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REDUCTION OF DYNAMIC LOADS OF THE BRIDGE CRANE DURING BRAKING BY OPTIMIZING THE MECHANICAL CHARACTERISTIC OF THE ELECTRIC DRIVE

One of the most effective ways of smooth, economical and secure braking of lifting cranes is dynamic braking. However, all known advantages of dynamic braking could be realized only by using optimum mechanical performances, in contrast to countercurrent braking (high smoothness of braking, low power losses, stop accuracy of the mechanism without load swinging). The lack of methodologies and recommendations, which might help to choose optimum performances in dynamic braking operating mode, significantly reduces effectiveness and restrains its wide use in travel mechanisms of cranes.

Since optimization of speed-torque characteristic of crane’s travel mechanism only by one criterion improves some indicators and, at the same time, worsens others, then it is necessary to perform the research of optimum speed-torque characteristic by using generalized optimization criterion, which includes: maximum dynamic loads, braking time of crane and amplitude of rocking of cargo. That is to say that, the main target of optimization of mechanical characteristic of bridge crane’s travel mechanism in dynamic braking operating mode, is to find such a characteristic in which the combination of dynamic loads and productivity parameters of crane will be the most acceptable.

Aim of the work: to present methodology and search results for optimum mechanical performance of bridge crane’s travel mechanism, during dynamic braking operating mode.

Search for optimum speed-torque characteristic of crane is performed by the method, which includes such stages as [1]:

1. Selection of factors, which determine speed-torque characteristic. Speed-torque characteristic of asynchronous motor in dynamic braking operating mode might be uniquely set using two factors: maximum motor torque $M_к^*$ and critical slip $s_к^*$. For a travel mechanism of 20 tone bridge crane, which is equipped with a wound rotor induction motor MTF 411-8, definitional domains of factors $M_к^*$ and $s_к^*$ are within $275 \le M_к^* \le 695$ (Hm); $0{,}058 \le s_к^* \le 1{,}350$.

2. The choice of optimization criterion. The process of braking the crane is comprehensively characterized by the following parameters: the maximum rating of dynamic loads on metal construction $P_м^{\max}$, the braking time t_T and the maximum amplitude of load swinging after crane’s stop $A^{\max}$. Harrington’s generalized desirability function has been used as an optimization criterion *D* [2]. In order to construct Harrington’s function, component values of optimization $P_м^{\max}$, t_T, $A^{\max}$ have been changed into dimensionless scale of desirability y^*, which allows to determine particular functions of desirability d_1, d_2, d_3:

$$d_1 = \exp[-\exp(-4{,}452 + 0{,}116 P_м^{\max})]\,; \quad d_2 = \exp[-\exp(-3{,}842 + 0{,}349 t_T)]\,; \quad d_3 = \exp[-\exp(-3{,}126 + 5{,}201 A^{\max})]\,.$$

Generalized function of desirability *D* is geometric mean of particular functions d_j:

$$D = \sqrt[3]{d_1 d_2 d_3}\,.$$

Meanwhile, generalized and particular functions of desirability vary from zero to one. Zero corresponds to an absolutely unacceptable value of optimization parameter, while one corresponds to the best.

3. *Selection of the mathematical model of the bridge crane.* Since transients of lifting cranes might be described by differential equations with sufficient accuracy for practical calculations, then it is expedient to perform optimization of speed-torque characteristic using computer experiment on the mathematical model of the crane. Optimization parameter values $P_{м}^{\max}$, t_T і $A^{\max}$ have been determined according to the results of the numerical integration of the system of nonlinear differential equations ,which describe the process of crane's dynamic braking bridge. That process is represented as a three-mass design diagram [3, 4].

4. *Algorithm for finding optimal mechanical characteristics of crane's electric drive in dynamic braking operating mode.* The process of optimization has been performed according to steepest ascent method (Box – Wilson method). First of all, the local domain of region D_j has been approximated by first-order equations of regression, which connects generalized criterion and variable factors; in order to do this the complete factor experiment has been conducted. By dint of regression coefficients, we will find the direction and the magnitude of steps to the optimum by two factors. In the first series of steepest ascent studies the movement to optimum has been conducted from the center of plane and let to increase the value of criterion *D* from 0,603 to 0,659.

In order to find a higher value of *D*, the second series of steepest ascent studies have been conducted from the new center of plane, which corresponded to the best experiment in the first series of studies. After that, the local domain of response surface *D*, with the center in the best point, has been described by the second-order equation of regression, due to central composite rotatable uniform-plan. In order to clarify the optimal value of *D* and the coordinates of the optimum, canonical transformation of regression equation has been conducted [4].

Thus, maximum value of the optimization criterion (D = 0,745), which is at the point with coordinates z_{1S} = 0,140 and z_{2S} = - 0,081, has been found. According to the value of that criterion, the next optimum mechanical characteristics of crane's travel mechanism corresponds to it $M_{к}^{*}$ = 380 Hm and $s_{к}^{*}$ = 0,337.

Conclusions: - the developed method of optimization by generalized criterion is an effective way to improve technical and economic indicators of lifting cranes and it might be used for the working cranes, as well as, for cranes which are being designed;

- for braking of bridge cranes of 20 tone lifting capacity, it is recommended to use the found optimum mechanical characteristic in dynamic braking operating mode, which allows to reduce the dynamic loads on the metal construction of crane by 18 -24%, to cut the amplitude of load swinging after crane's stop 3 - 5 times, in contrast to countercurrent braking.

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