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Research Article

THE CAUSES OF THE DAMAGE TO THE BEARING ROPE – FAILURE ANALYSIS

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ABSTRACT
In our laboratory we quite often experience problems with the operation of steel ropes. There is a range of causes related to lifetime problems of ropes. These problems are related to poor quality of input material used for wire production, mixing of different wire strengths in the rope construction, improper roping of the rope into the hoist system, improper rope operation, improper rope design for a particular type of operation as well as unfair practices of vendors. The subject of the article is the analysis of the rope showing the combination of a large number of the above factors leading to the damage of the rope. During the operation of the cargo cableway, the hauling ropes were damaged in a very short time. The Z wires from the surface layer of the rope started to release from the rope. Subsequently, the wires were unwinding from the layer, they created visible protuberant waves, they were braking and dropping out from the rope. The hauling rope had to be replaced. Than the samples were taken from the rope in order to find out the cause of the rope damage. Mechanical, metallographic and fractographic measurements were performed on the rope. The metallographic and fractographic measurements revealed the material defects of the wires of the rope caused during manufacturing of the Z wires from the surface layer of the hauling rope. The mechanical tests revealed differences in the tensile strength grade the operator required compering to the tensile strength grade the vendor declared. The above mentioned problems unambiguously show that it is appropriate to introduce a mechanical control of the rope properties in advance to its deployment. Checks must be performed by an independent testing laboratory. This procedure overprices inputs needed for the rope replacement. On the other hand, it can reduce the costs when a poor quality rope is deployed. Some of our customers have already adopted this approach. It helped to the increase in the safety of the operation of the mechanisms and it eliminated the problems with exchange and climes on bad quality ropes.

Keywords: steel wire ropes, cargo cable ways, quality, material, failure analysis.

INTRODUCTION

Steel ropes are complex flexible structures used in many technical applications, such as elevators [1], cranes [2, 3], marine applications [4], cable ways and hoisting mine applications [5]. In many high-rise residential buildings or multi-storey warehouses, machinery, so called lifts, are used for the vertical transportation of people or weights between attitudinally distant places [6].

Due to the specific design and critical safety requirements, diagnostics of ropes remains an important issue. Broken wire number in the steel ropes is limited by safety standards when they are used in the human lifting and carrying installations [7÷12]. Broken wires increase the stress in the inner wire strands as well as the contact force between the wires. This leads to a concentration of severe wear, which accelerates the density of broken wires locally, leading to short fatigue lives especially in the case with the most concentrated number of pre-broken wires [13÷17]. For the crack initiation mechanism of anodic dissolution, the stronger the corrosivity of solution was, the more easily the fatigue crack source formed, while, for the crack initiation mechanism of deformation activation, the lower stress ratio and higher frequency would accelerate the generation of corrosion fatigue crack source [18]. Wear is one of the primary factors for the degradation of the wire rope used for multilayer winding hoist. It decreases the carrying capacity and service life of the hoisting rope, which will affect the mine safety directly [19]. The increase in the longitudinal rope vibration will reduce the friction force between the rope and lining [20]. The limitation for transverse vibration displacement of wire rope becomes stronger, and the effect is fading when the rigidity reaches a certain value [21, 22].

The change of the value of acceleration and velocity in the lifting process, get variation rule of rope tension and deformation in the lifting process, study the influence to tension and deformation and vibration frequency from acceleration and velocity [23, 24].

The coefficient of friction of the wire rope changes little with increasing load and stabilizes, but decreases with the sliding velocity under dry friction condition [25]. The friction element can capture the sliding among different wires [26].

The application of finite element method when investigating the stress-strain state of a workpiece exposed to the gauge burnishing under the conditions of nonzero friction is considered [27÷29].

MATERIAL AND METHODS

The cargo cable way consists of two hauling ropes and one carrying rope. In order to provide the continuous transport of the material by skyline carriages the two carrying ropes are used in a different way – one carrying rope caries the empty carriages, the other one caries the full carriages. The single-strand rope, the diameter 35 mm is used for the branch carrying the full carriers. The branch for the empty carriages is equipped with a single-strand rope, the 22mm. diameter. The rope for the empty carriages branch was replaced, after the replacement the carrying rope was damaged in a short time. The damage was manifested by the release of the Z wires from the upper cover layer, the wires were breaking subsequently and dropping out from the rope structure. It was decided to put off the rope and find out the cause of the damage. The parameters of the analysed rope in terms of the delivered metallurgical certificate were 1 + 6 + 12 + 18 + 22Z 1270 U sZ.

