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ASSESSMENT AND MONITORING OF DANGEROUS FACTORS IN THE AREA OF STEEL ROPES SPLICING

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In the article, the authors conduct research on the assessment and control of hazards in the area of steel ropes splicing. The obtained results made it possible to clarify the reasons for the formation of dangerous factors such as: "undulation", wire strands breaks and loss of diameter of the steel rope. The main reason for the occurrence of dangerous factors is the uneven loading of wires and strands in the cross section of the steel rope. With the existing manual method of jointing, it is technologically impossible to ensure the uniformity of loading of all tucked strands, due to errors occurring on the length of each tucked strand, which directly depends on the human factor (experience and professionalism of the splicer) in the course of work. The authors propose a new method of jointing steel ropes using a polymer core, which is a conductor, which allows to exclude the human factor and to keep in place of jointing the permissible values of defective indicators by diameter.

Keywords: steel rope, machines operation, cable traction, splicing, acceptance indicators, hazards factors, polymer materials.

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ОЦЕНКА И КОНТРОЛЬ ОПАСНЫХ ФАКТОРОВ В ЗОНЕ СЧАЛКИ СТАЛЬНЫХ КАНАТОВ

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Проведены исследования оценки и контроля опасных факторов в зоне счалки стальных канатов. Полученные результаты позволили уточнить причины образования опасных факторов, таких как «волнистость», обрывы проволок прядей и потери диаметра стального каната. Основной причиной возникновения опасных факторов является неравномерность нагружения проволок и прядей в поперечном сечении каната. При существующем ручном способе счаливания технологически невозможно обеспечить равномерность нагружения всех заправляемых прядей в связи с погрешностями, возникающими в ходе проведения работ на длине каждой пряди. А это напрямую зависит от человеческого фактора (опыта и профессионализма счальщика). Авторами предложен новый способ счаливания стальных канатов с применением полимерного сердечника, являющегося кондуктором. Сердечник позволяет исключить человеческий фактор и сохранить в месте счаливания допустимые значения браковочных показателей по диаметру каната.

Ключевые слова: стальной канат, эксплуатация машин, канатная тяга, счалка, браковочные показатели, опасные факторы, полимерные материалы.

Introduction. In modern engineering, we use the machines with cable traction for high-tech tasks. Its characteristic is the use of steel ropes of an endless (infinite) type, where the rope is a ring with the formation of a section of its connection (jointing), called splicing. Splicing may be used as a method of joining two ends of a rope by weaving the strands of the outer layer to the core with the length sufficient for the formation of structural latches (nodes) of the tucked strands. The process of steel ropes splicing is realized manually by a certified splicer and is regulated by normative documents [1, 2].

Problem statement. In the study of the durability of steel ropes, despite the declared by the manufacturer resource of 15-20 years, the authors noted that after 5-6 years there are dangerous factors in the places of jointing: breaks, wear of wires, reduced diameter of the rope as a result of some damage to the core, loss of internal section, "undulation". All this is the basis for unscheduled repair of the rope with the replacement of the defective section and leads to significant material costs. These factors indicate a violation of physical and mechanical characteristics of the steel rope in the splicing area and lead to its premature wear [3, 4].

Theoretical part. Physical modeling of steel ropes splicing process allowed the authors to establish the causes of hazards in the area of splicing. For normal operation of the steel rope, it is necessary that the resultant load is equally applied to all wires and strands in their cross section [5]. However, in the splicing area there is a displacement of the resultant load relative to the axis by the amount of eccentricity, consequently, there is an uneven loading of wires and strands of the rope. Uneven loading appears in splicing nodes, as in manual splicing it is impossible to ensure the constancy of the length of each of the loaded strands. Excessive torque moment appears when operating with the load displacement equal in effect in cross section of the rope splicing along its length. The tucked strands are in a rigidly fixed state and do not provide the required mobility when bending the rope on the pulley (wheel). In the joint "lock" of the friction pair "core — strand — strand", the effect of "biting" of tucked strands appears, which in the process of operation leads to the formation of a dangerous factor called "undulation" (Fig. 1) [6].

