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Testing of hydrostatic drive of cranes mechanisms

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Abstract. At present, the experts of lifting, transport, construction and road equipment are tasked with significantly improving the productivity of loading and unloading operations, improving performance characteristics, increasing the durability and reliability of machines. One of the ways of solving these problems is the widespread use of hydraulic transmissions in various mechanisms of cranes, construction and road machines. The results of researches on the cranes (bridge, tower and portal) with hydrostatic drives of travel and slewing mechanisms are given. The results of testing are compared with the solutions on the computer. Recommendations for a significant increase hydrostatic drives limit number of fatigue cycles of welded joints of crane steel structures in relation to a drive with a phase rotor are given.

Key words: damages, loads acting on cranes steel structure, hydrostatic drives, fatigue of crane units, oscillograms of tests.

1. Introduction

The Department of lifting and transporting machines and equipment of NTU "KhPI" has accumulated rich experience in scientific research and implementation of hydrostatic drives, which were investigated by Zhermunsky B.I.,

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Chekulaev E.F., Povzyk V.M., Grigorov O.V., Gebgard K.I., Kovalenko V.O., Stryzhak V.V., Ziubanova D.M., Tsebrenko M.V. [1-8].
During these studies, it was discovered by using of strain gauging and records on the oscilloscope that these drives provide a significant reduction in dynamic loads. The following hydrostatic drives were investigated:
- separate hydrostatic drive of the 75/20 t bridge crane travel mechanism with high-torque hydraulic motors (designed by NTU "KhPI");
- slewing mechanism drive of a portal crane with the 10 tons' capacity with high-torque hydraulic motors (designed by NTU "KhPI");
- travel mechanism drive of the bridge crane with the 30/5 tons' capacity with low-torque motors;
- travel mechanism drive of the bridge crane with the 15/3 tons' capacity with low and high torque engines.

The most significant results of foreign researchers in studying of hydrostatic drive are given in articles by prominent German scientists [9-11].

2. Testing of hydrostatic drive of cranes travel mechanism and their comparison with the theoretical modelling

According to the instructions of the Kharkiv Lifting and transporting equipment Plant, the travel mechanism separate hydrostatic drive of a bridge crane with the 30.5 tons' capacity was created and thoroughly investigated (fig. 1).

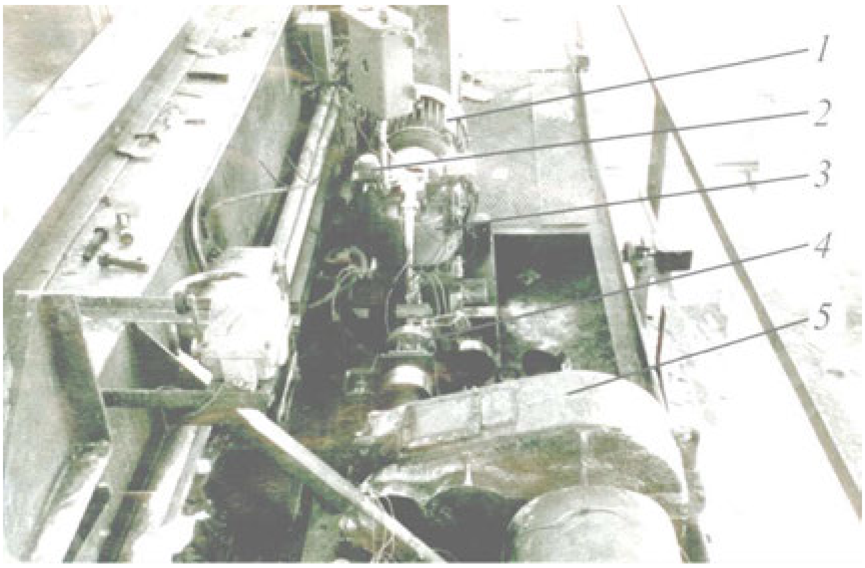

Fig. 1. Separate hydrostatic drive of the travel mechanism of a bridge crane with a capacity of 30/5 tons
1 - electric motor AO-62-4; 2 - hydraulic control system; 3 - pump II D №5; 4 - hydromotor II M №5; 5 - gearbox of travel mechanism of the crane.

