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Experimental Stress Analysis

NECESSITY OF EXPERIMENT FOR TECHNICAL STATE VERIFICATION OF SUPPORTING STRUCTURE OF FOUNDRY CRANE BEFORE ITS RECONSTRUCTION

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Abstract: There is emphasizes in this paper necessity of an experiment for verification of real technical state of a foundry crane. This experiment enables to take a decision about the next steps for a reconstruction process of the foundry crane, which has to undergo a reconstruction for increasing of hoisting speed from the original value 5,3 $m.min^{-1}$ up to the value 8 $m.min^{-1}$. If the stiffness of this crane is satisfactory and the durability of steel construction is adequate, so it can be performed the above-mentioned change. The core of the experimental analysis consists of values that are necessary for evaluation of technical state, as well as measured values and measuring methodology.

1. Introduction

At present it is necessary to solve questions how to improve technical level of many aged machines and machinery by means of reconstruction of them in order to improve their specific efficiency parameters, to save materials and to keep or to increase functional and operational reliability of them.

The technical experiment is an essential part of technical solutions also today, i.e. in the present time of widespread applications of computers. The experiment enables to obtain a whole set of complex inputs that are necessary not only for computer aided design of machines, but also in the area of testing or identification of them.

Intensification of future technical ability of heavy steel constructions depends on an ability to predict residual operational durability, above all. The prediction of residual technical durability of existing steel supporting structures is a serious technical, engineering as well as scientific problem. There are two main important impacts on operational durability. At first there are structural characteristics, for example construction materials, dimensions, shape and assembly of construction, as well as technological factors (surface treatment, welds, and joints). The second group of important impacts consists of operational characteristics, e.g. loading of construction, working environment (corrosion, high or low surrounding temperatures, radiation), as well as human factor (operating personnel).

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In the framework of this intention it was performed an expert recognition of steel construction of the foundry crane 250t/63t/12,5t – 26,4 m. There were fulfilled necessary measuring, control and inspection of given crane in order to evaluate its technical state and to consider possibility of future reconstruction for increasing of hoisting speed from the present value 5,3 $m.min^{-1}$ up to the value 8 $m.min^{-1}$. The inspection of crane's steel construction discovered a certain reduction of material due to corrosion process. The tensometric measurements after a long-year operation offered information about actual technical state of individual crane supporting structure parts and crane-crab supporting structure parts after 27 years of operation. By means of the experimental-analytic method was determined the residual durability, which is a substantial information for a possibility of hoisting mechanism reconstruction.

2. Inspection of crane

The foundry crane 250t/63t/12,5t – 26,4 m was inspected with regard to its technical state already in the year 1994. The most serious visually detected failure was an extensive damage of the left main girder in the fit-point of the balance beam of crane travel, namely in its lower part (Fig.1, 2, 3).