Fig. 1. Formation of dangerous "undulation" factor in the area of steel rope splicing

The displacement of the resultant load in the cross-section of the steel rope significantly reduces the level of safety during its operation. When the "undulation" develops, the loading in the cross section of the wire when the rope is bent on the pulley increases due to additional bending and tensile stresses. These stresses exceed the calculated values; because of that, most loaded wires of the strand begin to collapse at a lower number of loading cycles, which in turn leads to the formation of such a dangerous factor as the wire breakage (Fig. 2) [7].

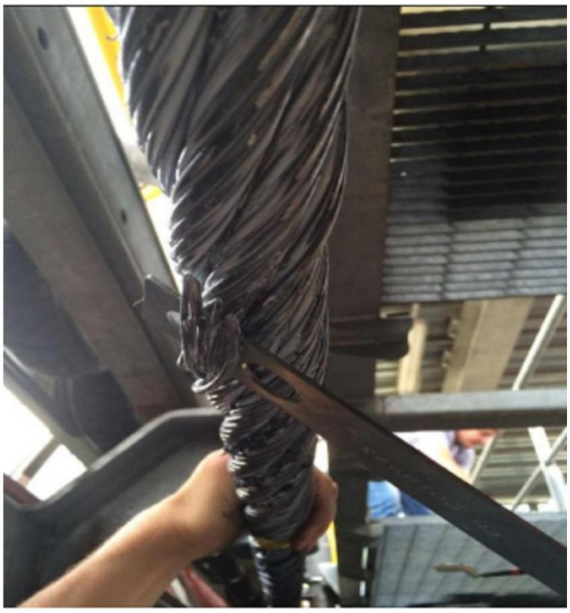
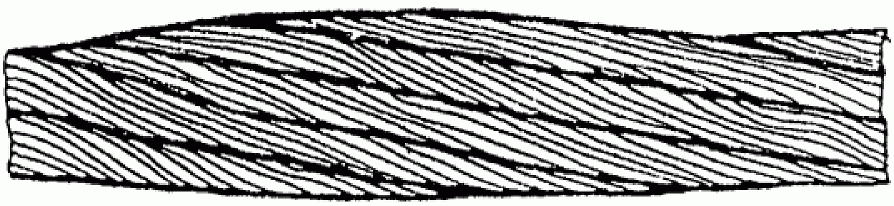
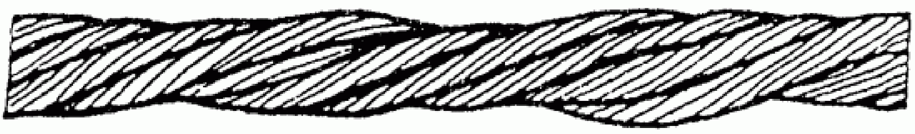


Fig. 2. Breakage of wires of one of the strands in the splicing area of the steel rope

With the existing manual method of splicing, it is technologically impossible to ensure the uniformity of loading of all tucked strands due to the arising errors on the length of each tucked strand, which directly depends on the human factor (experience and professionalism of the splicer) during the work [8]. The impossibility of ensuring the accuracy of cutting the tucked strand to the required length causes undesirable consequences. Cutting off a strand with an excess length when it is placed, leads to an increase in the diameter of the rope. If the strand is cut too short, there is the lack of support for the outer strands. The lack of support can reach several millimeters, which leads to a localized reduction in the diameter of the rope. More or less hard contact between the adjacent outer turns may result in the early emergence of various wire damages in this area. An increase or decrease in the diameter of the steel rope by more than 10 % of its nominal value is also a dangerous factor (Fig. 3) [9].



a)



b)

Fig. 3 Hazardous factor in the form of local increase (a) or decrease (b) of the steel rope diameter in the splicing area

Scientific novelty. The conducted researches allowed us to form a method of assessment and control of dangerous factors in the splicing area, as well as to improve the method of steel ropes splicing. The basis of the improved method is the polymer core developed by the authors, which can serve as a conductor that allows you to keep the permissible values of rejection indicators on diameter in the splicing area.

