The International Journal of
TRANSPORT & LOGISTICS
Medzinárodný časopis
DOPRAVA A LOGISTIKA

ISSN 1451-107X

STEEL ROPES NDT OF CRANES AT METALLURGICAL WORKS

Vasily Sukhorukov[1]

Keywords: steel ropes, NDT

Abstract: *This paper describe Non-destructive of the ropes.*

Introduction

Cranes at metallurgical works are often used in hard conditions, first of all under influence of high temperature. This is very actually for hot-metal cranes. Steel ropes of the cranes are subjected to this influence mainly. This is reflected on the rope bearing capacity and of course on the crane use safety. Non-destructive testing (NDT) provides with supervision for real condition of the ropes by periodical instrumental inspections.

1. Accidents with cranes because of rope break

The crane rope was broken at the converter shop of the SEVERSTAL metallurgical plant (Cherepovets, Russia) during a fusion in 1998. Then the foundry ladle with molten metal went down and about 50 tones of the metal flowed out of the ladle. Fortunately, there were no accident victims. But the shop stayed for 68 hours.

The reason of the rope break was the rope surface heating up to (600-800) °C and then deterioration of the rope tensile strength because of the rope metal structure change as like as its wire breaks. Tongues or flame arise when molten foundry iron with temperature (1250-1400) °C is poured into a converter from the ladle (Fig. 1). As a result some crane elements including ropes are influenced by sharp temperature drop. This leads to the rope metal thermocycling and then to the plastic deformations, changes of metal structure, arising of cracks in wires.

NDT of steel crane ropes can detect the rope deterioration and evaluate the rope durability loss. The magnetic steel rope flaw tester INTROS has been using for this purpose for many years [1, 2]. The instrument has been used successfully for crane rope NDT at the SEVERSTAL since 1999. But there was a time period when the rope NDT was interrupted. And another accident happened this time. It was more hard: four people perished.

The accident happened on 23.03.2004. The crane rope was broken, the ladle with molten foundry iron dropped down from 14 m height and the metal flowed out. It happened in spite of strict instructions established just after the first accident in 1998: to inspect the ropes visually everyday and to change them every two months. As it was showed by investigations of SEVERSTAL Laboratories and other research organizations in Moscow, Saint-Petersburg and Cherepovets the real rope condition depends on many factors and can be defined by use of combination visual and instrumental NDT methods. The INTROS instrument can detect not only surface rope defects like broken wires but

[1] **Prof. Vasily Sukhorukov**, INTRON PLUS, Ltd. Krasnokazarmennaya 17, 111250 Moscow, Russia, Tel.: +7 495 2293747, Fax: +7 495 510 1769, e-mail: vsukhorukov@intron.ru

inner ones like wire brake and wire wear inside a rope because of local abrasion and corrosion (local faults, LF). Besides it measures the rope loss of metallic area (LMA) because of wire wearing and stretching. But most important that the instrument detects change in rope steel structure under the thermocycling influence.

Fig. 1. *Pouring of metal into a converter at the SEVERSTAL plant*

2. Rope durability loss under high temperature effect

Steel rope heating at hot-metal cranes effects the rope strength and durability in two ways. The first one is the loss of tensile strength (LTS) by high temperature of rope wires. The second one is the LTS by normal temperature of the wires as a result of thermocycling. It is known that LTS because of thermocycling usually is accumulated by metal. Both factors effect on the crane rope in our case.

Taking into consideration, the time of high temperature effecting is not so long and the rope heat capacity and its heat conductivity are high, the temperature or wires inside the rope is not so high as on its surface ((600÷700) °C). But the strength of carbon steel is reduced more than twice even at temperature 400 °C. So the first factor of LTS – high temperature of rope wires must be taken into account.

The effect of second factor is more complicated due to accumulation of thermocycle metal fatigue. The real value of LTS depends on thermocycle number. In other words it depends on the rope working time. Thus, the LTS of the rope broken at SEVERSTAL in 1998 reaches three times at rope section close to the rope break location.

