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DIRECTIONS FOR LOAD AND SAFETY APPRECIATION OF CARRYING STRUCTURES COMPONENT ELEMENTS

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Abstract: *This paper presents the directions for load and safety appreciation of carrying structures component elements and their application to a particular object respectively carrying structure of rotating excavator working wheel. Load and safety of the carrying structure and its component elements are estimated based on the calculation of load and safety factors. The estimated load is based on the calculated value of load factors, while the safety by comparison of the calculated safety factors to the values of recommended minimum safety factors obtained by examinations of such structures in practice. With these indicators we have a situation where we are providing the static strength control of the analyzed elements. The paper presents numerical values of the load and safety coefficients for the excavator SRs-630 working in the coalmine "Suvodol" Bitola, for all characteristic working regimes in its exploitation lifetime. The numerical values of load and safety coefficients relate to clamps of the working wheel carrying structure and the most loaded joint of this structure.*

Keywords: *LOAD COEFFICIENT; SAFETY COEFFICIENT; CARRYING STRUCTURE; CLAMPS; ROTATING EXCAVATOR.*

1. Introduction

Load and safety appreciation of the component elements for a steel carrying structure is necessary to analyze the derived results of the examination of its stress-deformed shape. For this purpose, we are evaluating the stress shape of the separate element on the structure and the stress shape for the whole carrying structure.

From the computer attained images for local stress shape on the structure's element, which is subject of interest, we are performing a reading of stress values and perceived its layout in the metal structure of the element. For uniform stresses, the assessment of the stress shape of the element is made on the basis of the reported values of stresses from these images, while for complex stresses the assessment of stress shape is performed on the basis of the equivalent stress that takes into account the normal and tangential stresses and which is calculated by the famous phrase:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \tag{1}$$

To evaluate the load of the element we are using the *load coefficient* k_{oi}, which is calculated by the following equation:

$$k_{oi} = \frac{\sigma_{e\max i}}{\overline{\sigma}_{ei}} \tag{2}$$

where is:

σ_{emaxi} - maximum equivalent stress for the element i of the carrying structure for a particular load regime

$\overline{\sigma}_{ei}$ - medium stress for the element i

$$\overline{\sigma}_{ei} = \frac{1}{2}\left(\sigma_{e\max i} + \sigma_{e\min i}\right) \tag{3}$$

The load of the lattice carrying structure with n structural elements, overall for a load regime (working regime) is evaluated based on *the average load coefficient* $\overline{k}_o$ of the construction, which is calculated regarding the following equation:

$$\overline{k}_o = \frac{1}{n}\sum_{i=1}^{n} k_{oi} \tag{4}$$

Analog indicators may be performed, and the load of separate elements could be done with a different load regimes. In this case we are calculating *the medim load coefficient* k_{oi}^{max} of the element i for m load conditions, according to the following equation:

$$k_{oi}^{\max} = \frac{1}{m}\sum_{j=i}^{m} k_{oj} \tag{5}$$

where is:

k_{oj} - load coefficient of the element i in the j-th load regime

The control of the static strength for the structural element i of the carrying structure is implemented by comparing safety *coefficient* n_σ to minimum safety coefficient n_{min}, by the equation:

$$n_{\sigma i} = \frac{\sigma_{dozi}}{\sigma_{e\max i}} \geq n_{\min} \tag{6}$$

where is:

σ_{dozi} - permissible stress for the material of the structural element

The medium safety coefficient $n_{\sigma i}^{max}$ of the element i for m load conditions, is calculated by the following equation:

$$n_{\sigma i}^{\max} = \frac{1}{m}\sum_{j=1}^{m} n_{\sigma j} \tag{7}$$

2. Aspects in load and safety appreciation for specific real object

The above theoretical listed directions for load and safety appreciation of the component elements of carrying structures in this paper are applied to a carrying structure of rotating excavator, particularly to the working wheel carrying structure of the rotating excavator SRs-630 (Figure 1) and working conditions in the coalmine "Suvodol" which is placed in Bitola, R. Macedonia. This carrying structure is with lattice constructive design in console type, which supports two clamps bearing in the upper structure of the excavator. The geometric model of this carrying structure is shown in Figure 2.