Fig. 2 represents an oscillogram of intensive acceleration and braking of a crane with the 30.5 tons' capacity with a hydrostatic drive (hook load of 3 tons).

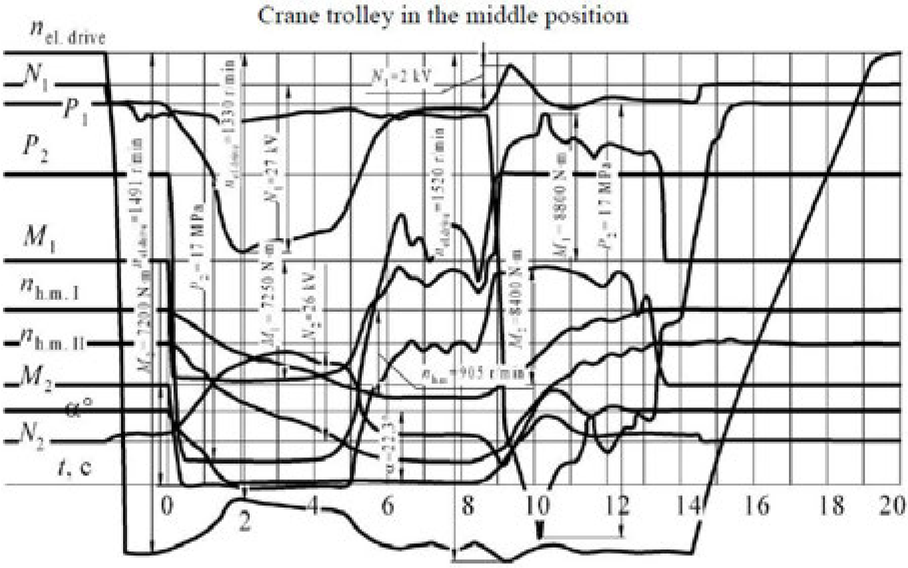

Fig. 2. Oscillogram of intensive acceleration and braking of the crane with a hydrostatic drive: Q = 30 t; t_{acc} = 6 s; t_{br} = 4.5 seconds.

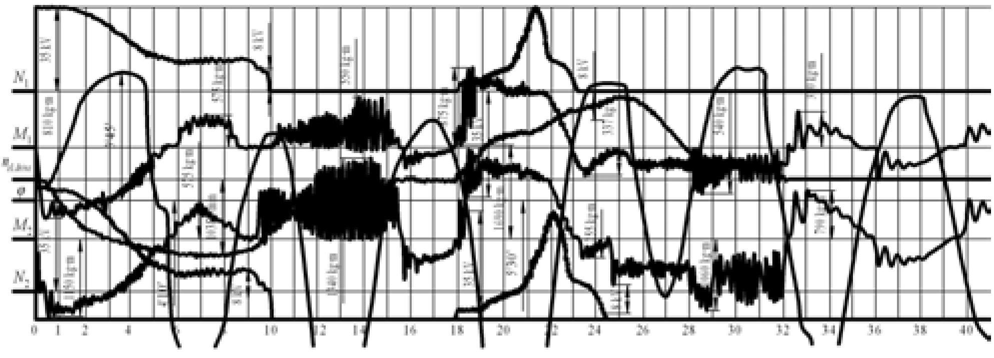

Fig. 3. Oscillogram of intensive acceleration and braking of the crane with an electromechanical drive: Q = 30 t; t_{acc} = 6 s; t_{br} = 4.5 seconds.

Fig. 3 shows an oscillogram of intense acceleration and braking of the crane with 30.5 tons' capacity with an electromechanical drive (hook load of 3 tons).

The experimental studies give an opportunity to compare the data obtained by mathematical modeling and the results of individual analytical solutions given by various researchers and make the appropriate conclusions.

The results of the experiments and their comparison with the solutions on the computer give grounds to assert (fig. 4), that the data obtained by modeling quite exactly coincide with the experimental ones.

