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Automated Assessment of Steel Wire Ropes Residual Life Time Based on Magnetic NDT Data

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Abstract

Assessment of steel wire ropes residual life time assumes a complex consideration of non-destructive inspection results and individual operational conditions of the rope. Different inspection data, loading conditions and loading cycle parameters should be involved in mechanical model that enables to make a valid life-time prediction. Special software complex supports the automated evaluation of NDT data and calculation of rope residual life time. This technique ensures more objective interpretation of inspection data, reduces the inspection costs and duration, that is especially important for such facilities as cable-stayed bridges and structures.
Accurate calculation of rope's tensile strength reduction assumes the availability of information about defect location in the cross-section of the rope. Modern MFL equipment makes it possible to separate the outer and inner broken wires.

Keywords: MFL inspection, residual life time, automated data processing

Magnetic non-destructive testing appears at present time to be a basic method of condition monitoring in many different rope applications, such as ropeways, lifting ropes, cable-stayed structures [1]. Its importance is reflected in modern industrial regulations and codes, for example, BS EN 12927-2004, ASNT E1571-06 and others. It reveals different types of rope defects – corrosion, wire breaks, abrasion, which are essential for assessment of rope current condition. However the main question, which stays before the maintainer of the rope, is an estimation of residual life time of the rope. Industrial regulations and norms of many countries contain the quantitative discard criteria for ropes in different applications. In addition it should be noted that the degradation process of the rope depends substantially on operation conditions of the rope. So in practice different ropes of the same type with similar defects have different residual life time. To develop a technique of rope residual life time estimation has been the aim of special investigation of INTRON PLUS Ltd. for last several years.

The main mechanical characteristic of the rope condition is residual load capacity, which enables, considering the operation conditions, to make an estimation of rope residual life time. Calculation of residual load capacity is based on results of the current and previous NDT-inspections, rope construction parameters and operation conditions. There is a big amount of data – new and previous - to be considered, so this estimation procedure should be automated.

The main object of non-destructive rope testing is measurement of loss of metallic area (LMA) and detection of localized faults (LF). LMA indicates such faults as corrosion and abrasion. LF are caused typically by wire breaks, both outer and internal. These rope faults reduce the rope's load capacity. While calculating wire rope residual bearing capacity one should take into consideration the distributions of both deterioration factors – LMA and LF over rope's length.

One shaft lifting rope 6x25(1+6;6+12)+IWRC of 63 mm diameter is taken as an example. Figure 1 shows distribution of LMA for during three consecutive inspections (blue color marks the first inspection, orange – the second inspection, red – the third inspection), carried out with help of Intros instrument (Intros MH24-64). Figure 2 shows the LF-distributions for the first and third consecutive inspections (LF- distribution for the second and first inspection are the same). Combination of distributed LMA and local wire breaks may be seen on these diagrams. LMA distribution of the second and third inspection shows obvious increasing at the distance of 450 – 500 m, coursed by rope abrasion, and some moderate increasing at the distance of 50 – 100 m. LF distribution of the first inspection contains no signals of wire breaks while the LF curve of the third inspection depicts multiple wire breaks at the distance of 100 – 160 m.

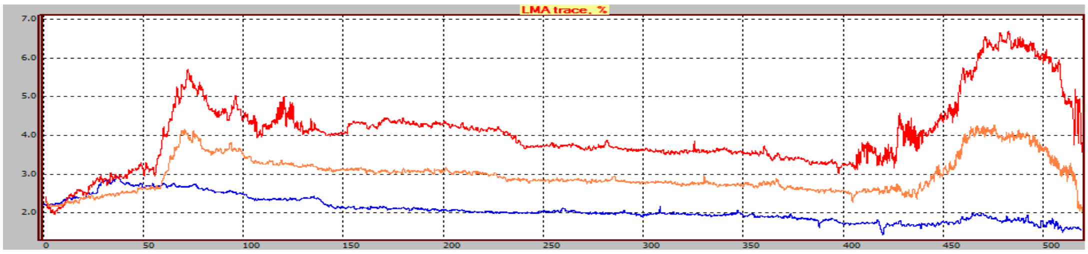

Figure 1 LMA-distributions of the shaft rope during three consecutive inspections

Effect of LF superposes on the LMA-effect and residual load capacity can be calculated as a characteristic of the weakest rope cross section.