Determining the general stresses of carrying structure of the rotating excavator and its clamps, the same one it's possible with their appropriate modeling and using the methods for matrix analysis of structures, which gives indicators of global stress shape. The local stresses as a characteristic of separate areas of the structure cannot be identified in this review of the carrying structure in this model of an overview. For determination of the local stresses, it is necessary to isolate parts of the structure that are the main overview of interest as stress shape and to consider them as separate spatial structural elements. In this case with application finite element method (FEA method) which is most appropriate for this purpose and suitable computer program are modeled the structural elements with spatial finite element in idealized form with a sufficient extent of closeness to the real element.

Fig. 1: *View of the rotating excavator SRs-630, the working wheel carrying structure being marked with red pointer.*

For load and safety appreciation of the component element of carrying structure and the structure as a whole, it is necessary to conduct an analysis of its global and local stress-deformed shape repeatedly, or for different loads of the structure that would take into account all different working regimes of the excavator. We are making a conclusion for load and safety of the carrying structure as a whole, on the evaluation of these parameters for its most loaded joint that is with riveted design (shown in Figure 1), and located in conducted a global analysis of state-deformed shape for this construction.

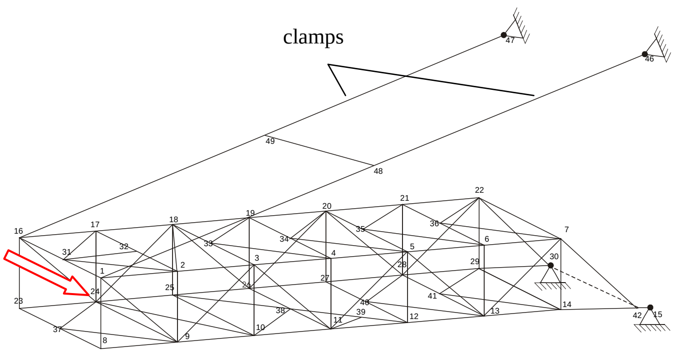

Fig. 2: *Geometric model of the clamps and carrying structure with the layout of all the joints with the most loaded joint marked by red pointer.*

The static strength of these structures is analyzed for dynamic loads which are totally credible and practically possible given the work of the excavator, but provided that they are maximized and constant.

For the excavator SRs-630 characteristic working regimes for mentioned coalmine are:

Regime I - Horizontal position (of the working wheel carrying structure) and turning left;
Regime II - Horizontal position (of the working wheel carrying structure) and turning right;
Regime III - Uppermost position (of the working wheel carrying structure) and turning left;
Regime IV - Uppermost position (of the working wheel carrying structure) and turning right;
Regime V - Nethermost position (of the working wheel carrying structure) and turning left;
Regime VI - Nethermost position (of the working wheel carrying structure) and turning right.

3. Load and safety appreciation

Load coefficients for the clamps and carrying structure

The load coefficient k_{oi} and medium stress $\bar{\sigma}_{ei}$ for both clams on the carrying structure of rotating excavator SRs-630 for specified characteristic on working regimes of the excavator, which was examined their stress-deformed shape, are calculated by the aforementioned equations and given in Table 1.

Table 1: *Medium stress and load coefficient for the clamps.*

Load regime	Medium stress $\bar{\sigma}_{ei}$ [kN/cm^2]		Load coefficient k_{oi}	
	right clamp	left clamp	right clamp	left clamp
I	5.55	5.04	1.99	1.98
II	5.55	5.04	1.99	1.98
III	5.54	5.05	1.99	1.98
IV	5.55	5.05	1.99	1.98
V	5.54	5.05	1.99	1.98
VI	5.55	5.05	1.99	1.98

The load coefficient k_{oi} and medium stress $\bar{\sigma}_{ei}$ for most loaded joint of the carrying structure of rotating excavator SRs-630, or joint 24, for all six working regimes of the excavator that was examined its stress-deformed shape are given in Table 2.