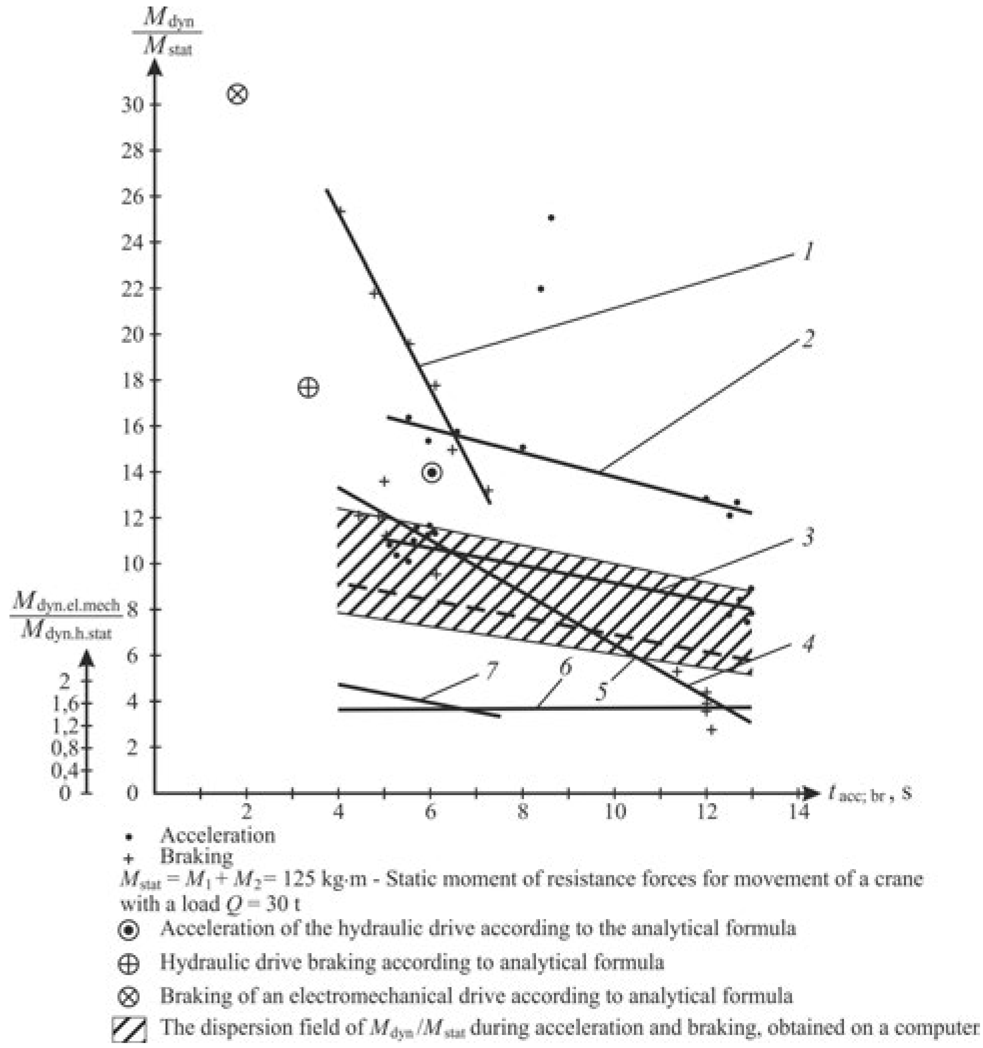

Fig. 4. Comparison of experimentally founded dynamic forces with theoretical:
1 - braking of the electromechanical drive; 2 - acceleration of the electromechanical drive;
3 - acceleration of the hydrostatic drive; 4 - braking of the hydrostatic drive;
5 - acceleration (initial) of the hydraulic drive, found on the computer;
6 - graph of the $M_{d\ el.meh} / M_{g.st} = f(t)$ at acceleration;
7 - graph of $M_{d\ el.meh} / M_{g.s}t = f(t)$ during braking.

The analysis of oscillograms of starting and braking modes of a hydrostatic drive of a full-scale crane convinces that the conclusions obtained as a result of the study of oscillograms of the simulation are correct and could be applied to a full-scale crane with a hydraulic drive.