3. Magnetic steel rope tester INTROS as an instrument for evaluation of rope condition of hot-metal cranes

The INTRON PLUS company was the first which used it for the condition evaluation of ropes effected by high temperature at hot-metal cranes. It is very important the instrument can detect and evaluate the LTS because of the thermocycle metal fatigue. This is possible due to the INTROS principle of operation. The instrument evaluates magnetic flow along a rope section and detects the flow allocation change connected to change in rope cross-section or to local faults presence.

The magnetic flow along the rope under test depends also on the rope metal magnetic properties. The thermocycling changes the rope steel structure, consequently changes its magnetic properties, magnetic permeability specifically. That means the magnetic flow through the rope section effected by thermocycling differs from the flow through a section without high temperature influence. This difference can be measured by the INTROS through channel of the LMA measure. So the change of rope strength can be evaluated as LMA in percent of the nominal rope cross-section value.

It is possible to monitor the rope condition by comparing rope testing data during a time period.

4. Rope condition monitoring using the INTROS

The magnetic rope tester INTROS is used for the rope NDT of hot-metal cranes at SEVERSTAL. The load ropes with 42 mm diameter are inspected by normal temperature weekly. Fig. 2 shows 6 records of the INTROS LMA channel in 2000. The time intervals between the records are a week approximately. The first record (I) corresponds to the new rope just after its handing on the crane. There are six peaks on the all records. They all correspond to the rope section (0÷110) m. The sections 2, 4, 6 with maximal signals correspond to the sections rope location over the lower pulley block close to it at the moment of the ladle reloading. The peak 2 is the highest because it corresponds to the rope which is nearest to hot metal flow. These sections are impacted by heat from melted metal and flame tongues.

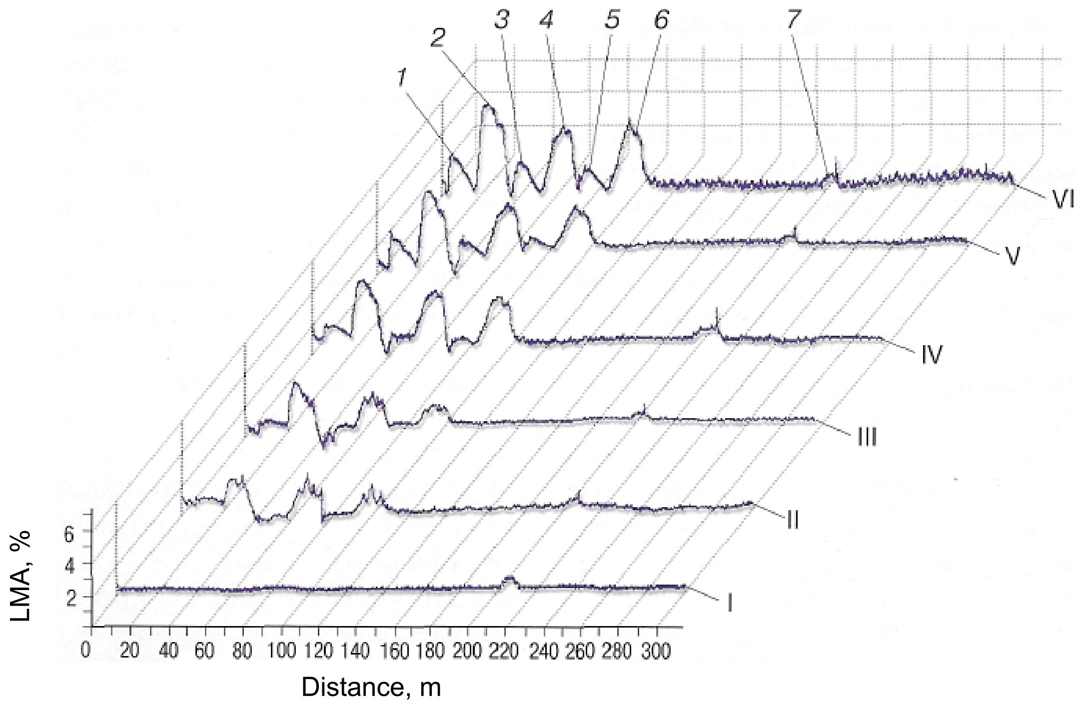

Fig. 2. *Records of the rope with diameter 42 mm at the SEVERSTAL hot-metal crane*

The sections 1, 3, 5 correspond to the section location close to the upper pulley block at the moment of the ladle reloading. The rope heating is significantly less than the rope sections 2, 4, 6 heating. So the peaks 1, 3, 5 are less than the peaks 2, 4, 6 due to the structure change of metal is negligible. The signals 1, 3, 5 arise mainly due to real loss of rope cross section because of the rope abrasive wear.