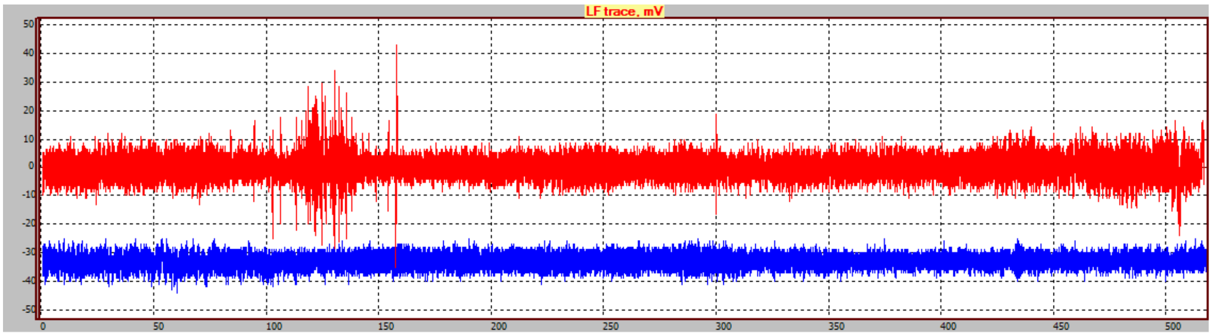

Figure 2. LF-distributions of the shaft rope for the 1st and 3d consecutive inspections

Calculation of residual load capacity should take into account the various parameters, such as rope construction, nominal load, material strength [2, 3]. The result of the calculation can be presented in terms of safety factor as the main rope strength characteristic important for a customer. Figure 3 depicts the distribution of safety factor of above mentioned shaft rope during three consecutive inspections.

The residual strength calculation technique was verified at experimental data, gathered with help of rope strength testing for different rope constructions [2].

The location of wire breaks at the rope cross-section greatly affects the residual safety factor of partly degraded rope. Two typical cases concerns wire breaks at the outer strand surface and inside the core of the rope. The influence of fault's location is different for various rope constructions. Two examples of this phenomenon are presented below.

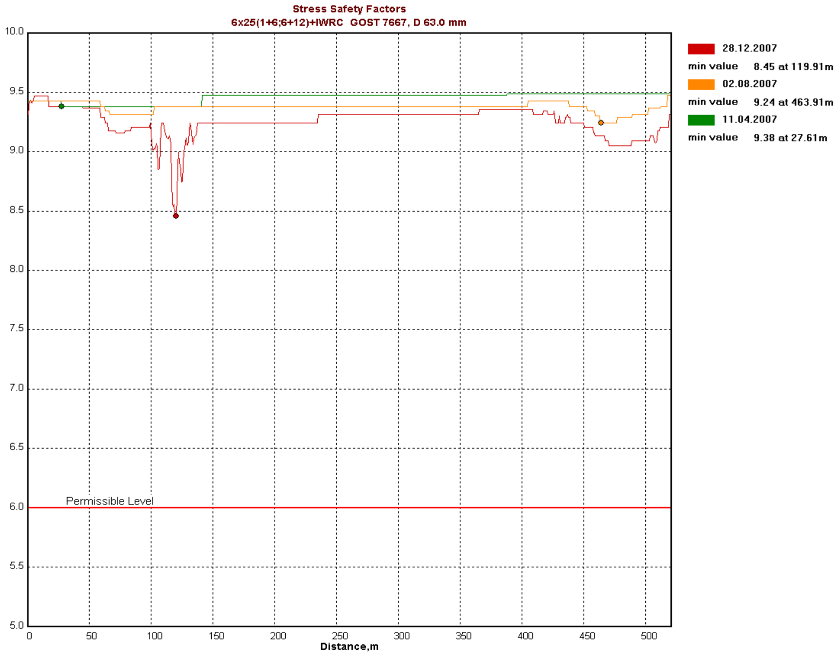

Figure 3. Distribution of safety factor of shaft rope during three consecutive inspections

Let's take a rotation-resistant multi-stranded rope DIEPA 1315 CZ 15x7-6x26/6x7+ IWRC (1x25), which is used in jib crane at offshore Sakhalin platform (the rope was also inspected with Intros instrument). Assume the loss of metallic cross-sectional area (LMA) be of 7 % as a result of either outer wire breaks or inner wire breaks (wire breaks in the core of the rope). Consider two different operating conditions: 1) rope is tensioned without torsional deformations and 2) tension is accompanied by moderate rotation of the rope swivel. Using the appropriate rope mechanical model we will get results shown in Table 1.

