CALCULATION OF RESIDUAL USAGE PERIOD OF BUILDING CRANE STEEL STRUCTURE

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ABSTRACT: The suitable management of residual usage period for building cranes is impossible without fatigue failure analysis and fatigue assessment of their steel structures. The present paper presents a methodology for calculation of residual usage period of building crane steel structures. The proposed method includes determination of weak points of crane steel structure, working cycle analysis, stress history analysis and calculation of the real stress history parameter for a selected weak point (element), on the basis of which is calculated residual usage period for building crane according to the new European standard EN 13001.

KEY WORDS: Building crane, residual usage period, steel structure

INTRODUCTION

Material handling machines used for construction works appear as durable assets of construction enterprises. They cost a lot of upkeep and expenses for their owners. In view of that there is a solid aspiration for ensuring maximal usage period of these material handling machines. At the same time the owners of construction enterprises have to observe the safety requirements of normative documents and keep the material handling machines and their steel structures in serviceability and operating state.

Cranes used for construction works (building cranes) represent one of the most important groups of material handling machines. By building cranes the main restriction for prolongation of their usage period is the limited fatigue strength of construction and the failure due to fatigue loadings in material. It is well-known that the severest accidents with building cranes appear as a result of fatigue failures. For example by tower cranes one of the most important causes for fatigue failure accidents is the zone of the welding connection between tower and slewing ring.

In view of that the suitable management of residual usage period for building cranes is impossible without fatigue failure analysis and fatigue assessment of their steel structures.

Figure 1. Welding connection between tower and slewing ring of tower crane

The aim of the present study is to propose a uniform approach for determining residual usage period of building crane steel structure.

CLASSES-S FOR BUILDING CRANES STEEL STRUCTURES ACCORDING TO THE STANDARD EN 13001

The assessment of residual usage period for cranes depends on the operating conditions of a crane and the quality of technical maintenance and repair works. According to the new European standard BDS EN 13001-1:2005[1] the operating conditions of crane include the following:

- the total number of working cycles performed by crane to date;
- the masses of lifted loads with crane and relative frequency of their appearance;
- the average distances covered by crane mechanism to date;
- the average number of accelerating motions per mechanism action.

It is well-known that at the design stage of crane is determined the operating duty of crane steel structure. In the new European standard series EN 13001 the operating duty is represented by classes-S for crane steel structure. They depend on the value of stress history parameter - s and the slope of the σ / N curve - m.

The new European standard series EN 13001 provides a suitable opportunity for determining of crane operating duty and S-classes. In dependence on the stress history parameter s in case of σ / N curve slope m=3 the values of the classified S-classes according to BDS EN 13001-3-1:2012 [2] are shown in table 1:

Table 1. Classes-S for building cranes steel structures according to standard BDS EN 13001-3-1:2012

Class	Stress history parameter
S02	$0{,}001<s_3\leq 0{,}002$
S01	$0{,}002<s_3\leq 0{,}004$
S0	$0{,}004<s_3\leq 0{,}008$
S1	$0{,}008<s_3\leq 0{,}016$
S2	$0{,}016<s_3\leq 0{,}032$
S3	$0{,}032<s_3\leq 0{,}063$
S4	$0{,}063<s_3\leq 0{,}125$
S5	$0{,}125<s_3\leq 0{,}250$
S6	$0{,}250<s_3\leq 0{,}500$
S7	$0{,}500<s_3\leq 1{,}000$
S8	$1{,}000<s_3\leq 2{,}000$
S9	$2{,}000<s_3\leq 4{,}000$

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Working cycle analysis

For residual usage period calculation it is necessary to provide correct input data for total number of working cycles, masses of lifted loads, relative frequency of load masses appearance, average covered distances and average number of accelerating motions. In view of that it is performed a working cycle analysis. For example a typical working cycle by tower cranes includes the following motions shown in fig.2:

- jib slewing and its positioning in the zone of target load;
- trolley movement and its positioning above the target load;
- lowering of load lifting attachment down to the target load and fixing of load;
- lifting of load up to the required height;
- jib slewing and its positioning in the mounting works zone;
- trolley movement and positioning of load above the assembly for mounting;
- lowering of load down to the assembly and its mounting;
- lifting of load lifting attachment up to its initial position.