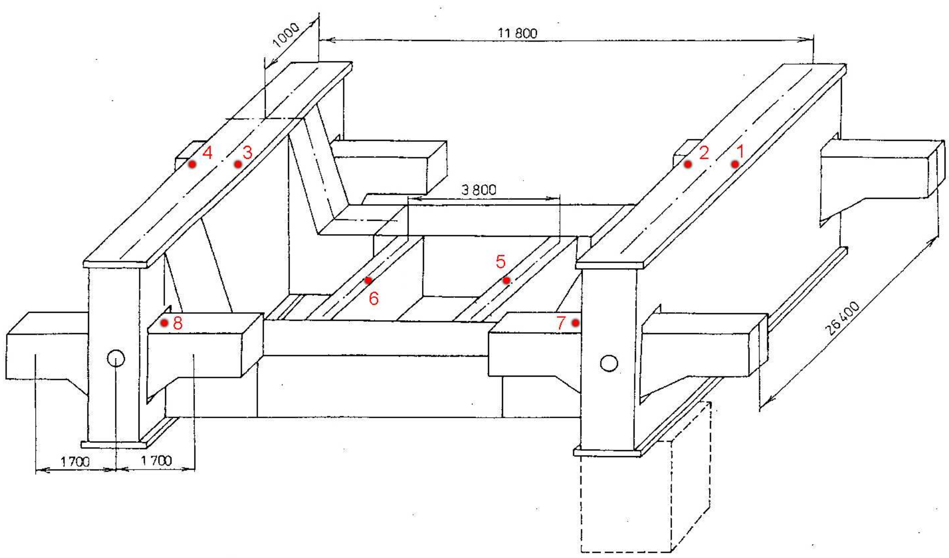

Figure 1: *Scheme of the foundry crane 250t /63t/12,5t – 26,4 m with marked points of strain gauge arrangement*

At that time it was stated a fact that this failure wasn't caused due to current crane operation. The main girder was repaired and after this reparation the given part was fully functional. The welds weren't damaged and also weren't identified any concave points. This fact is evident from the photo-documentation on the Fig.4.

During solution of this task were selected randomly certain points for measuring of thickness by means of the ultra-sound thickness-gauge ELCOMETER 204 (Fig.5).