Table 1. Relative loss of rope strength

Strength Loss , %			
Pure Tension		Tension with Rotation	
Outer wires breaks	Core wires breaks	Outer wires breaks	Core wires breaks
6.2	8.0	3. 2	10.6

The table shows, that in considered case the inner faults seem to be more dangerous, than the comparable outer faults. This is contrary to many other typical rope applications. Therefore a detailed modeling of rope failure with consideration of the rope loading is necessary, if anyone wants to predict the rope residual strength and life-time using the magnetic NDT data.

Another example considers the rope of Russian standard GOST 16853-88 of 28 mm diameter used in drill towers. This rope works on sheave wheels which may have different diameters. Let's take the following parameters: sheave diameter of one meter, which is accepted by mechanical norms for hoisting devices; typical breaking load of specified rope and nominal load of 100 tons. In the case of the rope without bending the calculated safety factor is equal to 6.18, but in the case of bending on the sheave wheel the safety factor appears to be just 3.1. This means near two times less. So the due conditions of rope operations should be considered while calculating its load capacity.

To ensure the efficiency and regularity of the rope residual life time estimation the whole calculation should be made in a framework of joint tool aimed for NDT interpretation and residual strength assessment. This problem has been solved to a certain extent by Wintros-

RopeStrength software developed by INTRON PLUS, Ltd. This software implements automated interpretation of inspection results, makes possible to work with series of inspections, calculates the current residual load-carrying capacity and makes prediction of residual life time. Figure 4 depicts degradation of rope safety factor with time vs. loading cycles (black points) and prediction of safety factor in nearest future (green points) made by Wintros-RopeStrength software.

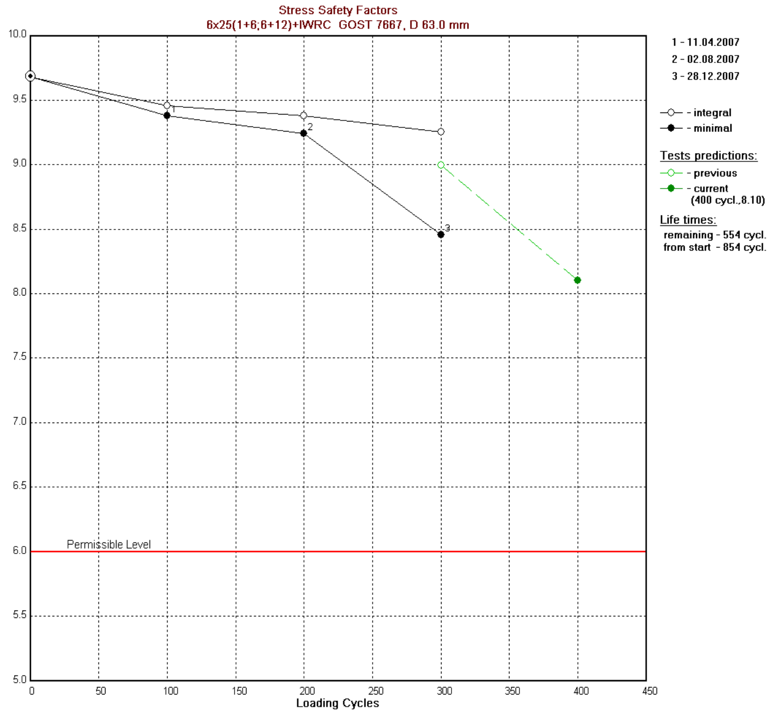

Figure 4. Degradation of safety factor of the shaft rope with operating time

Conclusion

Modern NDT equipment makes possible to estimate the residual life time of steel wire ropes. This estimation is being based on the serial rope inspections taking into account the defects location at the rope cross-section, rope construction parameters and actual operating conditions.

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