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Peculiarities of Designing Metal Constructions of Bridge Loading Cranes

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Abstract: Full-scale studies of the actual loads on the superstructures of ore-bridge loading cranes have been conducted. The combination of load histograms with lines of influence made it possible to obtain spectrograms of changes in internal force factors for bars of grate and travelling beams of ore bridge loading cranes with A7-A8 operating modes.

In modern production hoisting machines, especially unique ones, for example, ore loading cranes are the main equipment and as such, which provides quite a considerable part of income of the enterprise. Considering that the most expensive part of such a crane is its metal structure, which also has the longest service life, it is important to guarantee the passport performance, safety of the device and the operation of these cranes for the longest possible lifetime. Experience shows that working life of metal structures of hoisting cranes depends on many factors, among which the most important is the accuracy (precision) of design.

The transition to more accurate design calculations of metal structures requires obtaining reliable information about the actual load capacity and the actual conditions of future operation of a new crane. In addition, an inaccurate estimate of the load capacity of a metal structure may lead to a mismatch of the designed crane structure to actual operating conditions, as well as to incorrect prediction of the crane's residual life. This, in turn, may with time lead to significant premature destruction and accidents. Increasing the accuracy (precision) of the design will ensure a clear conformity of the newly created metal structure to the actual operating conditions.

In order to study the actual load capacity of metal structures of hoisting cranes, a full-scale experiment was conducted on the example of bridge loading cranes (ore-gantry cranes − PKK) of Zaporizhstal plant used at the blast-furnace ore yard. The following cranes were looked into:

PKK-3, PKK-4 – grate bridge loading cranes (Fig. 1, a);

PKK-5, PKK-6 – box girder bridge loading cranes (Fig. 2, a).

All of these cranes are classified as the basic equipment of the enterprise with A7-A8 operating mode, their technical characteristics are listed in table 1.

Table 1 – Technical characteristics of bridge loading cranes

Factors	Values	
	РКК-3, 4	РКК-5, 6
Width, m	76.35 82.35	76.35
Length of flexible console, m	21.0 46	23.75 47.5
Length of rigid console, m	25.0	23.75
Load capacity (with a clamshell), t	30	32
Efficiency, t/hour	400	700
Lifting speed, m/sec	1.08	1.33
Lowering speed, m/sec	1.5	1.5
Trolley travel speed, m/sec	3.46	3.33
Bridge travel speed, m/sec	0.5	0.5
Clamshell capacity, m^3	5.6	5.6
Clamshell lift height, m	25.0	35.0

In order to form histograms of loads on metal structures of bridge loading cranes' superstructures, photographs of the actual superstructure loading of each were taken in the ore yard for a month.

In the full-scale experiment, the following parameters were constantly fixed: the state of the clamshell (loaded, empty); the beginning, end and direction of trolley movement; the type of movable load. The starting and ending positions of the trolley were visually fixed at each movement relative to the meter marks placed along the superstructures, which provided a practical convenience and sufficient accuracy of measurements at the total length of the structures of 122.35 m and 123.85 m.

The statistical sampling of the experimental data was quite representative. After examining the results of the experiment, typical technological cycles for each test crane have been determined:

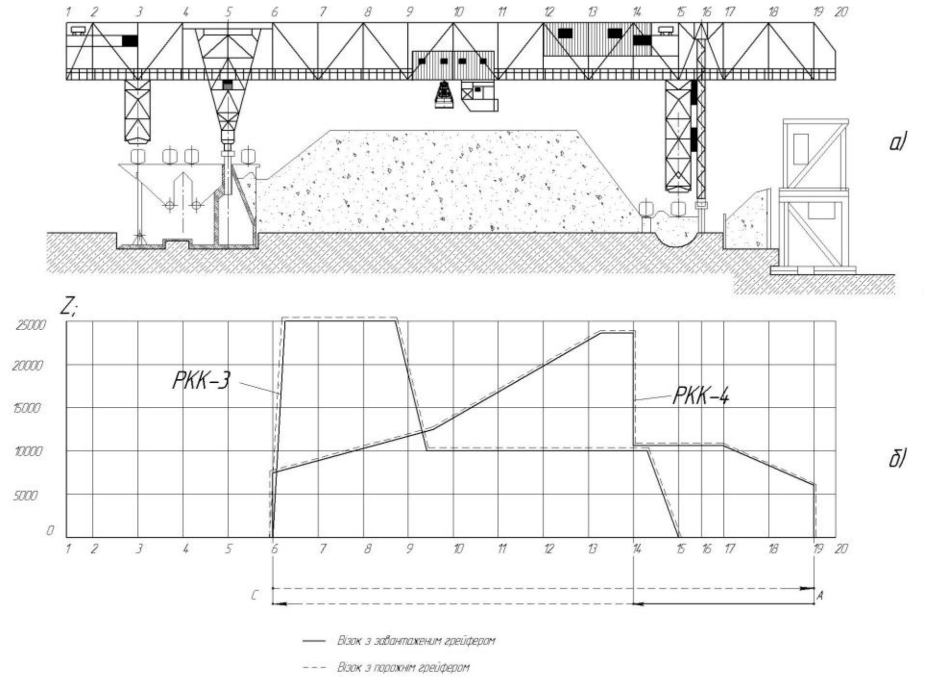
РКК-3 – loading of dolomite from the trestle into the intermediate trench, formation of mixed stack of dolomite and limestone;