The visual inspection of the rope revealed the significant wear of one side of the rope. On the worn side of the rope there were squeezes, scabbards and a strip of fine cracks stretching along the total length of the rope. Besides the depreciation of the rope numerous breaks of Z wires from the surface layer of the rope were found. The cracks allowed the wires to release; in consequence, continuing operation of the cargo cable way caused that the wires were breaking and dropping out of the rope.

On the overall length of the rope the total number of 37 nests of the rope damages with the local ruptures of the Z wires were discovered by the NDT inspection. Actually, after the NDT inspection the rate of the rope damage led to the consideration that the rope was damaged due to the poor quality of the material used to manufacture the rope.

Based on the results of the NDT inspection and the rope condition we decided to perform mechanical rope wire testing and metallographic and fractographic tests of the rope material and damaged rope wire locations. The samples were taken from a new unassembled rope from the reserve as well as from the damaged, put off rope.

RESULTS

The samples were subjected to tensile, bending, and torsion tests. 59 wires, i.e., 100% of both samples of the ropes were subjected to mechanical tests. During the course of unweaving of both rope samples we observed dints on the wires from all the layers of the ropes; the dint observed on the sample from the put on rope was stronger. The surface cracks observable on the Z wires of the surface layer of the put up rope did not occur on the wires of the inner layers of the rope.

The results of the mechanical tests unambiguously confirmed the above assumption. The Z wires of the surface layer of the non-assembled rope showed lower strength values than those declared in the rope conformity declaration. It is clear that the Z wires were manufactured in the 1180MPa strength class. The mechanical tests of the samples of the wires of the put up rope con-

Fig. 1. The view of the damaged rope, a) the release of the Z wires from the surface layer, b) the nest of the ruptures of the Z wires from the surface layer

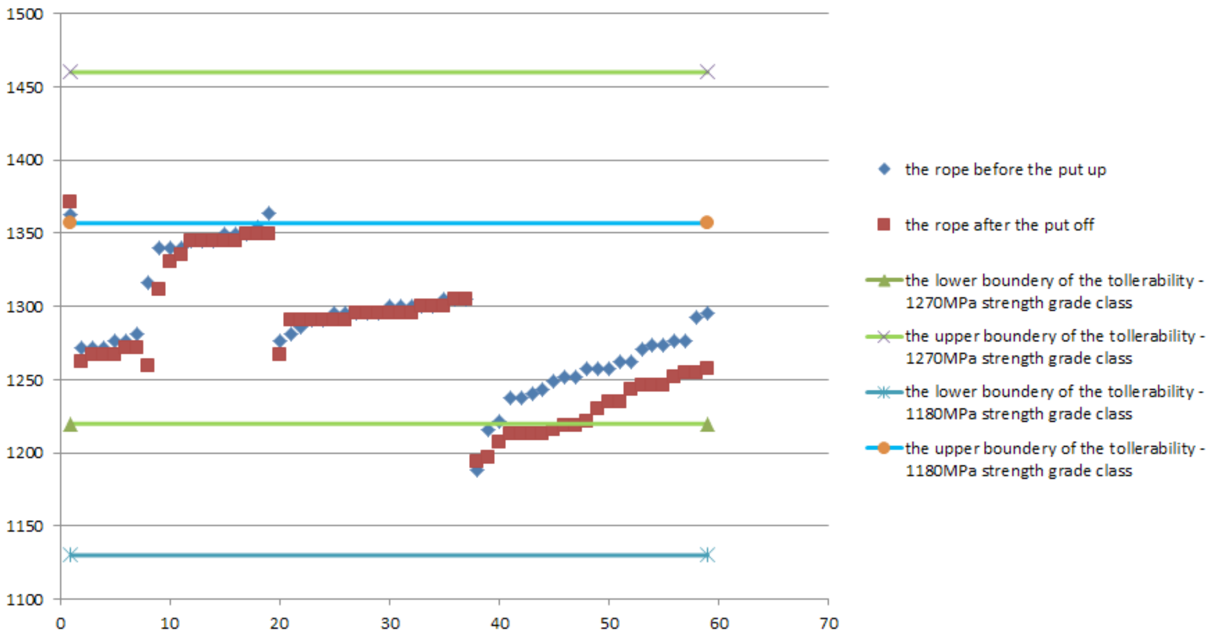

Fig. 2. The strengths grade courses for individual wires of both rope samples (put up red points, unassembled blue points)

firmed the trend manifested on the Z wires. The results showed an evident decrease in strength due to the surface breaking of the rope wires by the cracks (Figure 2).