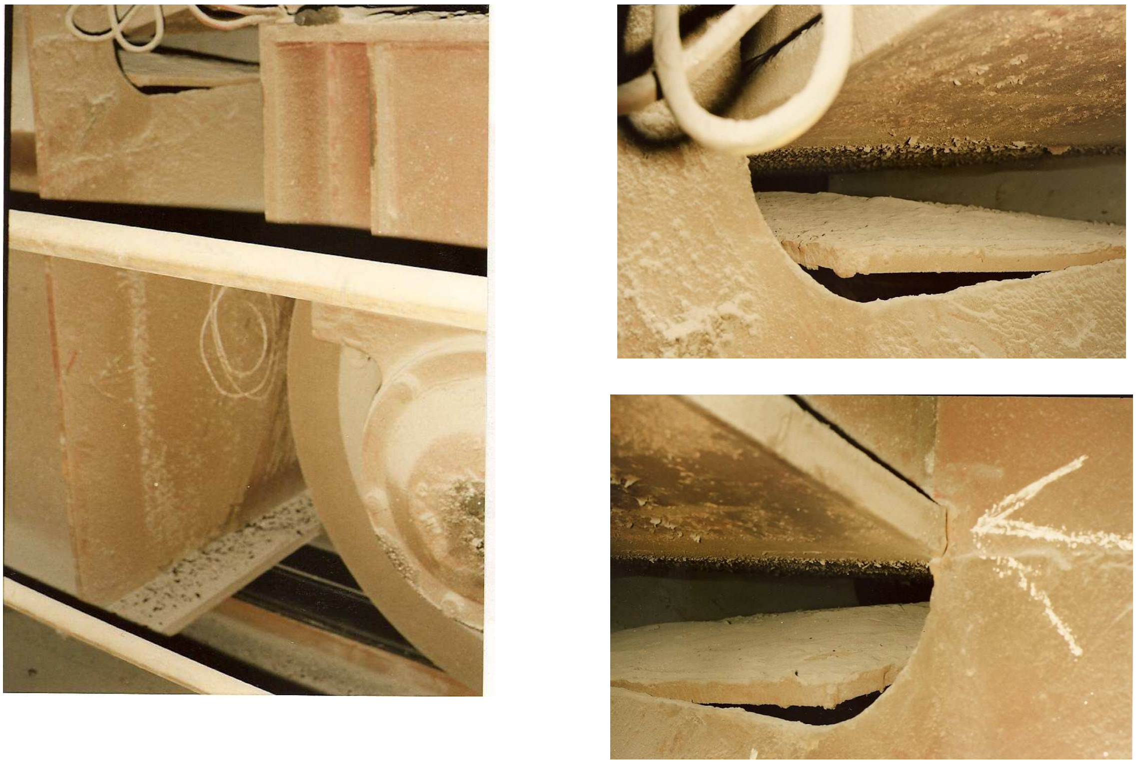

Figure 2: *Photo-documentation of the damaged place*

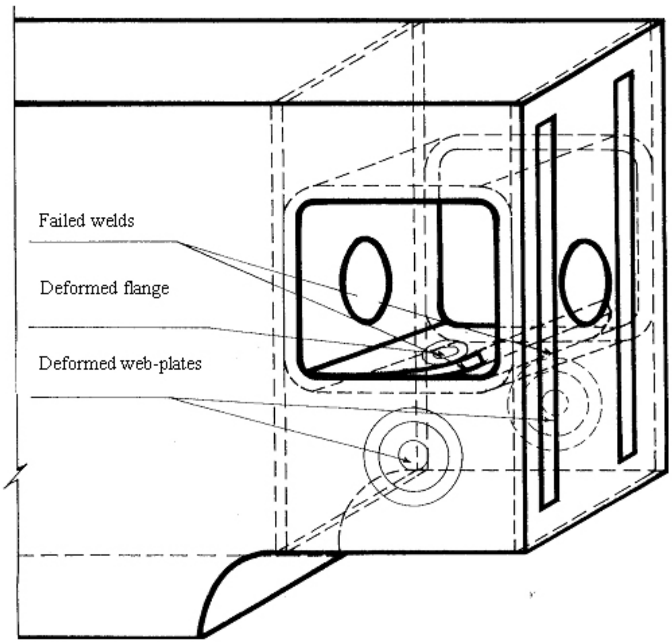

Figure 3: *Damage of main girder, illustrated schematically*

Figure 4: *The damaged places after repair*

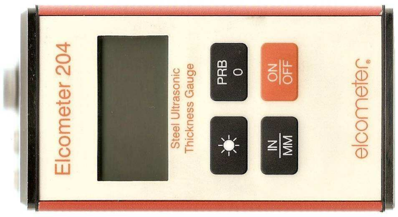

Figure 5: *The ultra-sound thickness-gauge ELCOMETER*

According to the thickness-gauge measurements it is possible to say that there is no relevant reduction of material during last years.

3. Tensometric measuring

On the basis of calculation of steel supporting structure and crane-crab of the foundry crane 250t/63t/12,5t – 26,4 m from the year 1995, together with a new visual inspection, was suggested a method of experimental verification of deformations, as well as verification of stress state. There were applied tensometric sensors in the selected points of the crane supporting structure according to the scheme on the Fig.1 and another measuring point was chosen on the main girder of the crane-crab (Fig.6). This point was only accessible place for the experiment on the crane-crab, because the whole surface of the crane-crab frame was occupied with mechanisms; other surfaces were polluted with graphite and the frame was covered with sheet-metal platforms.

From the Fig.1 is visible application of 8 strain gauge sensors fixed on the crane supporting structure plus one sensor on the crane-crab frame, i.e. together 9 sensors. The photo-documentation on the Fig.7 presents an example of sensor application for measuring of normal stresses in the points 1 ÷ 8.

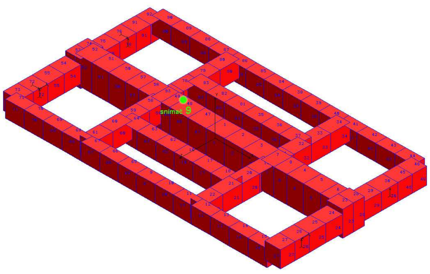

Figure 6: *Sensor on the frame of main*

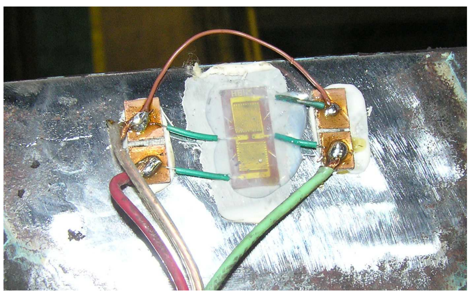

Figure 7: *Example of application of*

hoist crane-crab *sensor for measuring of normal stresses*

4. ExperimentAL determination of dynamic hoisting coefficient

The experimental hoisting coefficient was determined from measuring performed especially for this purpose. The time behaviour of loading of one sensor is on the Fig.8. With regard to the individual time behaviours it is evident that the value of hoisting coefficient doesn't exceed the value 1,2. The calculated hoisting coefficient value according to the standard STN 27 0103 is 1,331 for the main hoisting with lifting speed 5,3 m.min^{-1} and for the auxiliary hoisting it is 1,352.