РКК-4 – loading of limestone from a wagon tipper into the intermediate trench, loading of iron ore pellets from the trestle into a stack and from the stack into skips, formation of a stack of mixture of limestone with a concentrate at a ratio of 1:6, loading of the mixture from the stack into transfer cars;

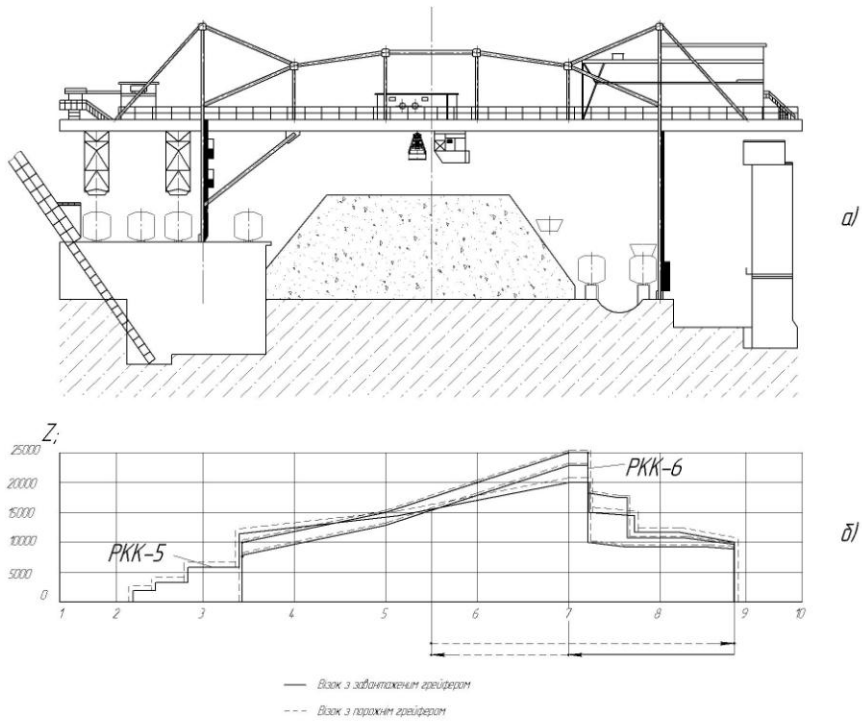
РКК-5 – loading of limestone from a wagon tipper into the intermediate trench, loading of iron ore from a wagon tipper into a stack and from the stack into transfer cars, formation of a stack of mixture of limestone with a concentrate, loading of the formed mixture from the stack into transfer cars;

РКК-6 – loading of limestone from a wagon tipper into the intermediate trench, formation of a stack of mixture of limestone with a concentrate, loading of the mixture from the stack into transfer cars, , loading of iron ore, silicomanganese and coke from a wagon tipper into a corresponding stack and from the stack into hoppers.

The obtained experimental cyclograms of actual loading for grate loading cranes are shown in Fig. 1, б, and for box girder loading cranes – in Fig. 2, б.



a) scheme of loading cranes
б) histograms of cycles
Figure 1 − Histogram of load cycles on metal structures РКК-3 and РКК-4



a) scheme of loading cranes
б) histograms of cycles
Figure 2 − Histogram of load cycles on metal structures РКК-5 and РКК-6

Bridge loading cranes operate outdoors and are most often exposed to the wind from Koksokhim plant, which contains sulphur compounds and other corrosive substances. These compounds, along with precipitation, form acidic solutions that accelerate the corrosion destruction of metal structures.