Subsequently, at the Uzlovsky machine-building plant, tests of separate drives of the travel mechanism of the crane with the 15/3 tons' capacity with low-torque (fig. 5) and high-torque (fig. 6, 7) engines were conducted. Fig. 8 shows the oscillograms of these tests.

Detailed analytical studies of the travel mechanism dynamics show that the use of a hydrostatic drive provides significant energy savings and reduces the equivalent power of the installed electric motors.

Summarizing the above, it can be argued that the hydrostatic drive reduces the load in the metal structure by at least 40%.

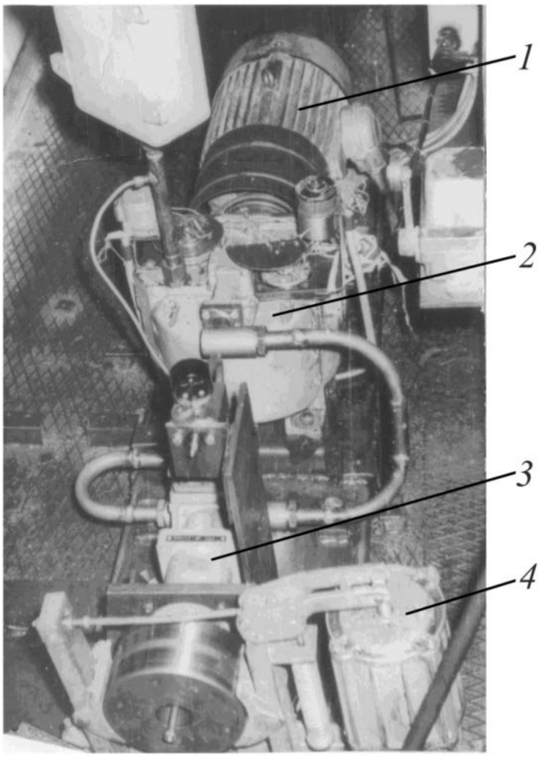

Fig. 5. Travel mechanism of the bridge crane with the 15/3 tons' capacity with a separate volumetric hydraulic drive and low-torque hydromotors. Uzlovsky machine-building plant.

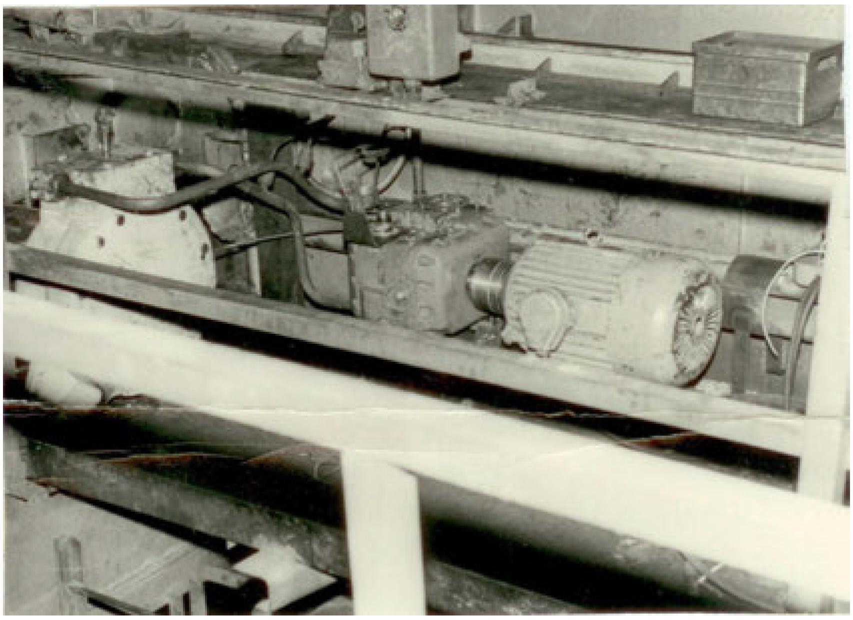

Fig. 6. Separate regulated volumetric hydraulic drive of the travel mechanism
(bridge crane with 15/3 tons' capacity with high-speed hydraulic motors,
Uzlovsky machine-building plant).

