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THE ANCHORS OF STEEL WIRE ROPES, TESTING METHODS AND THEIR RESULTS

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The present paper introduces an application of the acoustic and thermographic method in the defectoscopic testing of immobile steel wire ropes at the most critical point, the anchor. First measurements and their results by these new defectoscopic methods are shown. In defectoscopic tests at the anchor, the widely used magnetic method gives unreliable results, and therefore presents a problem for steel wire defectoscopy. Application of the two new methods in the steel wire defectoscopy at the anchor point will enable increased safety measures at the anchor of steel wire ropes in bridge, roof, tower and aerial cable lift constructions.

Key words: nondestructive testing (NDT), wire ropes, thermography, defectoscopy

Sidra čeličnih žičanih kabela, metode ispitivanja i njihovi rezultati. U ovom prilogu predstavlja se primjena jedne akustičke i termografske metode u defektoskopskom ispitivanju nepokretnih čeličnih žičanih kablova na najkritičnijoj točki, na sidru. Najprije su prikazana mjerenja i njihovi rezultati dobiveni tim novim defektoskopskim metodama. U defektoskopskim ispitivanjima na sidru naširoko korištena magnetska metoda pruža nepouzdane rezultate te stoga predstavlja problem za defektoskopiju čelične žice. Primjena dviju novih metoda u defektoskopiji čelične žice na točki sidra omogućit će uporabu mjera veće sigurnosti na sidru čeličnih žičanih kablova u konstrukcijama mostova, krovova, tornjeva, žičara.

Ključne riječi: ispitivanje bez razaranja (IBR), žičani kablovi, termografija, defektoskopija

INTRODUCTION

At present, there is a great boom in development of technologies, which puts a large emphasis on quality, reliability, life expectancy and effectiveness of products, devices and machinery. At the same time, there is a great demand to save energy, raw materials, and maintenance and qualified labor costs in the manufacturing process. NDT gains an important role in the evaluation of quality and reliability of products, together with saving energy and maintenance costs of machinery already used in production. Defectoscopy also becomes a significant part of entrance quality inspection of incoming raw materials, and in checkout quality tests of production. We use several methods. Our laboratory has introduced magnetic, acustic and thermographic methods for detecting cracks on steel wire ropes in our laboratory. The aim of the article is to present the possible way for detecting cracks in the area of anchorage of the steel wire ropes.

Defectoscopic devices for testing of steel wire ropes use a principle of magnetic flux leakage (magnetic method). The scattering of the primary magnetic flux depends on a size, shape and position of the non-homogeneity in a tested sample. Further, it also depends on a value of magnetic induction by which the sample was magnetized. The highest degree of scattering of the magnetic flux occurs at the surface non-homogeneity point located perpendicularly to the direction of the magnetic flux. In order to apply the magnetic method correctly, it is necessary to measure the above-mentioned magnetic characteristics of a tested sample, to choose the appropriate method of magnetization, and to determine whether the sample was magnetized to a sufficient degree[1].

Destructive tests as well as above mentioned nondestructive magnetic defectoscopic method for the evaluation of steel wire rope quality and safety characteristics are frequently used. Due to a doubtful signal from the magnetic and other defectoscopic methods at the anchor points, we were compelled to develop a new nondestructive defectoscopic method and device for testing of anchored steel wire ropes at the anchor.

We developed a new acoustic defectoscopic method by which it is possible to measure a change in diameter of steel wire rope within proximity of and at the anchor. We modified a method for measurement of an elasticity modulus of steel wire ropes by means of acoustic vibration [2 - 4].

At present, the method that monitors a temperature change within objects is widely used for the purposes of testing the electrical equipment and machinery. The

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method is known as thermovision. All objects emit photons within the infrared range of the spectra, and the number of the emitted photons depends on object's temperature. This relationship can be used for visible representation of a thermal field radiated by the surface of observed objects. The thermograhic method has a universal use, and is based on a transformation of infrared radiation into a visible spectrum. The measurement is contactless. The optical system registers emitted infrared photons from the observed object and conveys them to the detector, where the energy of the photons is transformed into electrical signals. The electrical signals are multiplied and used for the regulation of emission of electrons in an ordinary television screen [5-8].

