

SUBSTANTIATION OF STRUCTURE AND PARAMETERS OF HYDRAULIC STANDS WITH RECUPERATION OF CAPACITIES FOR DIAGNOSTICS OF ADJUSTABLE HYDROMACHINES

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Summary

Set of parameters which objectively characterize a technical condition of the hydromachine can be received at their bench tests. Considering the set forth above features of hydromachines, for reception of the maximal volume of the information at the minimal expenses of time and energy at tests apply stands with recuperation of capacities. Essentially new designs of stands with recuperation of capacities for test of hydraulic machines and mechanical units are offered and patented. The basic structures of test beds with recuperation capacities and bases of a choice of their parameters which allow testing adjustable hydromachines in a wide range of their parameters are considered. The developed stands allow raising quality of diagnosing of adjustable hydromachines essentially.

Keywords: hydromachine, stand, recuperation, control, test.

1. INTRODUCTION

Greater part of modern mobile technique - build-road, agricultural, communal et al produced with hydraulic drives a to 90% engine power is utilized in which. The technical level of modern gidrodrive is determined the parameters of his basic power aggregates – pumps and motors. In spite of ap-preciation of value of hydraulic drives, application of the managed power aggregates instead of fixed volume allows to extend an adjusting range, decrease the swept volume of pump and increase his frequency of rotation to frequency of rotation of billow of drive engine without intermediate mechanical transmis-sions, that on the whole diminishes sizes and mass of transmission and promotes its reliability.

One of important technological operations at making and repair of knots, aggregates and machines there are their tests and rolling. Tests provide the estimation of conforming to of producible good the requirements of designer and normative and technical documents, and also exposure of weak points in a construction and technology with the purpose of development of measures on their removal. Rolling allows in the process of making and repair substantially to promote reliability indexes, that promotes quality of producible wares in same queue. For organization of these technological operations at a production it is necessary operatively and objectively to estimate the state of aggregate which is tested. Diagnostics allows to define the actual consisting of technical object, and also character of change of him of time [1]. Knowledge of the real state of aggregate at tests allows to optimize time of tests and rolling, and also to expose and remove the lacks of construction, and also technologies of making of aggregates, knots and details.

2. OBJECTS AND PROBLEMS

The feature of hydraulic drive of mobile technique at tests and rolling is that variety of its kinds, and also different and difficult external environments are required by applications of different types of tester equipment. Creation and introduction of universal tester equipment allows to execute on him a test and rolling of aggregates of different type in the wide range of office hours.

Stands for the tests of aggregates de bene esse are divided by two classes: with the direct stream of power and with rekuperatsiy of power. Most modern are stands with rekuperatsiy of power with a hydraulic drive. Advantages of hydraulic stands with rekuperatsiy of power it is been [2]:

- smooth regulation of speed and parameters of loading;
- change of a direction loading in the process of tests and rolling;
- reliable protection of examinee aggregates from an overload;
- possibility of complete automation of tests and rolling, and also remote control the parameters of stand;
- small labour intensiveness of setting of equipment and examinee aggregates.

The row of constructions of hydraulic stands is developed with rekuperatsiy powers [3, 4, 5] which allow to execute tests and rolling, both hydraulic equipment and mechanical aggregates. Hydraulic stands can be executed on the opened chart, when the suction hydraulic

line of pump and weathering gidrodvigatelya is connected with a tank, or on the closed chart, when foregoing hydraulic lines are united between itself.

On fig. 1 the hydraulic chart of universal tent-bed test is presented with rekuperatsiyey of power [3]. A stand is contained by an engine 2, which is a drive for the managed pump 1, pressure hydraulic line 5 last reported through the managed throttle 4 with loading motor 3, and suction hydraulic line with a tank 13. Coupled hydromachines 6 and 7 connected by between itself a pressure hydraulic line 8, and their shafts are mechanically connected by a transmission 10. In the presented chart hydromachine 6 is a pump, and hydromachine 7 is a motors. Weathering hydraulic line of motors 9 and suction hydraulic line pump 6 and motor 7 connect with a tank 13. In addition, shafts of hydromachines 6 and 7 through a transmission 10 mechanically connected with the shaft of loading motors 3.

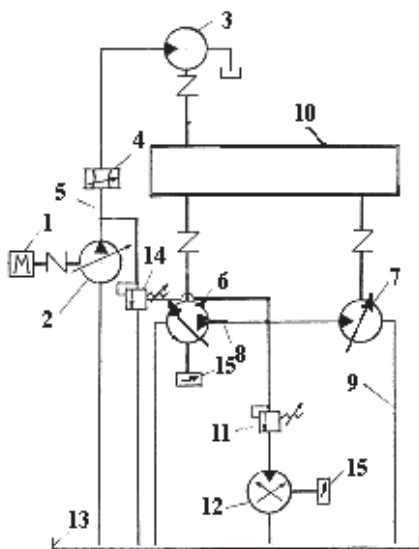


Fig. 1. The principle hydraulic scheme of stand.