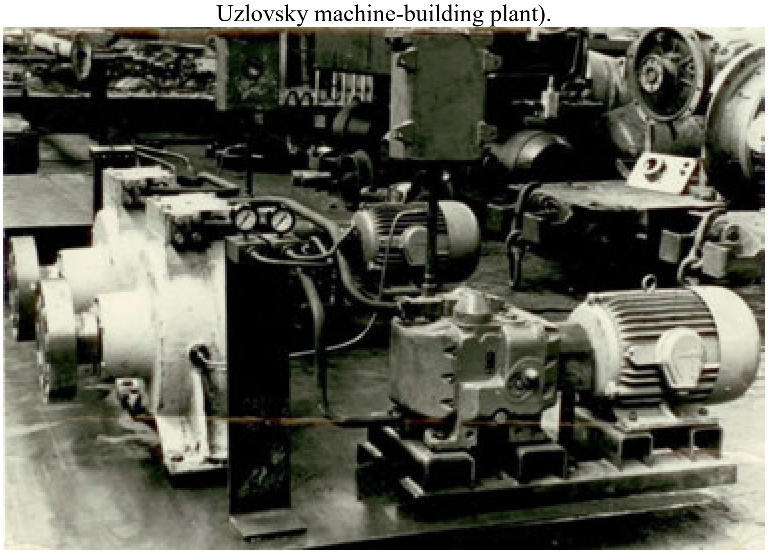

Fig. 7. Separate regulated volumetric hydraulic drive of the travel mechanism of the bridge crane with a capacity of 15/3 t. with a high-torque engine, Uzlovsky machine-building plant
(machinery on the line of readiness).

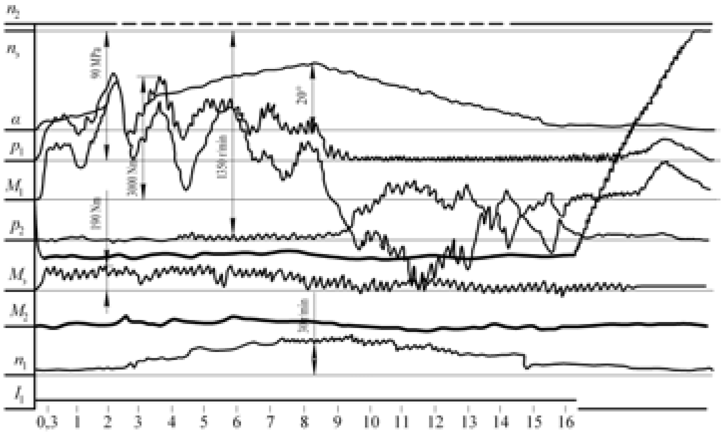

Fig. 8. The travel mechanism of a 15/3 tons' bridge crane with a separate drive and high-speed hydraulic motors. Oscillogram of field tests: n_2 - the pulse counter of the hydromotor speed; n_e - speed of rotation of a driving electric motor; α - angle of rotation of the pump cradle; p_1, p_2 - pressure at the pressure and drainage lines; M_e - torque of the electric motor; n_1 - rotation speed of the hydraulic motor; M_1, M_2 - torque of transmission shafts; I_1 - current of the electric motor rotor.

3. Determination of the limit number of fatigue cycles of Hydrostatic drive

According to the Weibull assumption, accumulated by N load cycles, fatigue damage d_N is:

$$d_N = \sum_{1}^{N} \Delta d = kN \,, \tag{1}$$

where Δd is the single fatigue damage in one cycle of loads;
$k = \text{tg}\alpha$ is the intensity of accumulation of fatigue damage.