It is obvious that Z wires of the surface layer have lower strength grade than the other wires of the rope. The strength grade degradation due to the operation is notable only for the Z wires of the surface layer. The values measured in the torsion and bend tests meet the criteria of EN 102642. The metallographic and fractographic tests of the wire ropes confirmed the results of the mechanical tests. The microstructure of the wires taken from both samples was the same: perlitic with ferritic crosslinking. The grains are oblong, in the direction of the wire axis. The local discrepancies in the grain size were observed due to a different degree of the deformation at the edge and inside of the wire (Figure 3).

A local decarburization of the surface was observed on the Z wires of the surface layer, where the cracks and the ruptures of the wires were located.

Upon above it can be stated the ruptures in the decarburized surface layer caused formation of the wires ruptures (Figure 4).

The hardness measurement of the Z wires helped to recognise different hardness values HV0.1 between the middle of the wire and its edge. The hardness of all tested samples in the middle was HV0.1 370 units. All tested samples had a hardness of HV0.1 370 units, at the edge of the wire it was HV0.1 270 units.

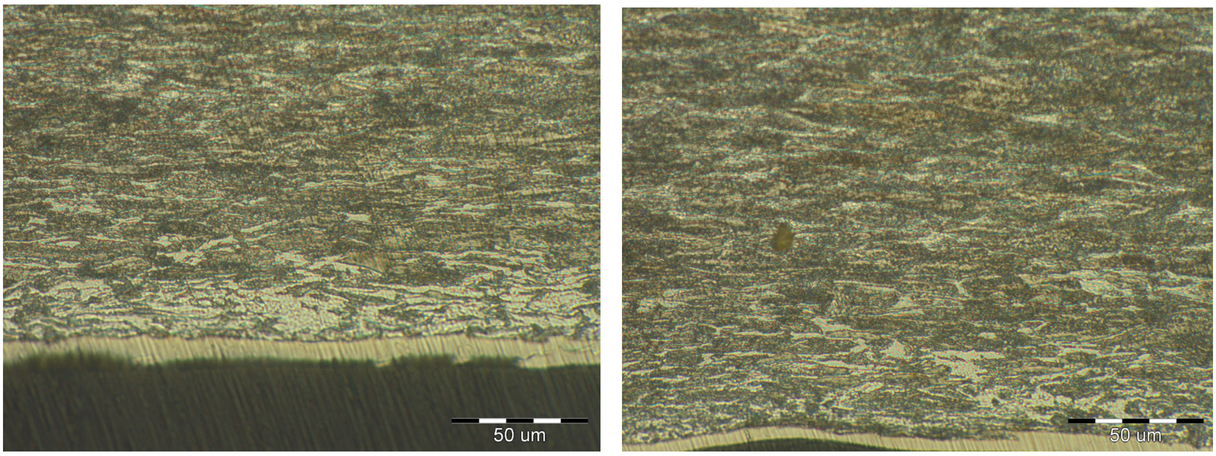

Fig. 3. The microstructure Z wires, the surface layer

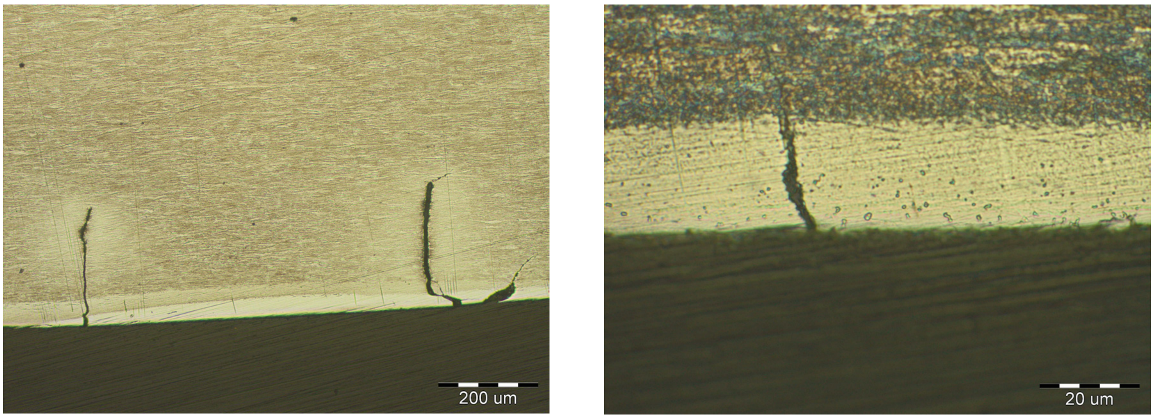

Fig. 4. The decarburized surface of the Z wires with the ruptures

DISCUSSION

From the above results of the mechanical tests, the microstructure tests of the wires and the measured hardness values it is clear that the rope was not manufactured from the patent wires used in the rope manufacturing in common. The decarburized surface of the wires and their microstructure are responsible for a significant wear of the rope surface, dints and abrasion. The cracks formed in the decarburized layer were spreading into the middle of the wire during the rope operation and led to the formation of the ruptures.