EXPERIMENTS AND DISCUSSION

NDT testing of loose wire ropes segments uses routinely above-mentioned magnetic method. The method gives very good results, which are reliable and reproducible, especially with use of attached sensory coils and Hall's sensors. The problems arise when this method is used to test immobile steel wire ropes anchoring bridge, roof or other constructions and drilling towers [1]. The greatest challenge arises during defectoscopic test of immobile steel wire rope at its anchor point. Due to rope anchoring, the diameter and profile of the rope suddenly change Figure 1, and this discrete transition represents obstacle for classic defectoscopic method. Magnetization and movement of attached sensory coil or Hall's sensor at the anchor point are difficult, and therefore defectoscopic measurements taken at this point are doubtful [1]. Based on our experience with the method of the scattering of the primary magnetic flux, we can conclude that this method gives false positive signals (irrelevant indications) at the anchor point as indicated in Figure 1[1].

During development of the appropriate conditions in application of acoustic defectoscopic method, we used assumption that by direct measurements of the tension force F, mass density ρ, wire rope prolongation Δl_{σ}, and original length of rope l_l we will be able to obtain a real value of steel wire rope cross-section. Figure 2 shows dependence of the measured cross-section value from the tractive force of unperturbed rope and ropes with various numbers of perturbed wires. Measurements were obtained for steel wire rope type 6x(1+12+18) according standard STN 02 4324.41, i. e. a rope consisted of 222 zinc plated wires. The rope was twisted in alternate lay and its diameter was 16 mm. According standard STN EN 12 385, this rope type is d 16 1570 FS sZ. Blue line shows dependence of the cross-section from the tension force in unperturbed steel wire rope. This calculated cross-section based on above measured parameters should correspond with cross-section value from manufacturer. Moreover, dependence should not decrease with increasing force, because the cross-section had a same value in three measurements at F of 12 500 N, 18 000 N, and 24 000 N, respectively. It is clear that according to results in Figure 2, the cross-section value decreases with increasing tension force. Discrepancy between cross-section calculated value and value from manufacturer points out an error in measurements of the input parameters for the tension force F, mass density ρ, wire rope prolongation Δl_{σ}, and velocity of propagation of sound in the rope $\sqrt{}$. Following lines shows dependence of the cross-section from the tension force in steel wire rope containing perturbed wires: magenta line 30 perturbed wires, yellow 42 perturbed wires, and cyan 55 perturbed wires.

The profile of dependences measured from ropes with perturbed wires is similar to the dependence measured from unperturbed rope, decrease of cross-section value with the increasing tension force. This further indicates the inaccuracy in measurements of input parameters.

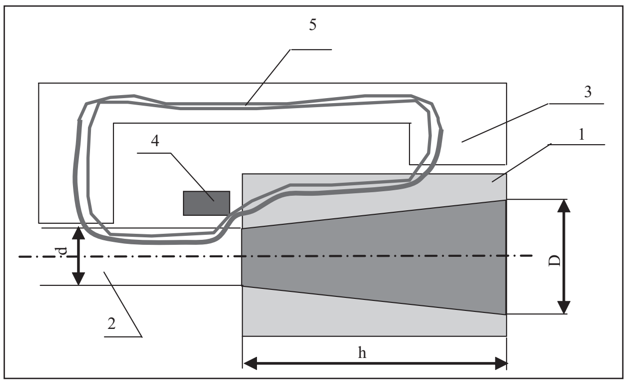

Figure 1 Rise of irrelevant indications within steel wire rope at the anchor. 1 is a conical cable end, 2 is a steel wire rope, 3 is a magnetic yoke, 4 is a point where irrelevant indication arises, 5 represents magnetic flux force lines.