Pressure hydraulic line 8 reported through a loading valve 11 and flowmeter 12 with a tank 13, and pressure hydraulic line 5 through a loading valve 14 reported with a tank 13. Loading valve 14 executed a differential, here his managing cavity is united with pressure hydraulic line 8. Hydromachine 6, loading motor 3 and flowmeter 12 supplied the sensors of angular speed 15. Pressure hydraulic line 5 and 8 supplied the sensors of pressure.

A hydraulic stand works as follows. At including of engine 2 pump 1 gives through a throttle 4 on a pressure hydraulic line 5 working liquid in a loading motor 3, which drives to the rotation a transmission 10. Rotation through a transmission 10 passed on the shaft of pump 6, which forces a working liquid on pressure hydraulic line 8 in a motor 7, which passes a rotation on a transmission 10, what and recuperation of power at stand is provided.

Transmission 10 must provide speed of rotation of billow of pump higher, than at gidromotora 7, in order

that serve of working liquid of pump 6 was higher consumable expense by a motor 7. Surplus of working liquid given a pump 6 given on weathering in a tank through a loading valve 12 and flowmeter 15. Change of tuning of loading valve 14 provides the change of pressure in a pressure highway 8, and, consequently moment on the billows of gidromashin 6 and 7.

Change of serve of pump 2 or tuning of throttle 4 changes frequency of rotation of loading motor 3, and consequently, through a transmission 11, changes frequency of rotation of billows of gydromachines 6 and 7. Setting of differential loading valve 14 with a management from pressure in the pressure highway of 8 gydromachines 6 and 7, provides the changes of moment on the billows of examinee aggregates at their permanent frequency of rotation or provides the change of frequency of rotation of billows of examinee aggregates at a permanent moment.

3. MAIN SECTION

Hydraulic, kinematics and power calculations of hydraulic stand with rekuperatsiyey of power executed the known methods. The feature of calculation is a choice of gear-ratio of transmission and determina-tion of drive engine power.

Flow of working liquid of hydromachine working in the mode of pump:

$$Q_H = n_H \cdot q_H \cdot \eta_{H0}, \quad (1)$$

where n_H - frequency of rotation shaft of pump, q_H - displacement of pump, η_{H0} - volumetric efficiency of pump.

In a kind recuperation of power on a stand will present the serve of pump in a kind:

$$Q_H \geq (Q_M / \eta_{0M}) + Q_{HK} = \alpha \cdot Q_M \quad (2)$$

where Q_M - rate of flow in motor, η_{0M} - volumetric efficiency of motor, Q_{HK} - flow of working liquid through a loading valve, α - coefficient flow of pump.

At such denotation $\alpha - 1$ is a relative amount of working liquid, which does not pass through gidromotor.

Frequency of rotation shaft of pump is determined from dependence:

$$n_H = n_M \cdot i_m, \quad (3)$$

where n_M - frequency of rotation shaft of motor, i_m - a transfer relation of transmission.

Taking into account dependences (1) (2) will get

$$i_m \geq \alpha \cdot (q_M / q_H) \cdot (\eta_{0M} / \eta_{0H}), \quad (4)$$

In this case the required power drive of stand is determined on dependence:

$$N_n = \frac{\Delta p}{\eta_m} \cdot (Q_n \cdot (1 - \eta_n) + Q_m \cdot (1 - \eta_m) + Q_n \cdot (\alpha - 1)), \quad (5)$$

where Δp_k - an overfall of pressure on a loading valve, η_n, η_m, η_m - general efficiency of pump, motor and transmissions accordingly.

Taking into account the accepted denotations and foregoing dependences will transform a formula (5)

$$N_n \geq \frac{\Delta p}{\eta_m} \cdot n_n \cdot q_n \cdot \left[\alpha - \eta_n + \frac{q_m}{q_n} \cdot (1 - \eta_m) \right], \quad (6)$$

In case if $q_m = q_n$ power of drive of stand on dependence (6) appears in a kind

$$N_n \geq \frac{\Delta p}{\eta_m} \cdot n_n \cdot q_n \cdot (\alpha + 1 - \eta_n - \eta_m), \quad (7)$$

For example, at the use as power aggregates of drive of stand axial piston hydromachine (APH) hydrodrive type GST-90 with nominal power pump and motor of $N_m = N_n = 46$ kWt and displacement $q_n = q_m = 90$ sm³, $\eta_n = \eta_m = 0,92$, accept $\alpha = 1,15$. Consequently, $i_m \geq 1,15$, and drive power of stand of 14,3 kVt. According to dependence (7) $N_n \geq 0,31 \cdot N_n$. At the tests of every aggregate individually on the opened chart the total expenses of power make $N_n \geq 92$ kWt, that consumable power at tests goes down in 6 times. Taking to account that a hydraulic drive is provided in a chart (Fig. 1), a that decline of power will be a few less than.