After increase of lifting speed up to the value 8 m.min^{-1}, the calculated hoisting coefficient will be 1,352 for the main hoisting, thus the real value will be 1,22. Such value is not relevant from the point of view of crane steel structure dynamical properties. There is illustrated on the Fig.9 the time behaviour of stress increments obtained from individual sensors during one of loading regimes.

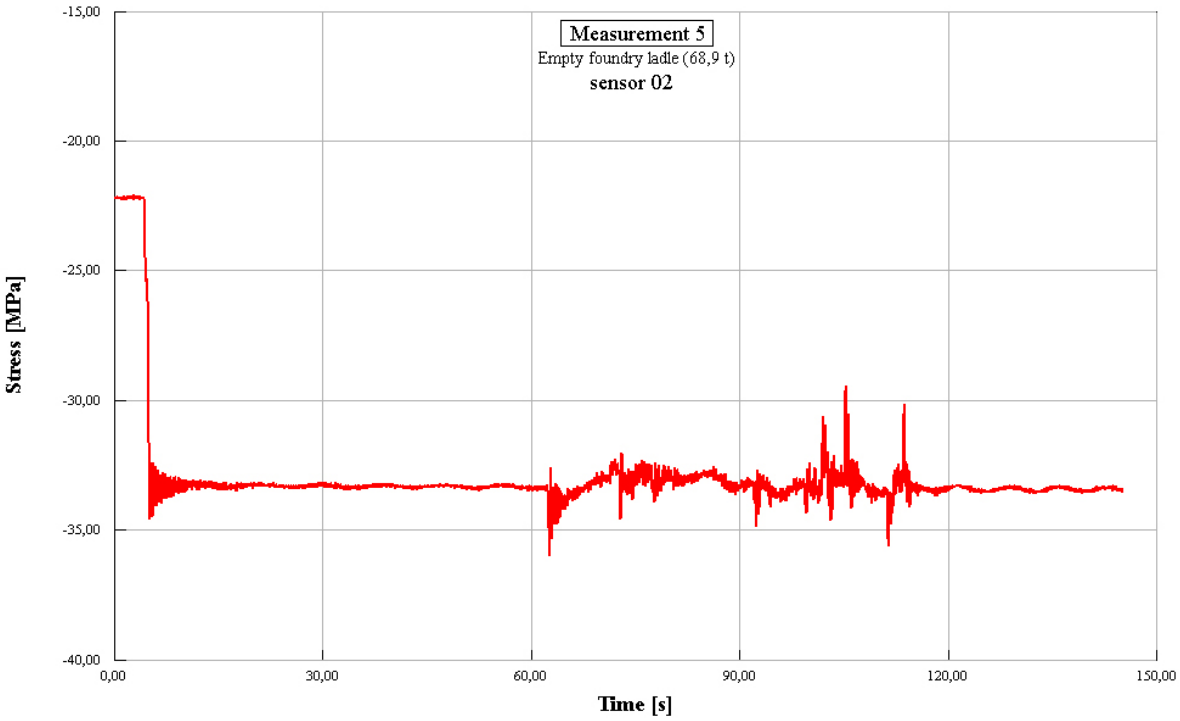

Figure 8: *Time behaviour of loading for determination of dynamic hoisting coefficient*

5. Determination of durability by means of measured results

The foundry crane 250t /63t /12,5t – 26,4 m has been working in current operation for 26 years. Its projected technical durability can reach values from interval 200 000 ÷ 2 000 000 number of cycles during the whole technical life, according to the Tab.3 from the standard STN 27 0103. The foundry crane is categorized into the operational group J5 according to the Annex II of the STN 27 0103, the stress spectrum is S3 and so the number of technical life cycles is N_2 = 200 000 ÷ 600 000.

