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Residual Lifetime of Lifting Instalation Established by Non-Destructive Methods

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Abstract

The paper present theoretical studies and practical determinations in machines operating in dynamic mode fatigue. After expiry of the normalized lifetime of lifting equipment (overhead cranes, cranes, etc.). arises determination of residual functioning so that under normal safety to function at a normal operating capacity or diminished but not more than 15-20%. For exemplification is considered the investigation of a high gantry crane, MPT 20/5 – 20/4/4 m. In conclusion, after our determinations, the machine can operate with kinematics parameters set initially, but with reduced nominal load of 133 kN, i.e. approx. 13 t, and the lifetime of approx. 7.5 years

Keywords: fluctuating stress, deformation, crane, bearing structure, fatigue

JEL: A19, Q40

1. Introduction

As defined in ASTM E 1150-93, fatigue is "the process of structural permanent change, localized and gradual, occurring in a material subjected to conditions that produce fluctuating stresses and deformations specific to one or more points, which may culminate in cracks or complete break after a sufficient number of fluctuations".

Two phases are crucial for determining the remaining duration of life on some machines operating in dynamic mode (Verschoof, 1999; Lu & Mäkeläinen, 2003; Nakasone, Yoshimoto & Stolarski, 2006):

a. Technical inspection phases: visual inspection, non-destructive control (PL, US)

b. Expertise phases: static and dynamic calculations, and remaining duration of life.

After expiry of the normalized lifetime of lifting equipment (overhead cranes, cranes, etc.). arises determination of residual functioning so that under normal safety to function at a normal operating capacity or diminished but not more than 15-20%.

2. Technical inspection/examination

Necessity and opportunity of this procedure is in accordance with HG 2139/30.11.2004, regarding the classification and the useful life of equipment and in accordance with L64/21.03.2008 regarding the safe operation of pressure vessels, installations and high fuel consuming equipment.

For exemplification is considered the investigation of a high gantry crane, MPT 20/5 – 20/4/4 m, with the following characteristics:

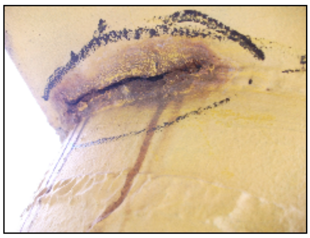
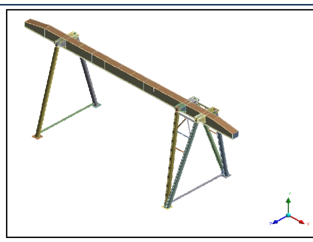
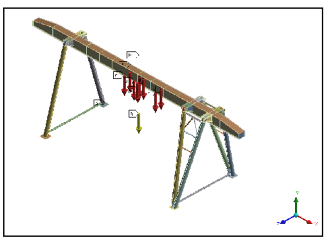
MPT - gantry crane type 20/5 - hook load: main mechanism rated load = 20 t; rated load auxiliary mechanism = 5 t

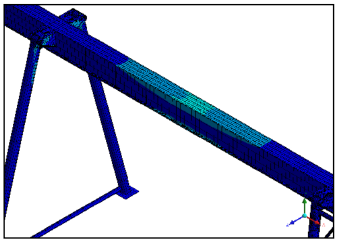
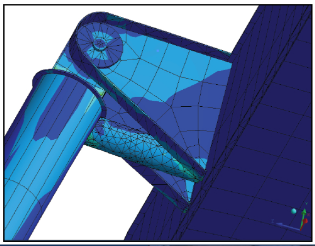
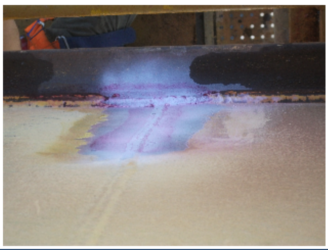
The crane has an effective workduration of 19 years and it’s wanted to establish remaining duration of life in full security and working conditions.


Figure 1. MPT 20/5 gantry crane

Investigation works / technical examinations will be held as follows:

Table 1. Steps for investigation/technical examination

A. Equipment inspection - which consists of a visual inspection of the entire load bearing structure, on parts, fig. A1,2,3,4, visual inspection (VT), check load cables.	A.1  A.2  A.3.  A.4. 
B. Static / dynamic analysis by FEM of strong stressed areas [7], and determining areas for non-destructive testing (PL, US), where: 2.1 Establishing input parameters: B.1. - calculation model (fig.) B.2. - forces acting on the structure (fig.)	 B.1. B.2. 

2.2 Analysis of results B.3. - The most stressed zone, the central one (fig.) B.4. - the most stressed zone between the crane foot and clamping beam; the correlation between the calculation model and the real cracks (fig.)	B.3.  B.4. 
C. Non-destructive investigation /examination of previously established areas, fig. C.1. - US control of welding of main carriage taxiways, fig. C.2. - PL control of the main beam welding area/ running trolley	C.1.  C.2. 
D. Calculation to estimate the remaining duration of life [5], [6]	Loads used to verify the fatigue may be determined according to EN 13001, SR CENT_TS 13001-3-1, SR EN 13001-2 + A3, EN 1993-1-9-2006 (see paragraph 3).
E. Technical Report writing. Conclusions.	

