REALIZATION OF ENERGY-SAVING CONTROL MODES ON CRANES OF GREAT LOAD- CARRYING CAPACITY

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Abstract: saving energy is highly important for all types of lifting machinery. Research shows that it is possible to reduce energy consumption in mechanism drives at all stages of movement. Energy-saving control has already been implemented on cranes at the Dnister Hydroaccumulating Power Plant. The article describes the conditions and results of the implementation.

Key words: load-lifting machinery, control mode, energy-saving, frequency shifter

1. PROBLEM SETTING AND ITS CONNECTION TO IMPORTANT SCIENTIFIC AND PRACTICAL TASKS

Operating efficiency of the load-lifting machinery (LLM) can be achieved through rational modes of controlling its mechanisms. Such modes presuppose maximum speed action and expenditure of energy minimization.

Reduced expenditure of energy for the execution of one cycle is possible not only through energy return during recuperative braking of the mechanism to the electric circuit or to supply the other mechanisms, but also at the stages of acceleration and stable movement due to the increased coefficient of efficiency of the drive.

Practical implementation of crane mechanism drive control using the energy-

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saving modes has been provided at the Dnister Hydroaccumulating Power Plant that possesses 6 unique hydraulic units each with the 250 MWatt capacity, thus, being the largest in Europe.

Erecting cranes at the site joint ground (fig.1) and those at the base depot of waterpower equipment (fig. 2) of the Dnister Hydroaccumulating Power Plant have differences connected to the fact that it is necessary to work with the equipment at 56-meter depths and to carry out preparatory operations in site joint composition with maximum speed and precision.

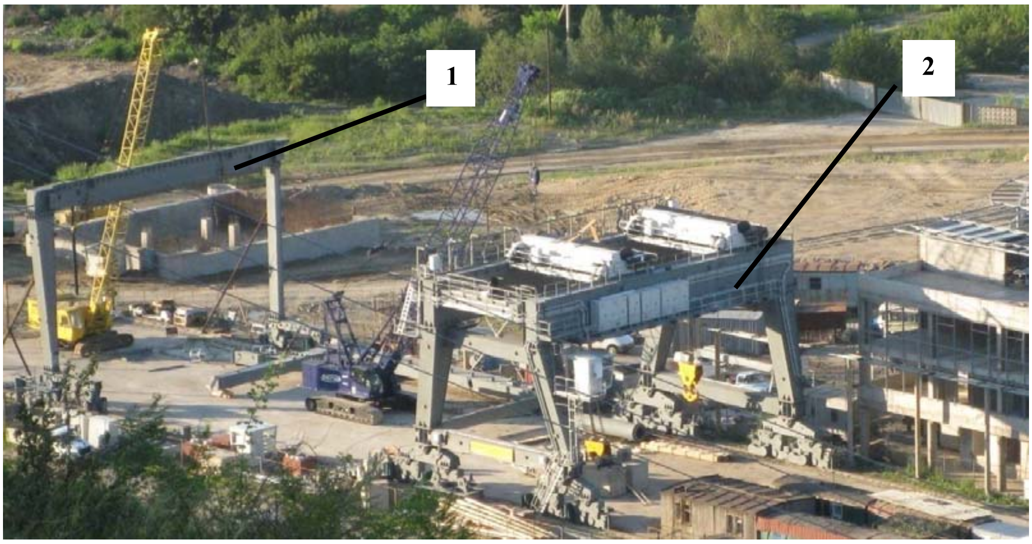

Fig. 1. Crane assemblage:
1 – assemblage of a portal bridge special-purpose crane with the main hoist load-carrying capacity of 125 t; 2 – assemblage of a portal bridge special-purpose crane with the main hoist load-carrying capacity of 840 t

