study of drawn steel wires submitted to fretting-fatigue in the solution of sodium chloride. Experimental tests were conducted to reproduce the contact conditions in spiral strands undergoing free bending deformations and submitted to corrosion. They also researched [10] the influence of aqueous environment on the fretting behaviour of steel wires used in civil engineering cables. Wang carried out lots of studies of the hoisting rope failures. He investigated the effect of terminal mass on fretting and fatigue parameters of a hoisting rope during a lifting cycle in a coal mine [14].

Wang et al. [11] investigated the effect of strain amplitude on fretting–fatigue behaviour of steel wires in a low cycle fatigue by employing a fretting-fatigue test rig which was able to apply a constant normal contact load. He looked into the effects of fretting parameters on stress distributions of contacting wires during the initial stage of fretting-fatigue of steel wires using the finite element method too. He realised the finite element analysis of a hoisting rope and three-layered strand for the exploration of fretting fatigue parameters and stress distributions on the cross-section. The effect of displacement amplitude on fretting fatigue behaviour of steel wires in low fatigue cycle strain levels were examined by Wang as well.

III. PROPOSED METHODOLOGY

A. Stresses Calculation in Straight Wire Ropes

The wires in straight wire ropes under tensile load are mainly strained by tensile stresses. The real tensile stress in the wires will not be considered in most cases. Instead of this the stress condition will be normally characterized globally by the rope tensile stress (nominal tensile stress). This global rope tensile stress is

$$Z=S/D \qquad (1)$$

Where, S = the rope tensile force,

A = the wire rope cross-section,

Which means the sum of the cross sections of all wires in the rope with the diameter is

$$A = 4X^2 \qquad (2)$$

A very practical form for the tensile rope stress is the diameter related tensile rope force

$$F = S/d^2 \qquad (3)$$

S is again the tensile rope factor and

D is the nominal rope diameter.

This diameter related tensile rope force has the advantage that both factors S and d are well defined and well known for the rope maker and rope user. A further advantage is that in most cases the calculation result includes in its deviation of the rope diameter.

B. Elasticity Module Calculation of Strands and Spiral Ropes

As already mentioned, the non-linearity of the stress extension curve is relatively small for strands and spiral ropes. There is also only a small increase of the rope elasticity module with the number of loadings. The smaller the number of wires in the rope, the more likely this is to be true. There was only the very small difference of E = 600 N-mm^2 between the first, second and third measurement with an almost constant rope elasticity modules E_S = 198 N-mm^2. Calculations for the rope elasticity module for strands and spiral ropes with a small number of wires.

The Calculation can be done with the help of the equations above. The rope elasticity module is by definition

$$E = Z/N \qquad (4)$$

For the tensile stress and the definition of the strand extension is the rope elasticity module for strands and spiral ropes is given by Poisson ratio which can be

$$V = Vi = 0.3 \qquad (5)$$

For all wire diameters and winding radii in steel spiral ropes because the length related force between the wire layers is small and the lateral contraction is almost only caused by the tensile stress in the wires.

IV. CONCLUSION

In this survey, we presented the comprehensive review and theoretical study of different strategies by which strength of wire rope can be enhanced. This review, discussed various methods used to calculate the most significant rope quantities such as rope geometry, wire stresses under tension, bending and twist, rope elasticity module, rope efficiency, torque, bending cycles and the discard number of wires breaks. Also presented theoretical stresses calculation in straight wire ropes as well as elasticity module calculation of strands and spiral ropes.

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