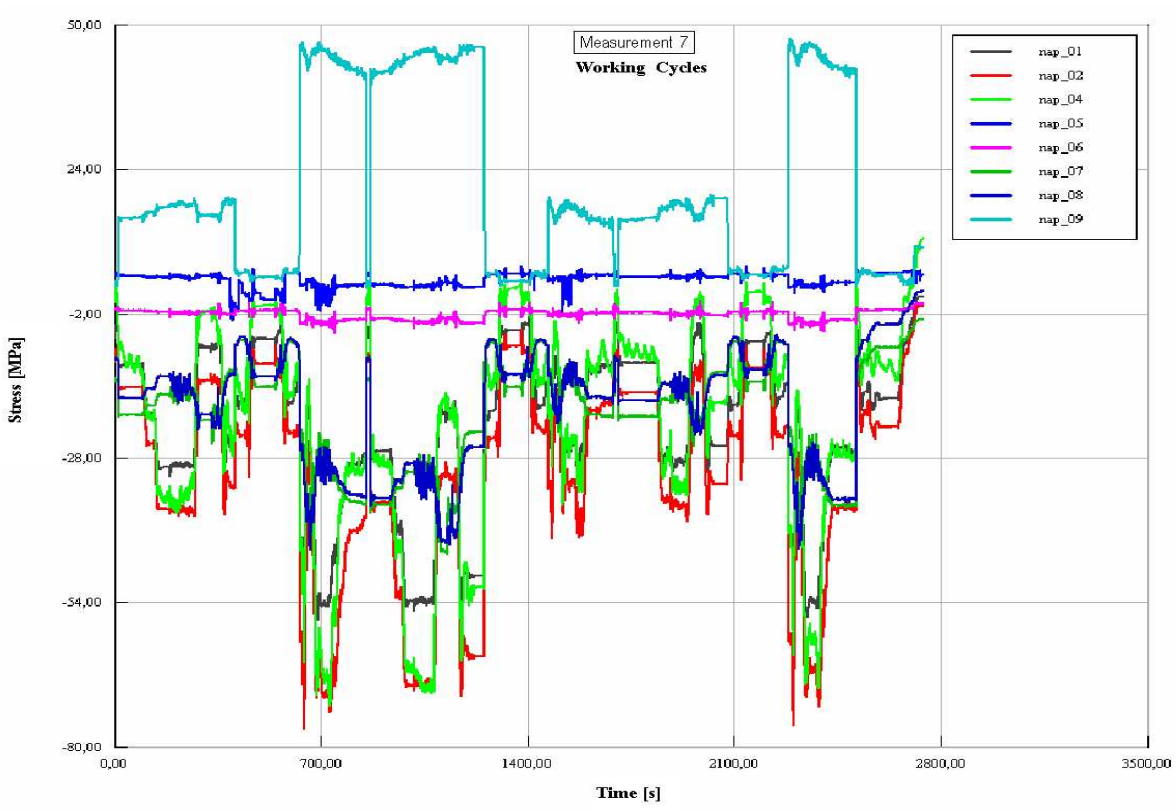

Figure 9: *Time behaviours of relative deformations converted to stress values for measured working cycle.*

According to the information obtained from the user of crane, the daily amount (during 24 hours) of handled hot metal ladles is approx. 45 pieces. During the up to now operational life it presents 350 000 cycles, i.e. 300 days x 45 ladles x 26 years. Taking into consideration this calculation, the crane is near the middle of its technical durability. This hypothesis will be verified by means of experimentally obtained results and by means of methods specified in the standards STN 73 1401 and STN 27 0103.

Calculation of durability from the measured data was performed according to method from the STN 73 1401, Chapter 8.7.1.2, whereas there were applied data from the Fig.26 and from the Tab.28, corresponding to the STN 73 1401.