The splicing conductor is a hollow polymer cylinder with a length exceeding the length of the splicing to the value of the two extreme ends of the tucked strands. The outer profile of the conductor in the cross section is made in the form of a star with the number of rays equal to the number of strands and the height of the rays is not less than half the diameter of the strand. The conductor has a helical shape with a rope turns equal to the strand pitches in the rope, and with a radius of segments between the rays equal to the radius of the cross section of the strand. In this case, the rays at the top are made in the form of a dovetail, and the hollow cylinder in each joint unit of the "joint" has oval holes corresponding to the diameter of the cross section of the strand in the shrink tube at an angle of the lay. The number of holes is equal to twice the number of strands. The holes are evenly staggered along the helical line along the conductor, in pairs by the number of strands and strictly opposite each other by the radius of the hollow cylinder (Fig. 4).

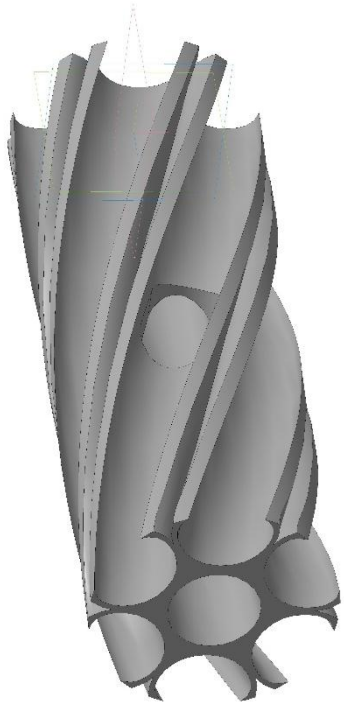


Fig. 4. Polymer conductor for steel ropes splicing

To ensure mobility of the strands in a joint (node) of a rope, the ends are clamped by a shrink tube with the subsequent temperature processing. Before that, the powder antifriction material is placed inside the tube. This material due to its layered structure provides mobility of the splicing strands by sliding powder nanoparticles, which has good adhesion properties in the friction system "core — strand — strand", where there is the displacement of the layers of this material. This eliminates the possibility of the effect of "biting" of the splicing strands in the splicing joint. To ensure the mobility of the strands in the body of the conductor, a powder antifriction material is sprayed on its surface, filling the surface of the conductor and the inter-strand cavities. This allows the strands of the outer layer to move in the longitudinal plane and around their axis, dividing the resultant load throughout the rope and minimizing wear from the conductor at the bending of the rope on the pulley (wheel).

The existing core on the entire splicing length is replaced by the conductor design, consisting of a movable cylindrical rod, the diameter of which is equal to the diameter of the strands in the shrink tube, which allows ensuring the completeness of the support area of the strands of the outer layer and eliminates the formation of voids due to the lack of length of the splicing strands. The ends of the strands in the heat-shrink tube are spliced into the body of the hollow cylinder of the replaced core, passing them through the oval holes in each "joint" by replacing the movable cylindrical rod with the ends of the strands treated with a heat-shrink tube. Then they put a solid line on the outer surface of the rope along the length of splicing and under the load control its straightness (Fig. 5).

Fig. 5. Control line of axial displacement (torsion) of steel rope around its axis

Conclusion. The conducted by the authors researches allowed them to clarify the reasons for the formation of dangerous factors in the areas of steel ropes splicing. Timely identification and elimination of hazards let us keep to a minimum damage to people and property at the enterprises that operate machines with a traction rope. The main advantage of the improved steel rope splicing is the exclusion of the human factor during splicing. The conductor proposed by the authors can be manufactured for any type of a steel rope according to the specified parameters with the pre-prepared oval holes for strands splicing of the outer layer into the joint, which significantly improves the splicing quality.

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