Table 2: *Medium stress and load coefficient for the most loaded joint.*

Load regime	Medium stress $\bar{\sigma}_{ei}$ [kN/cm^2]	Load coefficient k_{oi}
	most loaded joint	most loaded joint
I	5.00	2.00
II	5.00	2.00
III	6.00	2.00
IV	6.00	2.00
V	5.50	2.00
VI	5.50	2.00

The medium load coefficient k_{oi}^{max} for the clamps and working wheel carrying structure of the excavator for all regimes are provided in Table 3.

Table 3: *Medium load coefficient.*

Load regime	Medium load coefficient k_{oi}^{max}		
	right clamp	left clamp	most loaded joint
I - VI	1.99	1.98	2.00

Safety coefficients for the clamps and carrying structure

The safety coefficient $n_{\sigma i}$ for clamps and working wheel carrying structure of the excavator SRs-630 for the characteristic regimes of the excavator that was studied their stress-deformed shape is calculated by the aforementioned equations and presented in Table 4.

Table 4: *Safety coefficient.*

Load regime	Safety coefficient $n_{\sigma i}$		
	right clamp	left clamp	most loaded joint
I	2.52	2.77	1.84
II	2.52	2.77	1.84
III	2.52	2.77	1.53
IV	2.52	2.77	1.53
V	2.52	2.77	1.67
VI	2.52	2.77	1.67

Empirical data for the excavators indicates that working wheels are carrying structure on the minimum bases with a coefficient with a value n_{min}=1.3.

The yield strength of material for the clamps and II case of loading is σ_T=36 kN/cm^2, and the permissible tension stress has a value σ_T=36 kN/cm^2

The yield strength of material for the joint 24 and II case of loading is σ_T=24 kN/cm^2, and the permissible tension stress has a value σ_{doz}=18.4 kN/cm$^{2.}$

Medium safety coefficient $n_{\sigma i}^{max}$ for the clamps and working wheel carrying structure of the excavator for the six working regimes is given in Table 5.

Table 5: *Medium safety coefficient.*

Load regime	Medium safety coefficient $n_{\sigma i}^{max}$		
	right clamp	left clamp	most loaded joint
I - VI	2.52	2.77	1.68

4. Conclusion

The paper provides directions for the load and safety appreciation for the component element of the carrying structures and displays their application at specific real object. The paper presents load and safety data for the working wheel carrying structure and its clamps for the excavator SRs-630, and also presents the working conditions of the same one into the coalmine "Suvodol" Bitola, R. Macedonia. These parameters presented into the paper enable verification of the static strength of the carrying structure and its clamps.

For the specific excavator the load coefficient k_{oi} for the right clamp is 1.99 and for left clamp is 1.98 and for all working regimes, and therefore the medium load safety coefficient k_{oi}^{max} for the clamps has the same value. For most loaded joint of the carrying structure value of this coefficient is 2.00.

The safety coefficient $n_{\sigma i}$ for the left clamps is bigger than the safety coefficient for the right clamp, for all listed working regimes. For the right clamp the medium safety coefficient $n_{\sigma i}^{max}$ has a value of 2.52 while for left clamp is 2.77. The safety coefficient $n_{\sigma i}$ for most loaded joint for all regimes is lower than the safety coefficients for the clamps. For this joint the medium safety coefficient has a value of 1.68.

The values of the load coefficients for the clamps and most loaded joint of the carrying structure are within the values for these ratios derived from examinations of similar rotating excavators working in the approximate working conditions.

The values of the safety coefficients for the clamps and most loaded joint of the carrying structure and towards it and for all of its joints are bigger than the minimum safety coefficient n_{min} =1.3 for carrying structures, derived from previous researches on rotating excavator in the world frames.

The derived results for the safety coefficient magnitudes in this paper can be generalized to clamps and carrying structures of other rotating excavator with a similar geometry and comparable working conditions.

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