Examination of construction with regard to fatigue limiting state ensures, with an acceptable probability, that the construction will not be damaged or cracked due to fatigue during the time period of projected durability. After the Chapter 8.7.1.2 from the STN 73 1401, in the case of normal stress loading of construction detail, the fatigue durability can be calculated using curves in Fig.10 and from relation:

if $\Delta\sigma_M \,.\, \varphi > \Delta\sigma \,.\, \gamma_{Ff} \geq \Delta\sigma_D \,.\, \varphi$, then

$$N = 2 \,.\, 10^6 \;[\Delta\sigma_c \varphi \,/\, (\Delta\sigma \,.\, \gamma_{Ff}\;)]^3.$$

Using the “rainflow” method for analysis of main girder loading, the highest amplitude is $\Delta\sigma_{max} = 79$ MPa.

From the above-mentioned equation the value of durability (determined in number of cycles) is $N = 2.10^6\,[106 \,.\, 0,87/\,(79.1)]^3 = 3\,181\,442$ cycles. Amplitudes that are less or equal to the value 106 MPa don’t have an impact to durability for notch-case K3 and operational group J5.

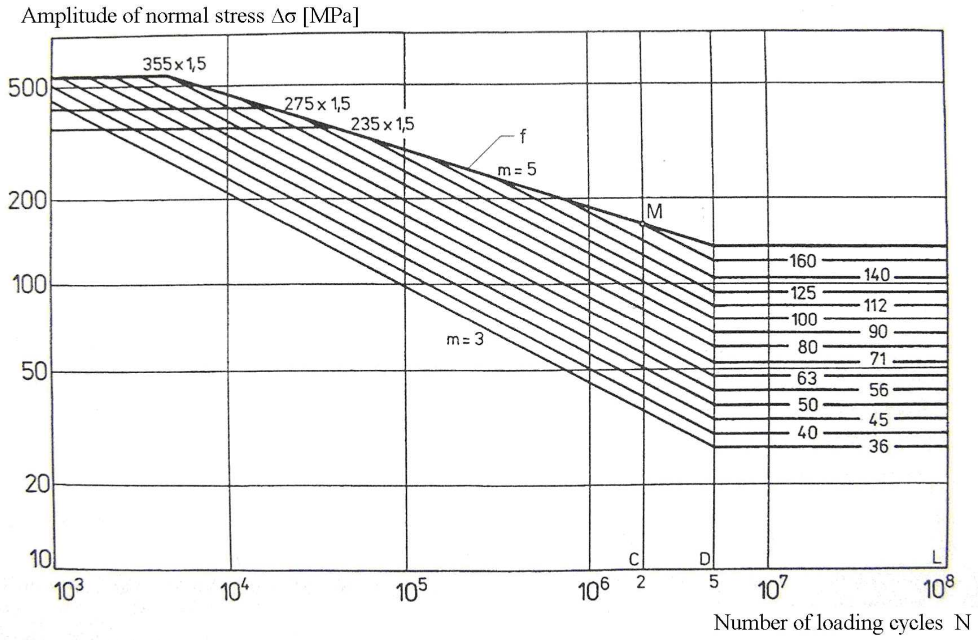

Figure 10: *Dependence between amplitude of normal stress Δσ and number of loading cycles N for various categories of details*

6. Concliusion

The results obtained from tensometric measuring confirm a fact that increments of stresses, together with stresses caused by the own weight as well as from other factors, don't exceed the limit stress values. The measured value of the dynamic hoisting coefficient is less than value given in the related technical standard. Thus, increasing of hoisting speed from the original value 5,3 $m.min^{-1}$ up to the new value 8 $m.min^{-1}$ is possible and the steel construction of the given crane is suitable from the point of view of the strength. The tensometric measuring of stress state in the main girders of crane-bridge, in the balance beam of crane travel and in the main girder of the 250t crane-crab confirm a sufficient reserve of lifting capacity. After the whole process of durability evaluation it is possible to say finally that the present state of crane steel construction is characterized by a sufficient stock of fatigue durability.

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[2] Haibach,E.: Betriebsfestigkeit. VDI-Verlag GmbH, Düsseldorf, 1989.
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[4] STN 27 0103 Navrhovaní ocelových konstrukcí jeřábů. Výpočet podle mezních stavů