If to suppose the INTROS readings of LMA channel consist of two components:

LMA = LMA(t) + LMA(w),

where

LMA(t) – thermocycling component;

LMA(w) – wearing (abrasive et al.) component,

then

LMA(t) = LMA - LMA(w).

Let us try to evaluate the relative safety factor (LFS) using the residual bearing capacity of a rope, which is the ratio the safety factor (SF) of the rope section under test to the safety factor of a standard rope:

SF = 1 – [LSF(t) + LSF(w)],

where
LSF(t) – loss of safety factor due to thermocycling influence;
LSF(w) – loss of safety factor due to wearing.

Function LSF(t) is defined experimentally using the rope (or wire) specimens effected by thermocycling.

Fig. 3 shows safety factor allocation along the rope corresponding to the trace VI at the records of Fig.2. The safety factory dropped to SF = 0.87 at section of the trace VI and to SF = 0.90 at sections 4 and 6. Evidently the SF approached close to the rope discard level SF = 0.825. But if to take into account only the LMA value of trace VI for sections 2, 4, 6 (5.5 % for 2 and 5 % for 4, 6) one gets the result the LF = 0.945 (for section 2) and LF = 0.95 (for section 4 and 6).

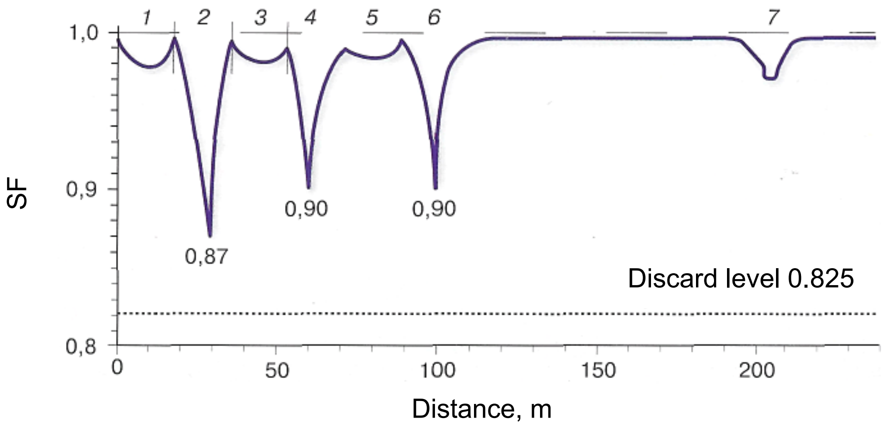

Fig. 3. *Safety factor (SF) allocation along the rope*

The real loss of safety factor considering influence of thermocycling is 13 % (section 2) and 10 % (section 4 and 6), but not (5.5÷5.0) %.

The peak 7 on the all traces corresponds to the break of central strand of the rope metal core. The break cannot be detected visually but its presence was confirmed by the rope unwinding after its discard.

Conclusion

Using the described procedure it is possible to evaluate approximately loss of rope under test safety factor not only because of rope mechanical wearing but also because of rope thermocycling.

References :

[1] V. Sukhorukov. In-Situ Nondestructive Testing of Steel Wire Ropes in Russia: Current State, Proceedings of the 10th International Conference “Investigation, Production and Use of Steel Ropes”, Podbanske, Slovakia, 21-24 Sept. 1998, pp. 229-237.

[2] V. V. Sukhorukov, V. S. Kotelnikov, V. G. Zhukov, A. A. Khudoshin. Importance of rope NDT for safe lifting of load cranes. Proceedings of O.I.P.E.E.C. Technical Meeting, Lenzburg, Switzerland, September 2003, pp. 131-136.