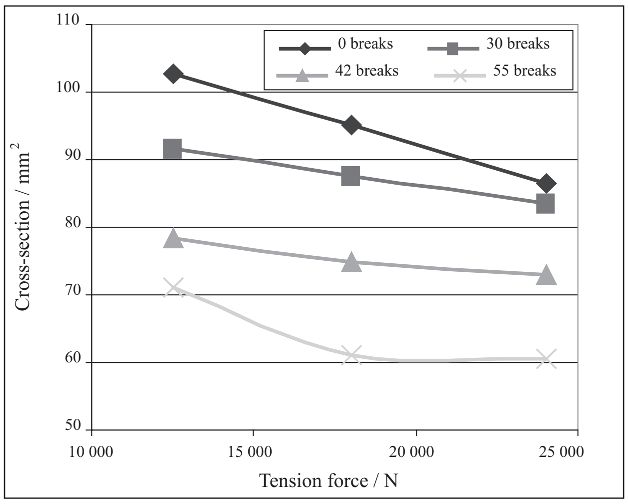

Figure 2 Dependence of the measured cross-section from the tension force in the unperturbed rope and ropes with various numbers of perturbed wires. Tension force F applied along the wire axis is on x axis, and cross-section obtained by acoustic method is on y axis. The value of cross-section was calculated from Eq. 4 with use of the measured values of parameters by acoustic method, the tension force F, mass density ρ, wire rope prolongation Δl_{σ}, and velocity of propagation of sound in the rope √.

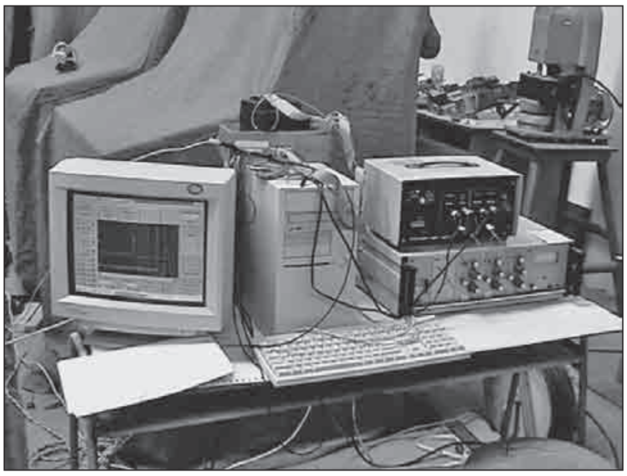

Figure 3 Acoustic method measurement set up. Acoustic analysis part of the set up.

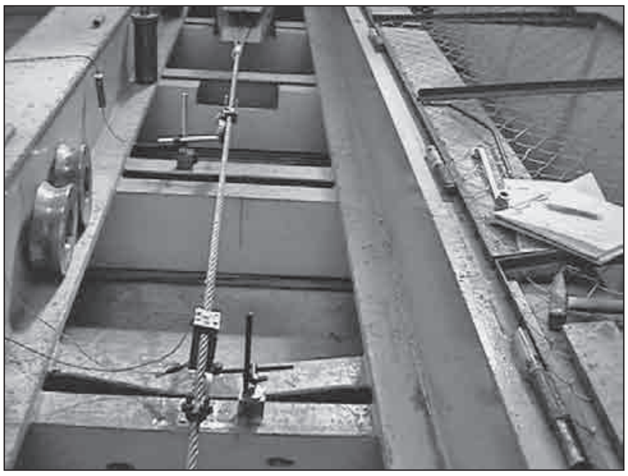

Figure 4 Acoustic method measurement set up. Display of the measurement part of the set up – microphones and deviation gauger.

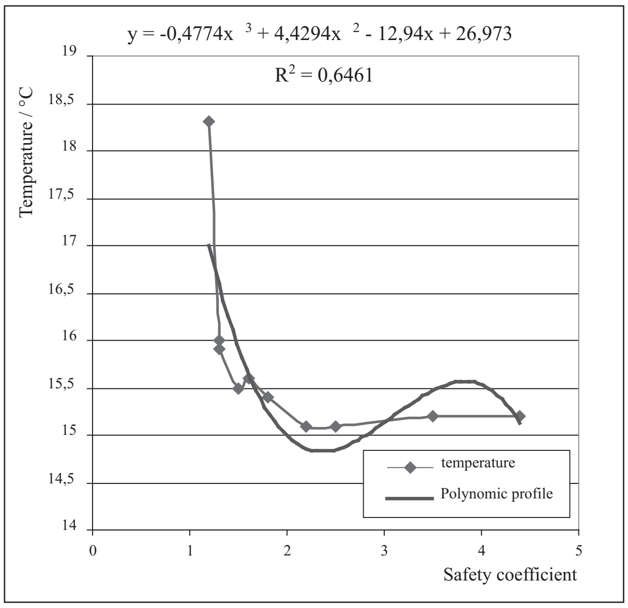

Figure 5 Relationship between temperature and safety coefficient in sample. Safety coefficient is on x axis, and measured temperature by thermographic method is on y axis.