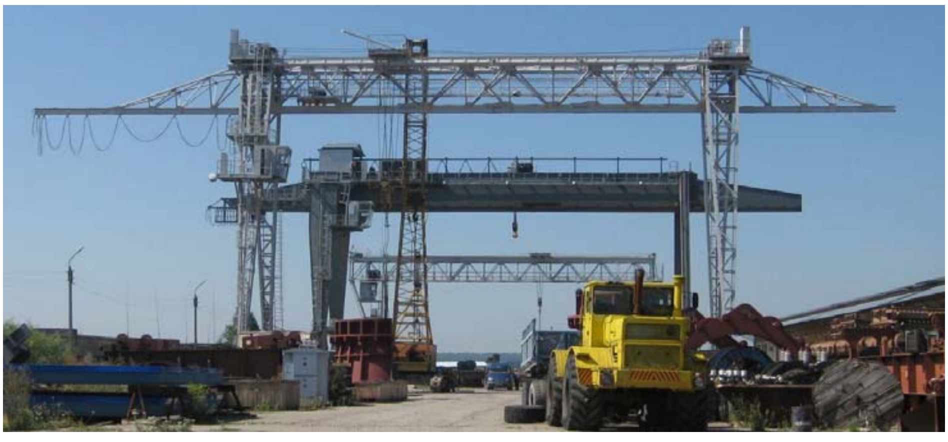

Fig. 2. portal bridge special-purpose cranes with the main hoist load-carrying capacity of 125 t

2. ANALYSIS OF THE RESEARCH OF THE ENERGY CONSUMPTION REDUCTION PROBLEM IN LOAD-LIFTING MACHINERY DRIVES AND POSSIBLE SOLUTIONS OF THE PROBLEM

Quantity of the energy consumed and the possibility of realizing energy-saving modes of controlling load-lifting machinery mechanisms depends on the drive types.

Analyzing mechanical properties of the frequency steering drive and comparing them to those of the regulated three-dimensional crane hydraulic drive we come to the conclusion that the properties look completely similar while operating in the I and II quadrants. That is why we can assume that operation of these drives in engine mode and in generator mode are analogous.

The research carried out at the NTU "KhPI" shows the ratio of coefficient of efficiency in the electromechanical drive with phase-wound rotor and in the three-dimensional hydraulic drive during transient processes and stable movement. Here we introduce the concept of «integrated» or «average coefficient of efficiency» $\int\eta$ during a certain period of time *t*.

$$\int\eta = \frac{\int_0^t \eta dt}{t} \tag{1}$$

It is worthwhile to consider the character of changes in $\int\eta$ during the acceleration cycle under the condition of reaching different values of relative velocity Ω/Ω_0 and different loading of drives (fig. 3).

The diagrams show that in the whole scope of relative velocities and loadings the integrated coefficient of efficiency of the hydraulic drive is higher than that of the electromechanical one (we can assume that the frequency steering drive has the same effect).

Diagrams of $\int\eta_{e2}$ to $\int\eta_{eM}$ ratio (fig. 4) under the condition of reaching different values of relative velocity, different loading of drives and the same value of Ω_0 for both drives show that this ratio, and thus the energy expenditure at acceleration, reaches the highest values when the drives are being used within the near-zero scope of values of Ω/Ω_0 (it is characteristic of bridge shifting mechanisms and the assembly crane bogey and mechanical treatment shop crane bogey). The diagrams also demonstrate that the more the drive is loaded by the torsion moment, the more energy effect the hydraulic drive produces.

This leads us to the conclusion that the three-dimensional hydraulic drive incurs a significantly less energy loss than the above mentioned electromechanical one. The frequency steering electrical drive with vector control is the most similar one to the three-dimensional hydraulic drive in its mechanical properties, possible control modes and energy recuperation at braking stage, which enables us to extrapolate the conclusions given above as to the energy expenditure reduction for the given type of drives.