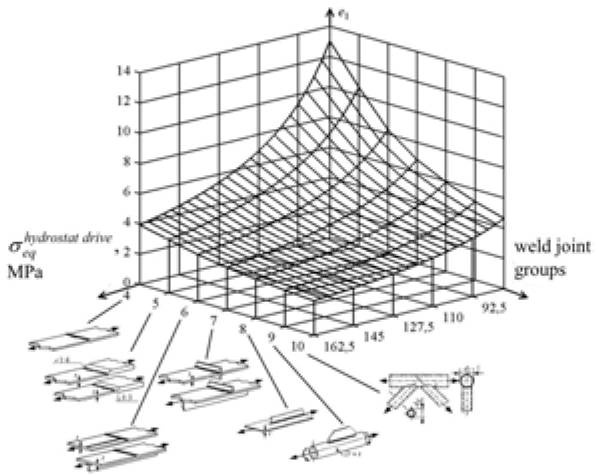

Fig. 9. The ratio of the maximum number of cycles of tiredness in a hydrostatic drive and a motor with a phase rotor $e_1 = N_{hydrostat\ drive} / N_{ph\ rot}$ for groups of welded units at a stress concentration with an equivalent stress reduction of 40% when using a hydrodynamic drive.

The Wöhler curve reflects the dependence of the durability of the component or the design unit on the level of operating stresses in stationary load. It is known that 80-95% of damage creates cycles with tensions close to the maximum, which can occur at the moments of maximum loads, that is, during start-up and inhibition.
Fig. 9 shows results of determination of the limiting number of cycles for hydrostatic drive based on the Weibull theory of damage and the Wöhler curves.

4. Conclusions

It is clear from the calculations that the use of a hydrostatic drive is an effective way to increase the permissible number of load cycles of welded joints of crane steel structures. Reducing the equivalent cycle stress even by 40% can increase the number of permissible load cycles by at least 2,3 times, for example, for a stress concentration group of 10 with for St3 material. The growth of the ratio e_1, and accordingly the number of cycles to destruction, increases with a decrease in the equivalent tension of cycle and reaches the maximum value in the area of transition to an area of unlimited endurance. The bigger the item No of the group of the welded node by the concentration of stresses, so growth is more slowly, due to the gradual decrease of the limit of unlimited endurance. Further scientific developments in this direction can be directed at consideration of specific constructions and cases of loads.

References

[1] Grigorov O., Anishchenko G., Petrenko N., *Steel structures of lifting, transporting, construction, road, ameliorative machines*, tutorial, NTU "KPI", Kharkiv, 2011.

[2] Grigorov O., Petrenko N., *Lifting machines*: tutorial, NTU "KPI", Kharkiv, 2006.

[3] Grigorov O., Strizhak V., Petrenko N., *Rational drives of lifting, transporting, road machines and logistic parks*, monograph, edited by Grigorov O, KNARU, Kharkiv, 2016.

[4] Grigorov O., Druzhynin E, Anishchenko G., Strizhak M., Strizhak V., *Analysis of Various Approaches to Modeling of Dynamics of Lifting-Transport Vehicles*, International Journal of Engineering & Technology, **7** (4.3), 2018, p. 64-70.

[5] Grigorov O., Druzhynin E, Strizhak V., Strizhak M., Anishchenko G., *Numerical simulation of the dynamics of the system "trolley - load - Carrying rope" In a cable crane*, Eastern-European Journal of Enterprise Technologies, **3** (7-93), p. 6-12.

[6] Grigorov O., Selection of an electric motor for a hydraulic crane drive, Russian engineering journal, **56**, Issue 1, 1976, p. 43-46.

[7] Grigorov O., Comparison of hydraulic and electric crane drives with regard to electric motor power, Russian engineering journal, **55**, Issue 11, 1975, p. 40-44.

[8] Grigorov O., *Energy consumption in adjustable hydrostatic and electro-mechanical drives*, Russian engineering journal, **53**, Issue 4, 1973, p. 32-37.

[9] Weishaupt E., Völker B., *Energiesparende electrohydraulische Schaltungskonzepte*, O+P "Ölhydraulik und Pneumatik", nr. 2, 1995.

[10] W. Backe., *Technische Treds der Fluidec*, O+P "Ölhydraulik und Pneumatik", nr. 11−12, 1995.

[11] Kordak R., *Der sekundärgeregelte hydrauliche Antrieb in mobilen Arbeitsgeräten*, O+P „Ölhydraulik und Pneumatik", nr. 11-12 1995.