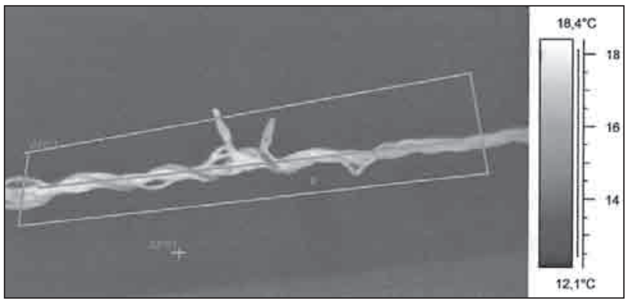

Figure 6 Ruptured steel wire rope. Thermogram – transformed infrared field into visible spectra.

Taking together, the measured results and equations describing acoustic method, it is clear that to obtain reproducible results in repetitive measurements, we have to measure with higher accuracy the input parameters: initial length of the rope section, tension force in the rope and the velocity of sound propagation in the rope. Then, based on accurate above-mentioned input parameters, value of a mass density and a coefficient of thermal extensibility, we can accurately determine cross-section of the rope in a section of interest.

The velocity of acoustic wave propagation within the wire steel rope is detected by sensors attached to the rope. A stroke force is developed by a pendulum consisting of a ball, angle-measuring instrument and magnetic support stand. The pendulum creates a reproducible mechanical stimulus in the steel wire rope with the same characteristics in repetitive experiments. The tension force in the tested rope is measured by a cylindrical sensor containing four tensometers. Set up for measurement input parameters by acoustic method is showed in Figures 3, 4.

By the acoustic measuremens applied on the steel wire ropes thermographic tests of the ropes were done as well. This method was used in experiments with suspended load with a loop. Specimens were fastened between the bolts of the testing device, which corresponds to the way of fastening fixed load-carrying anchor ropes to various constructions. Figure 5 shows relationship between an increase of temperature in the cross-section of a perturbed steel rope and safety coefficient, i.e. dependence on the value of the tension force. With the decreasing safety coefficient value of the tension force increases, for example tension force is greater at the safety coefficient of 2 than at the coefficient of 4,5. Displayed relationship in figure 5 clearly indicates that with the increasing tension force, or decreasing safety coefficient, temperature in the rope cross-section increases. Increase in temperature is gradual until safety coefficient of 2,5. The increase becomes quite steep at the coefficients with value < 2,5. Figures 6, 7 displays a thermal field of steel wire rope sample after rupture.

CONCLUSIONS

Based on the results in testing of steel wire ropes at anchor obtained by means of acoustic method and thermovision in our laboratory, it is possible to conclude that both methods can reliably detect defects. To im-

Figure 7 Ruptured steel wire rope. Same rope (figure 6) in visible light.

prove application of both methods, it is necessary to do measurements in the various weather conditions. This will be an aim of a research project in near future. Preliminary results indicate that increased tension in the tested sample results in increased temperature and also in faster propagation of an acoustic signal. Present results show that the acoustic method gives reliable information about relative change in the cross-section of steel wire rope under different tension forces, however initial determination of cross-section is inaccurate. As all defectoscopic methods, the acoustic method is relative, and thus it is necessary to do initial measurements of the tested section when there is no damage. According results in figure 2, cross-section decreases with increasing tension force. Discrepancy between cross-section calculated value and value given by manufacturer indicates an error in measurements of the input parameters: tension force in the rope, mass density, velocity of acoustic signal, and length change of the rope section. Therefore it is necessary to improve accuracy in measurements of input parameters. Results obtained by thermographic method indicate that it is necessary to improve sensitivity of this method as the change in the temperature is gradual in a wide range of the safety coefficients and significant change arises with coefficient of 2 or less, when damage of the rope is critical and near rupture. Therefore, at the moment, thermovision is useful for determining already critically damaged ropes. It can be used as one of the method for diagnostic of the technical properties of steel wire ropes at the anchor points.

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Note: The responsible for English language are Katarína Štroffeková, Kurt Magsamen and Viera Nemčoková, Košice, Slovakia