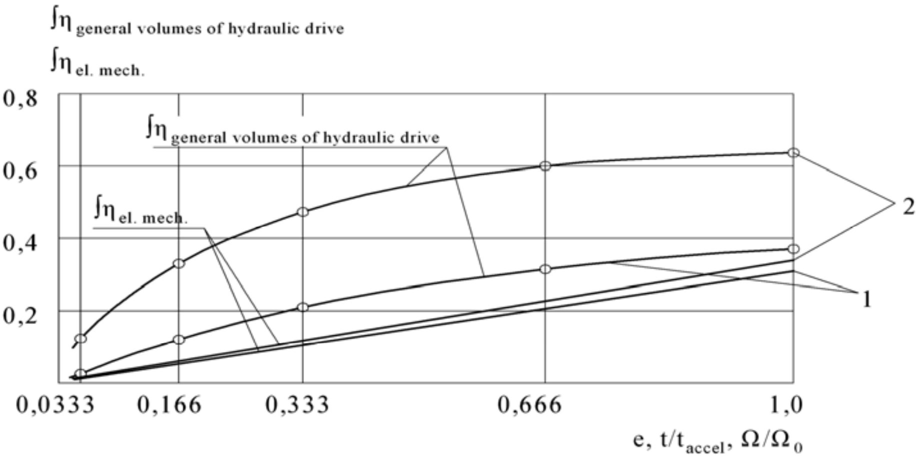

Fig. 3. Diagrams of dependency of the integrated coefficient of efficiency in the three-dimensional hydraulic drive and in the electromechanical drive with phase-wound rotor on *e* which is the regulation parameter (current productivity to nominal productivity ratio), t/t_{accel} which is relative time, Ω/Ω_0 - relative velocity under different loadings 1, 2 ($M_2 > M_1$)

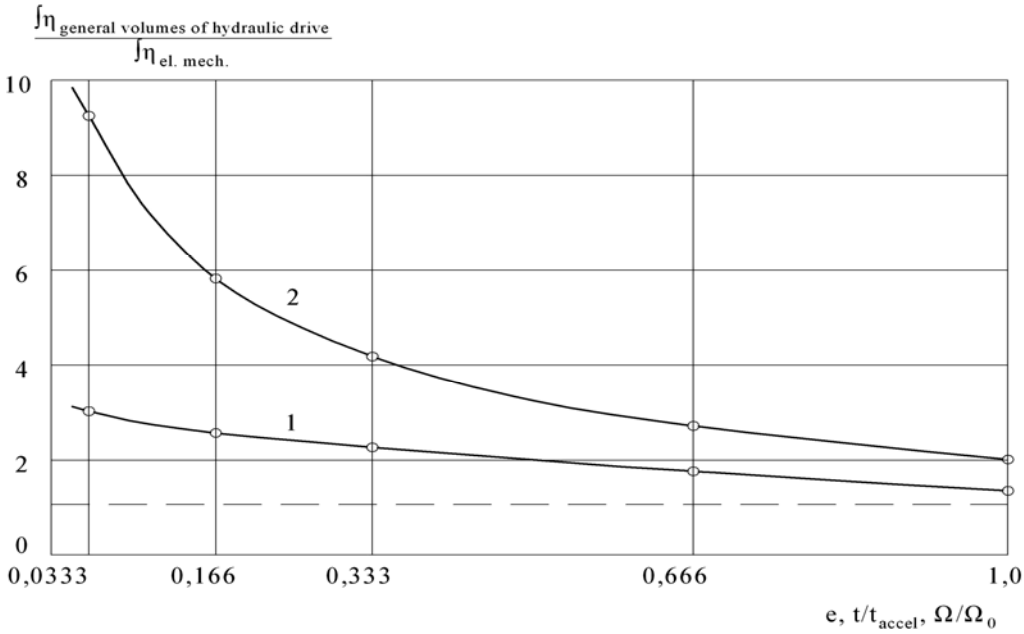

Fig. 4. Diagrams of dependency of $\int\eta_{e2} / \int\eta_{eM}$ on *e*, t/t_{po32}, Ω/Ω_0 with different loadings 1, 2 (the dashed line corresponds to $\int\eta_{e2} / \int\eta_{eM} = 1$, $M_2 > M_1$)

3. REALIZATION OF ENERGY-SAVING CONTROL ON CRANES AND CONSTRUCTIONAL PECULIARITIES

As regulation and control devices we use STRUM (СТРУМ) frequency shifters produced by limited liability corporation «Crane electrical drive».

All the cranes are equipped with a cage with rotating chair-console produced by limited liability corporation «Crane electrical drive» which incorporate all the crane control devices as well as alarm mechanisms. Radio control devices by limited liability corporation «Crane electrical drive» that are used on all the cranes insure full control over all the mechanisms over the whole area of crane operation.

The crane's set of electric equipment insures control over the twelve electric engines for eight different mechanisms. The producer of frequency shifters, programmed controller, control cabinets and consoles is at the same time the electric part project developer and assembling organization. Such an integrated approach has become the basis for optimal technical solutions.