During the operation of the rope the broken wires started to realise, subsequently they were breaking and dropping out from the rope structure. Despite the considerable abrasion all of the rope ruptures confirmed the above mentioned course of the damage to the rope wires.

Mechanical properties of the rope wires indicate a reduction in load capacity of the Z wires of the surface layer; the Z wires did not accomplished their function – to work as a surface layer.

The actual strength grade class of the wires stated by the mechanical tests was lower than the strength grade class the supplier declared. The rope clearly meets the parameters of the 1180MPa strength grade class.

CONCLUSION

The analyses of the damage of the rope used on the cargo cableway revealed poor quality input material used for the production of the rope. The Z wires had a lower strength grade as well as decarburized softer surface in which cracks were formed during the operation. The cracks were spreading into the cross-section of the wire subsequently and then the wires were cracking

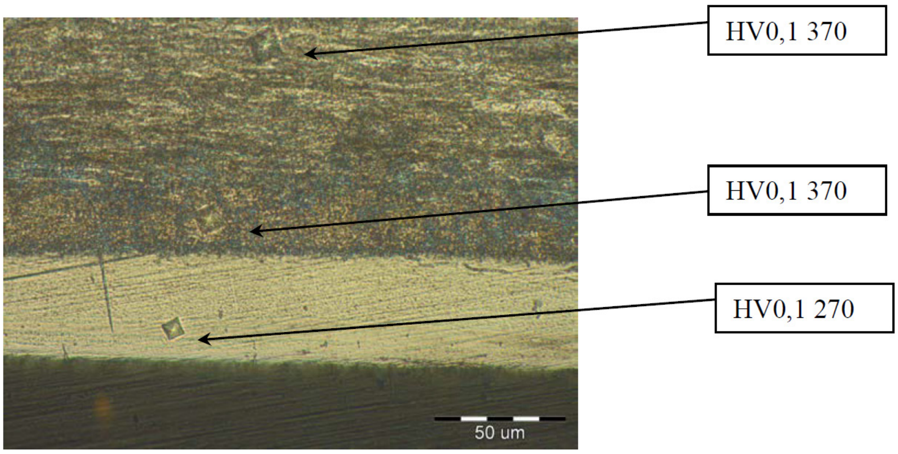

Fig. 5. The measurement of the hardness of the rope samples

and the fractures were created. The cumulation of the fractures in to the nests considerably weakened the metallic cross-section of the rope, which could have caused the abruption of the rope.

Pursuant to the above tests, rope analyses, conclusions we proposed the steps for the operator:

- mechanical tests of hauling ropes and a carrying rope before their put up,
- regular non-destructive inspections of hauling ropes and a carrying rope.

The implementation of these steps led to the increase of the life time of the carrying ropes. Nowadays, the carrying ropes have been in operation for eight years.

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