It is well known that the internal force factors in the elements of metal structures of hoisting cranes depend on the position of the movable load along the superstructure according to the lines of influence.

Lines of influence for mostly loaded bars of grate bridges are shown in Fig. 3, and for Sprengel pulling and travelling beams of box girder bridges, as statically indeterminate structures, − in Fig. 4.

Lines of influence help to determine forces and their marks for bars and travelling beams depending on the position of the trolley on the crane bridge. The frequency of finding the trolley in a given place while performing technological operations by the loading crane is taken into account for every such position in the histogram. Joint examination of the lines of influence and histograms of the actual loading made it possible to obtain spectra of internal force factors in the bridge elements of the ore loading cranes. For example, the spectra of the actual load of the bars of the grate bridge PKK-3 are shown in Fig. 5, and in Sprengel pulling and travelling beams of PKK-5 and PKK-6 − in Fig. 6

Having experimental histograms of the actual loading of the superstructures of specific loading cranes and using the lines of influence for internal force factors for each element of the metal structure, it is possible to make accurate (precise) strength, rigidity and fatigue calculations.

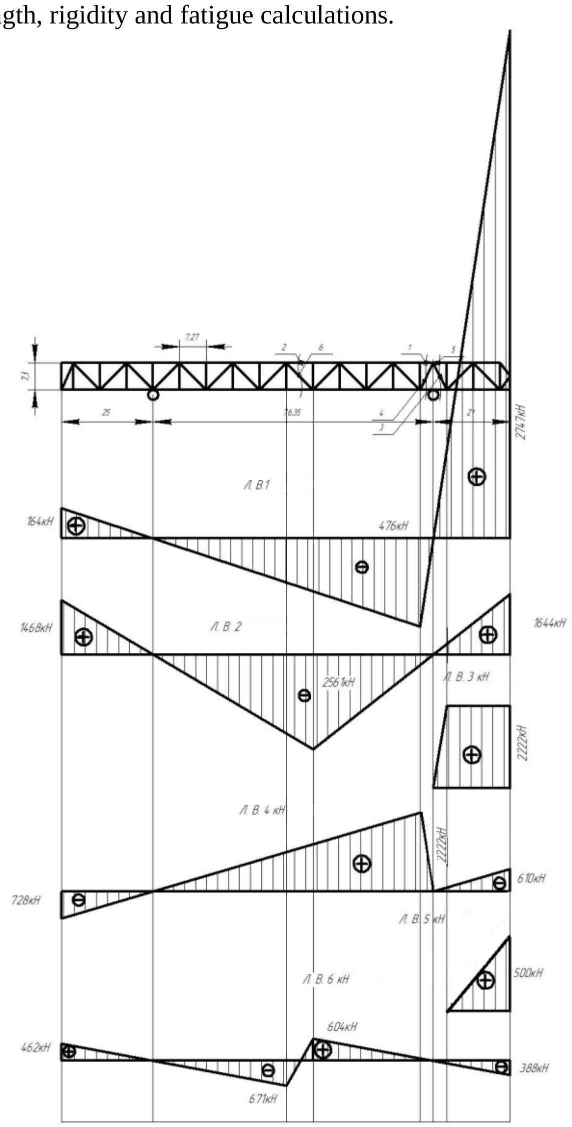


Figure 3 – Lines of influence for PKK-3 and PKK-4

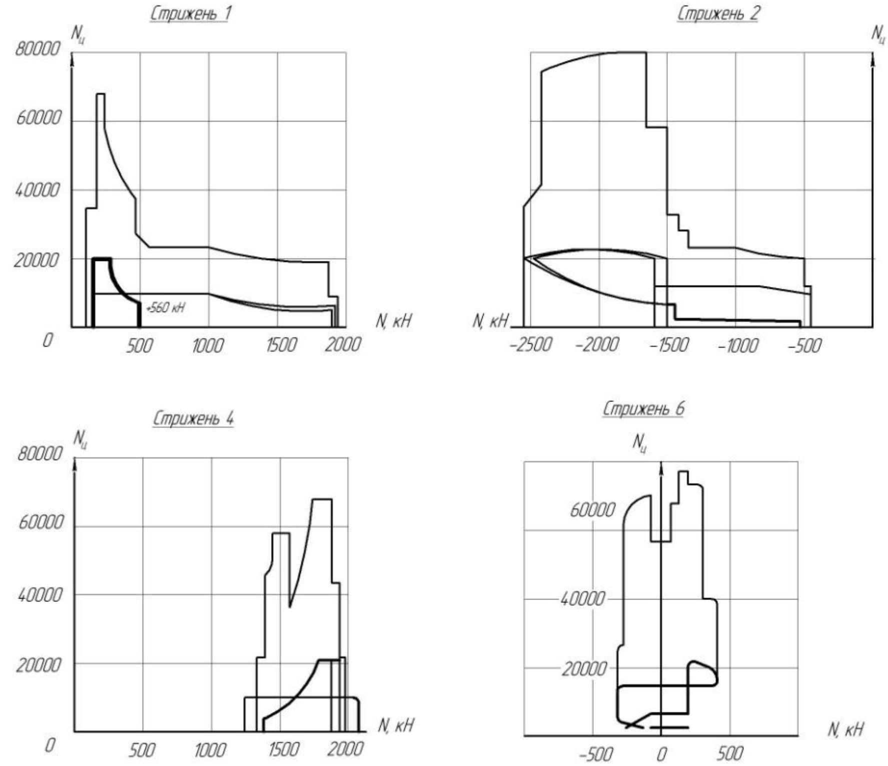


Figure 4 − Spectra of actual forces in rods РКК-3

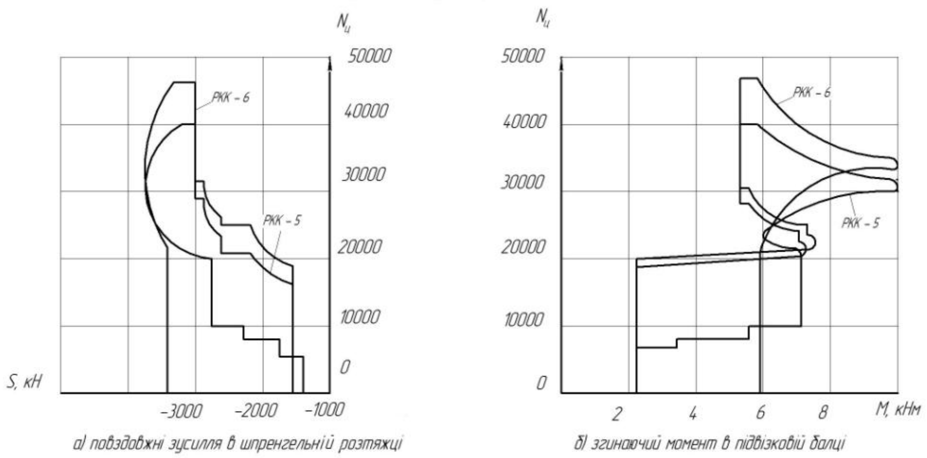


Figure 5 − Spectra of actual internal force factors acting on elements of metal structures РКК-5 and РКК-6

In addition, the available combination of actual histograms and lines of influence makes it possible to determine the operating mode of each section and the metal structure element of each particular loading crane. How justified this conclusion is may be seen from the histograms, which clearly show that some sections of the superstructures are not loaded by a moving loaded trolley. It is also evident that each loading crane performs its technological reloading operations, which determine the configuration of the load histogram typical of this particular crane. For uniform operation of the entire length of the metal structure and its elements, loading cranes should swap places periodically, but it is impossible to do so in reality.

In conclusion, it should be noted that for accurate (precise) design of metal structures of bridge loading cranes, − and ideally of every crane, − it is necessary to specify, as a part of the technical task, the range of loads, the sequence and intensity of their reloading, their territorial placement in the freight yard, description of technological process of reloading and other characteristics of freight flows. For lack of such a possibility, this information should be presented in the form of a mathematical model, which would be quite close to the actual state of loading of metal structures and their real operating conditions. Probabilistic models (Bayes formula, RAIN method, Monte Carlo method, etc.) of loading of metal structures of bridge loading cranes at work in a specific place of the ore yard and under specific operating conditions may be recommended.

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