As far as technical parameters are concerned the most interest is raised by the crane with the 840-ton load-carrying capacity (fig. 5), that concurrently possesses a considerable load-lowering height.

Technical properties: operating mode group as to ISO 4301/1 is A2; the main hoist load-carrying capacity is 840 t, the accessory hoist load-carrying capacity is 16 t; the main hoist height is 56 m, that of the accessory hoist is 76 m; the crane span is 20,5 m; the crane foundation is 12,75 m; mechanisms velocities: that of the main hoist is 2,4 m per minute, that of the accessory hoist is 12,6 m per minute, that of bogey travel is 10,02 m per minute, that of bogey travel for accessory lifting is 4,98 m per minute, that of crane travel is 19,8 m per minute; main hoist mechanism velocity regulation scope is 1:100, that of the rest of the mechanisms is 1:50; crane mass is 450 t.

The hydraulic unit for the assemblage and maintenance of which the crane is purposed is set in the shaft (fig. 6). Operations with its joints should be carried out by the separate control of the each of the two 420-ton hook assemblies as well as by concerted operation of the both hook assemblies. The completion of one lifting operation, even at nominal speed, takes a lot of time which requires stable functioning of the equipment without taking into consideration the duration of activation.

Purposed for the concerted operation cross bar (fig.7) allows for a slight vertical deviation which is visually controlled by the machinist relying on the device readings. However, on the complete travel track which is approximately 50 m even smallest velocity differences can necessitate repeated levelling. Despite the synchronization requirement the direct task of the same voltage frequency that feeds electric engines has turned out to be sufficient for stable movement and even load division on both hook assemblies.

The first of the large-size units assembled by the crane, which is the framework of the hydraulic unit (fig. 8), requires several hours of operating at microvelocities for removal of all fitment bores with the rakers.

Fig 5. Portal bridge special-purpose crane with the load-carrying capacity of 420/420/16 t

Fig. 6. The hydraulic unit shaft

Fig. 7. Cross/radial/transverse cross arm/bar for the concerted operation of the main hoist mechanisms

Fig. 8. Framework of the hydraulic units

Operation at minimal velocities enables us to precisely position load grippers which is exceptionally important in hardly accessible areas.

It is also important to mention the compactness of the control equipment (fig. 9) which considerably reduces the scope of additional metal constructions.

Fig. 9. Crane control device placement

4. IMPLEMENTATION RESULTS

Maximal energy consumption reduction due to frequency shifters usage has considerably decreased the electric circuits loading. Basically, it has translated to an increased coefficient of power capacity (k_p) that in some cases has reached 0.98. Consumption of the current active component exclusively has allowed decreasing the circuit loading by 30...40%, especially when the loading is below nominal.

It is especially significant to highlight the experience in implementing recuperative braking. Power supply of the crane is at the cutting edge of the modern technology, it is provided from a separate source with the use of closed electric cables and circuit voltage control. During continuous operation in braking mode, that is lowering near-nominal loads, generating energy into the circuit has become comparable to its consumption in acceleration mode and stable movement mode. At this point operating from a separate transformer has proved to be unstable. This is connected to the impossibility of transforming electric power towards voltage increase. The mandatory presence of consumers on the parallel lines of crane power circuit has become the best solution to this problem.

Even during crane testings, recuperative braking allowed to apply brakes to a fully stopped electric engine which, in addition, practically excluded dynamic loading on the metallic structure and crane mechanisms. To increase production in case of great scopes of liftings all cranes have undergone trials at speeds increased by 200%. Quadratic dependence of moment on power circuit frequency with stable voltage introduces limitations as to loading at super-synchronous velocities. In this case doubled velocity is only acceptable if the load weight is below 25% of the nominal one.

Concerted operation of the two lifting mechanisms with a near-nominal load at various velocities has showed unstable functioning in some velocity scopes. It demonstrated itself in stable self-oscillations that caused vibrations in all metal constructions. Implementation of programmed frequency shifters allowed to turn off undesired velocities at the stage of adjustment and made it possible to avoid alterations in schemes and kitting of the equipment.

It is necessary to underscore the operating stability of load trolley mechanisms. With a considerable width of load trolley rails necessary to mount drums of appropriate rope capacity synchronous functioning of mechanisms made it possible not to use special rigid hitches between two load trolleys.

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