For drafting of diagnostic model of drive of stand the method of formalization of functioning is accepted on the basis of generalized three key element [6]. The power aggregates of hydraulic drive can be presented charts which have three entrance variables, functionally related to other elements. As variables for knots accepted: knot taking of power, knot entrance of working environment and knot taking of working environment. Thus every element is described the system from 3 equalizations.

One of signs of change of the technical state of aggregates of hydrodrive, both in the conditions of exploitation and at tests and rolling there is power efficiency. For the aggregates of by volume hydrodrive select three indexes, which represent power efficiency: complete, volume and mechanical efficiency. The analysis of these indexes at tests allows simply to determine the technical state of aggregate, and the dynamics of their changes allows operatively to set duration of tests, and also to set reasons of low quality of good. Therefore as a basic sign of the state at the tests of power hydraulic aggregates efficiency is accepted.

Important direction of perfection power aggregates of hydraulic drives is an increase and stabilizing of efficiency in all of range of operating parameters. The increase of technical level hydraulic drives of mobile technique is provided the increase of nominal pressure to 30.45 MPa, by the increase of nominal frequency of rotation of pumps to frequency of rotation drive engine, and also by application of the managed power aggregates

with the purpose of diminishing of losses of power in a transmission. Forcing power of machines on results in the decline of their efficiency, that requires development of additional complex of structural and technological measures for providing of his increase and stabilizing. Application of the automated facilities of diagnostics at the tests of new or modernized constructions allows substantially to shorten time of polishing of pre-production models to the serial making.

The methods of determination efficiency of rotor hydromachinyi are known, which are based on the theory of similarity [7]. In obedience to this theory, general efficiency of pump is determined on dependence:

$$\eta_n = \frac{1 - k_{y1} \cdot \sigma_1}{1 + k_{f1} + (k_{\mu1} / \sigma_1)}, \quad (8)$$

where $k_{y1} \sigma_1$ - specific power from the losses of working liquid; k_{f1} - specific power which is lost on a dry friction; $k_{\mu1} / \sigma_1$ - specific power of losses on a viscid friction in a pump; $\sigma_1 = p / \mu \cdot \omega_n$ - a criterion of similarity of flow of viscid liquid in an equivalent crack for a pump, which is named the Zommerfel's function, p - pressure in a general pressure line, μ - dynamic viscosity of working liquid, ω_n - angular speed of shaft of pump.

For motorts general efficiency is determined on dependence:

$$\eta_m = \frac{1 - k_{f2} - (k_{\mu2} / \sigma_2)}{1 + k_{y2} \cdot \sigma_2}, \quad (9)$$

where k_{f2} - specific power which is lost on a dry friction in a motor; $k_{\mu2} / \sigma_2$ - specific power of losses on a viscid friction in a motor; $k_{y2} \sigma_2$ - specific power from the losses of working liquid in a motor; $\sigma_2 = p / \omega \cdot \omega_m$ - a criterion of similarity of flow of viscid liquid in an equivalent crack for a motor; ω_m - angular speed of motor billow.

Taking to account for (8) and (9) $\omega_n = i_m \cdot \omega_m$, that $\sigma_1 = i_p \cdot \sigma_2$.

The values coefficients of specific powers losses of energy in power aggregates are determined on the characteristic sizes of hydromachines:

- from the losses of working liquid

$$k_{yi} = \frac{C_{yi}}{e_i} \left(\frac{\delta_i}{q_i} \right)^3 \quad (10)$$

where: C_{yi} - coefficient of losses; $0 \leq e_i \leq 1$ - adjusting parameter; δ_i - equivalent gap;

$q_i = \sqrt[3]{\frac{q_i}{2 \cdot \pi}}$ - characteristic size of hydromachine.

– from losses on a dry friction:

$$k_{\mu_i} = \frac{C_{\mu_i} \cdot \bar{q}_i}{e_i \cdot \delta_i}, \quad (11)$$

where: C_{μ} – coefficient of losses on a viscid friction.

In the above-mentioned dependences \bar{q}_i for concrete type of hydromachine the characteristic volumes \bar{q}_i of size are permanent, all of other are determined the structural features of units and details of hydromachines, and also technology of their making, as a rule are variable at tests.