3. Methods for fatigue calculation

When applying the procedure for calculating the approximative residual lifetime, two distinc cases may occur:

I. There exists complete documentation for developing the calculation model, then it can be applied as calculation maner:

Fininte element method or analytical method:

- for welded constructions – establishing welding details;
- for mechanisms or elements in mimevement: shafts, bolts etc. – safety coeficients method;

II. Complete documentation for developing the calculation method does not exist – electroresistive tensimetry analysis method.

There are currently three different methodologies for calculating fatigue, which correspond to three "theories" distinct approach (Fisher, Kulak & Smith, 1998; Lee, 2005; Lu & Mäkeläinen, 2003).

a. Method σ - N

Method based on stress analysis is used to calculate the unlimited durability. Primary experimental data are presented as diagrams of sustainability in coordinates "maximum stress - number of cycles to failure" (Wöhler curve). Failure is defined by the total separation of the two parts of the specimen tested.

b. Method ε − N

The method is based on the analysis of specific strains used for calculating the limited durability. It is applicable to the parts without initial cracks, stressed under elastic-plastic regime, usually made of forged steel or materials without defects. Primary experimental data are in the form of charts of little sustainability in coordinates "cyclic strain - number of cycles to failure" (Coffin-Manson curve), caused by constant amplitude tests on specimens axially tested. Failure is defined differently by the appearance of visible cracks, by sudden variations in the load or dynamic stiffness of the specimen, which define what is considered to be the period of "initiation" of fatigue cracks.

c. Fault Tolerance Method

The method is based on the analysis of crack propagation for parts with initial cracks (usually welded or riveted structures). In this case, the stress singularity at the crack tip requires the use of fracture mechanics sizes.

Primary experimental data are in the form of charts "crack propagation speed - variation of intensity of stress" drawn in logarithmic coordinates (Fisher, Kulak & Smith, 1998; Lee, 2005). Method permits calculating of length of a crack extending from an original size, detected by non-destructive methods, to a final dimension, comprising a safety factor to a critical value (Enachescu & Rosca, 2014; Dumitru, Budică & Motoi, 2015). Method involves regular inspection and acceptance of the existence of the initial crack. In practice, the application of variable amplitude solicitation decomposes into blocks of solicitation, repeated over time, each block consisting of several groups of constant amplitude stress. In Figure 2. is considered a block composed of 3 groups of sinusoidal stress of different levels (amplitudes).

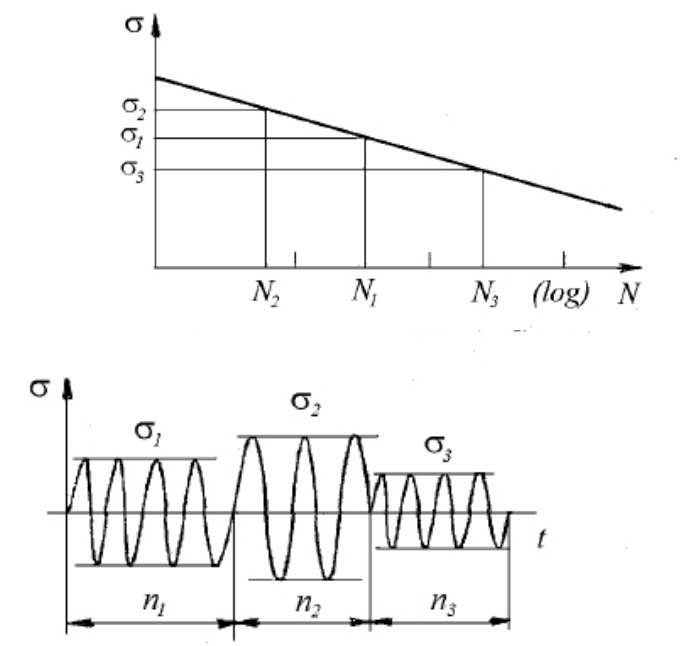


Figure 2. Block of solicitation

If $\overline{n}_i$ is the number of cycles for wich correspond the N_i durability, then each group of stress produce the damage $D_i = \overline{n}_i / N_i$, and the damage caused by the three groups of distinct sinusoidal block is:

$$D = n_1/N_1 + n_2/N_2 + n_3/N_3 = \sum (n_i/N_i) \leq 1 \quad (1)$$

4. Conclusions

By following the steps described in first part of the paper, based on metal fatigue theory and practice, one can perform a full study of an equipment (here the lifting crane MPT 20/5).

Therefore, it is stated that following presented methodology it can be done the estimation of remaining duration of life of studied equipment, according to recommendation of STAS 11694-83 and SR EN ISO 13920.

The machine can operate with kinematics parameters set initially, but with reduced nominal load of 133 kN, i.e. approx. 13 t, and the lifetime of approx. 7.5 years.

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