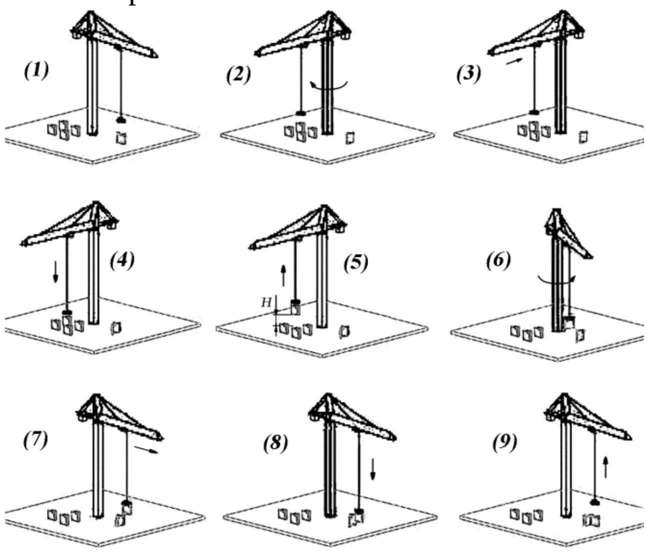

Figure 1. Typical structure of working cycle by tower crane

Stress history analysis

The next step is to perform a stress history analysis in a selected element (weak point) of crane steel structure (for example see fig.1).

The necessary input loadings for calculations and their dynamic factors are determined according to standard BDS EN 13001-2 [3]. It is recommended to use the severest (maximal) values of dynamic factors and loadings. The stress state of crane steel structure and stress history in selected element (point) for a working cycle of crane is obtained by performing loading and stress analysis. An example for stress history in crane element obtained in one working cycle of crane is shown on fig.3.

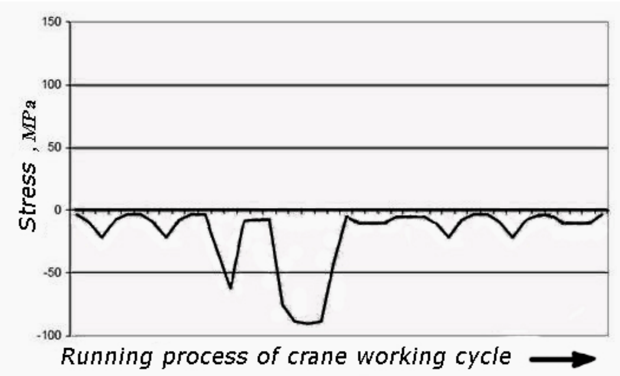

Figure 2. Typical stress history in a crane element

The next step is to classify the stresses from obtained stress history into groups of stress ranges-$\Delta\sigma_i$ (or $\Delta\tau_i$) (i=1..n). Typical methods for performing of this classification into groups of stress ranges-$\Delta\sigma_i$ and stress ranges counting- n_i are: reservoir-method; rainflow-method, etc.

Calculation of total number of executed working cycles N

On the basis of $\Delta\sigma_i$ and n_i is calculated the stress spectrum factor - $k\sigma$ for analyzed working period Δt_N by using the following equation:

$$k\sigma = \frac{1}{\sum n_i} . \sum_{i=1} \left(\frac{\Delta\sigma_i}{\max \Delta\sigma} \right)^3 .n_i \qquad \textbf{(1)}$$

The number of loading cycles-ΔN executed for analyzed working period-Δt_N also must be calculated:

$$\Delta N = \sum n_i \qquad \textbf{(2)}$$

The total number of executed working cycles N is calculated by the equation:

$$N = t_N.C_y.k_D \qquad \textbf{(3)}$$

Where:

t_N - total number of years for crane operation to date;

C_y – number of days for crane working in one year;

k_D – number of loading cycles executed for one day, which is calculated on the basis of number of loading cycles-ΔN for analyzed working period-Δt_N ;

Calculation of the real stress history parameter and the residual usage period for building crane

The real stress history parameter $s_D(m=3)$ is calculated by the equation:

$$s_D(m=3) = k\sigma.v = k\sigma.\frac{N}{N_C} \qquad \textbf{(4)}$$

N_C - reference number of stress range cycles. For crane steel structures $N_C = 2*10^6$ according to [4].

After that is calculated the residual stress cycles:

$$N_O(m) = \frac{(s_T(m) - s_D(m))}{k\sigma}.N_C \qquad \textbf{(5)}$$

, where $s_T(m)$ is the theoretical stress history parameter of crane in accordance to schedule date of manufacturer;

The residual usage period in years for building crane:

$$t_O = \frac{N_O(m)}{C_y * k_D}, [years] \qquad \textbf{(6)}$$

CONCLUSIONS

The suitable management of residual usage period for building cranes is impossible without fatigue failure analysis and fatigue assessment of their steel structures. The present paper presents a methodology for calculation of residual usage period of building crane steel structure. The proposed method includes determination of weak points of crane steel structure, working cycle analysis, stress history analysis and calculation of the real stress history parameter for a selected weak point (element), on the basis of which is calculated residual usage period for building crane according to new European standard EN 13001.

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