Investigation change of the state aggregate which is tested is a change of signs the state. Thus basic sources of uninvariance there is an object of diagnosing. As a result of break-in process details of aggregates takes a place changes of internal factors, that is reflected at the level general efficiency of aggregates. Descriptions of drive of stand at tests have statistical changeability the analysis of which allows to estimate the basic sign of diagnosing. For the analysis of the state of aggregates which test apply two indexes: mean value and dispersion of general efficiency of aggregates for period of their test. The size of mean value allows to set conforming to of aggregate the normative requirements, and an analysis of dispersion is time of break-in process.

4. RESULTS OF RESEARCHES

On the presented stand in joint-stock company «Strojhydraulika» managed bent axis APH trimot type 403.112 is tested. His issue accustoms from 2008 for application in the hydraulic transmissions of build-travelling and agricultural technique. The distinctive feature of new series is possibility of providing of the discrete adjusting of the displacement. Thus two workers of volume, maximal $q_{\max} = 112 \text{ sm}^3$, and the minimum displacement is set depending on the technical terms of customer. By undeniable advantage of hydraulic drives with discretely managed motors is providing of two workings speeds, and also possibility of putting in these speeds without the stop of machine, that promotes the productivity and management quality substantially.

A standard pumping unit and original adjuster is applied in the construction of APH type 403.112. With the purpose of verification of capacity of gidromashiny its tests were conducted on a stand with rekuperatsiey of power, which is presented on fig. 2, and setting two managed machine 403.112 on a stand shown, on fig. 3.



Fig. 2. The stand with recuperation of powers for tests APH 403.112



Fig. 3. Setting of two hydromachines 403.112 at the stand.

Treatment of values of parameters of tests allowed continuously to determine the signs of the state of hydromachin: mean value and dispersion of efficiency. The analysis of these signs allowed to define accordance of the technical state of aggregates the requirements of technical document for development of machines, and also to specify time of their break-in process. The additional task of tests was verification of longevity by work of regulator of number of cycles of switching, which would provide his tireless durability at the base number of cycles of loadings, what corresponded continuous work of hydromachine during the set interval of time with switching of regulators of every aggregate.

The given stand also can be applied at tests and break-in process mechanical units. In this case units which are tested are installed instead of transmission 10 (fig. 1).

The loading cycles APH 403.112 at the stand are presented on diagrams which are shown on fig. 4. On diagrams are shown Q_1 – rate of flow the hydromachine, which works in a mode of the motor, and Q_2 - rate of flow the hydromachine, which works in a mode of the pump. Switching of operating modes was provided with hydraulic allocators which conditionally are not shown on the basic scheme fig. 1.

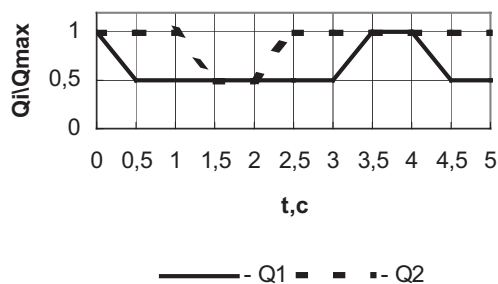


Fig. 4. The loading cycles of hydromachines

The results of the conducted tests were confirmed by a capacity and longevity of the developed construction of managed variable displacement hydromachines 403.112. with the discrete adjuster.

5. CONCLUSIONS

For providing of diagnosing of the technical state of power aggregates of hydraulic drives at their tests and break-in process it is suggested to apply hydraulic stands with recuperation of power.

The row of constructions of such stands is developed. The method of calculation parameters of hydraulic stand with recuperation of power is offered. At the tests of hydraulic aggregates of expense of power on their conducting go down in some times. Continuous analysis of signs of the state of aggregates which test apply two indexes: mean value and dispersion of general efficiency of aggregates for period of their test.

REFERENCES

1. Sjiricin T.: *Reliability of gidro- and pnevmodrives*. M: Machinostroenie, 1981 (in Russian).
2. Volkov D., Nikolaev S.: *Reliability of build machines and equipment*. M: Vysh. school., 1979 (in Russian).
3. Gorbatij V., Nikolenko I. and other.: *The stand for tests of hydromachine with recuperation of power*. – A.s. USSR № 1606750. Bul. № 42., 1990 (in Russian).
4. Gorbatij V., Nikolenko I. and other.: *The stand for tests of hydromachine*. A.s. SSSR № 1613683. - Bul № 46., 1990 (in Russian).
5. Nikolenko I., Komarov A.: *The hydraulic stand for test of mechanical units*. Patent of Ukraine № 64366/ Bul. № 2, 2004 (in Ukrainian).
6. Berengard Ju., Gajcgori M.: *Algorithm of forming of mathematical model of hydrodrive of arbitrary structure*. Engineering science. № 1, 58 – 65., 1977 (in Russian).
7. Kondakov L., Nikitin G., Prokofiev V. and others: *Machine-building hydrodrive*. – M.: Machinostroenie, 1978 (in Russian).