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# Experimental Work of the Hydraulic Equipment of the Multi-Purpose Machine Mm-1

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***Abstract*: The purpose of the tests was to verify the theoretical studies performed, as well as to confirm the functionality of the developed multi-purpose machine with excavation and bulldozer equipment. Mounting on the basis of TTZ-80 working equipment allowed us to conduct experimental studies, with the determination of energy performance indicators during the most energy-intensive operation - digging and leveling the soil.**

***Keywords*: multi-part machine, equipment, soil, power, hydraulic pump, pneumatic circuits.**

## I. INTRODUCTION

The expansion trend in the use of hydraulic excavators is realized mainly through the use of various types of interchangeable working equipment. The main excavator manufacturers have created a number of new interchangeable working bodies designed to perform various tasks. This ensures the best use of the energy resources of the machine and mechanization in technological operations that use manual labor. Research is underway to increase the number of types of interchangeable equipment and working bodies. Leading foreign excavator construction companies in France, the USA, Italy, England, Finland, Japan equip the manufactured hydraulic excavators with 5-10 types of interchangeable working equipment with 20-40 interchangeable working bodies such as a direct shovel and reverse, grabs, hook suspensions, cultivators, hydraulic hammers and hydraulic drills, buckets with cultivators, cracking equipment for pavements, rotary cultivators and trenchers, equipment for forestry operations, profile and leveling buckets, grippers for loading and, cargo packaging, pipes and logs a lot of jaw grapples etc [1]. The MM-1 machine is versatile and compact. This is a machine with high maneuverability and multifunctionality that allow performing many types of work unattainable for traditional road-building machines. This machine can be supplied with dozens of interchangeable tools, which ensure the versatility of the loader. Technical features of the machine with excavation and bulldozer equipment. The presence of a hydraulic passage in the transmission; gear pump type NSh-32M4 (Bulgaria), which provides the work of the hydraulic passage and the hydraulic cylinders of the dozer blade, as well as the rotary column of excavation equipment; a pumping station consisting of a gear pump type NSh-100-3 (Russia) to ensure the operation of excavator hydraulic cylinders [7].

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## II. METHODOLOGY

According to the requirements of regulatory documents, energy evaluation of excavation equipment and determination of power consumption are made on the basis of measurements of the torque and speed of their drive. The operation of all actuators of the excavation equipment of the prototype machine is provided by 2 gear pumps, and for energy assessment it is necessary to determine the power expended on their drive. The design of the pump drives does not allow direct measurement of the torque and then calculate the power consumed by their drive. The current GOST 300067-93 "Universal single-bucket full-rotary excavators"/2/allows the determination of estimated indicators by indirect measurement methods in cases where direct measurements are difficult due to the design features of the tested equipment.

It is known that the power to drive a gear pump is determined by the formula:

$$N = \frac{QP}{61{,}2n} \qquad (1)$$

where: $N$ - power for pump drive, kW;
$Q$ - volumetric flow of the pump, l / min;
$P$ - working pressure, MPa;
$n$- total efficiency pump.

The volumetric flow of the pump in l / min is calculated by the formula:

$$Q = \frac{nq}{1000} \qquad (2)$$

where: $q$- pump displacement per revolution, cm3;
$n$- rotation frequency of the drive shaft of the pump, min-1 [4].The working volume per revolution "" and the total efficiency the pump are its main indicators. From the technical characteristics of the pumps it is known that both for the pump NSh-32M4, and NSh-100-3, efficiency can be considered the same and equal to 0.85, and the working volumes "" are, respectively, in the first case 31.5 cm3 and in the second 32 cm3 [9].Thus, to determine the power of excavation equipment consumed by hydraulic pumps, it is enough to carry out only direct measurements of the operating pressure and the speed of their drive shafts.

The energy assessment was carried out jointly with the Uzbek Scientific Research Institute of Mechanization and Electrification of Agriculture (UzMEI) on the basis of a special test program approved by the UzMEI and Tashkent Automobiles and Roads Construction Institute (TARCI) working group in accordance with the recommendations of GOST 300067-93 “Single-bucket universal full-circle excavators”.

## III. LITERATURE SURVEY

Research on the problems of developing technological processes for multi-purpose machines based on the TTZ tractor multi-part machine was carried out by T.I.Askarhojaev [1, 2, 3], L.Ulmasova [3] and K.J.Rustamov [2], research and theoretical calculations of the process of digging, drilling and moving learned by V.I. Balnevne [4], L.A.Hmara [4], Yu.A.Braykovskiy [5], S.I. Kornyushenko [5], I.P. Krutikov [7], and hydraulic excavator operating equipment systems researched by Shapoval, Zaslavskiy, Balovnev, Pohvalov [8].

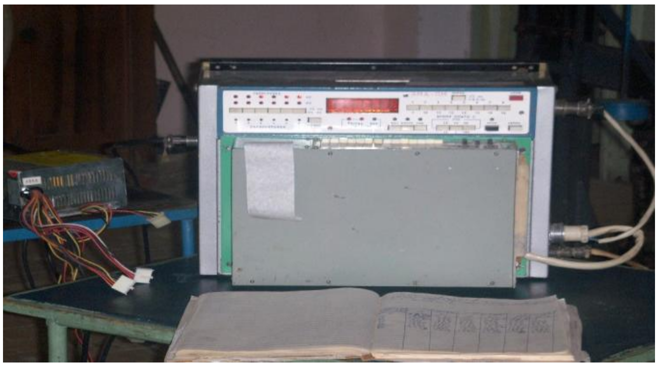
## IV. EXPERIMENT AND DISCUSSION

In accordance with the test program and energy assessment methodology, direct measurements of the following parameters were carried out:

**Table I. Measured parameters**

| № | Name of indicator | Dimension |
|---|---|---|
| 1 | Oil pressure: | |
| | at the exit of the hydraulic ship pump | MPa |
| | at the outlet of the pumping station | MPa |
| 2 | Rotation frequency: | |
| | engine | $s^{-1}$ |
| | pumping station | $s^{-1}$ |
| 3 | Oil temperature | °C |
| 4 | The time spent on the cycles of excavation equipment:<br>- when collecting soil<br>- when lifting the bucket<br>- when turning the boom<br>- when extending the boom<br>- when unloading soil<br>- when turning the boom to the face<br>- lowering the bucket | s (minute)<br>s<br>s<br>s<br>s<br>s<br>s<br>s |

**Methods and means of measurement.** In accordance with the specified governing documents (GOST 300065-93 and GOST 300067-93), the tests were carried out using methods of electrical measurements of non-electrical quantities and, in particular, by means of electrotensometry. Since energy assessment is carried out according to the average values of the measured parameters, the compact measuring and recording equipment EMA-P was used as measuring strain gauge equipment (Pic.1). The equipment was calibrated by the TK-22 strain gauge and its technical condition during the tests, it was also controlled by this strain gauge.



**Pic.1. Measuring and recording equipment EMA-P**

EMA-P Tensoequipment (Russia) provides average values for the experiment on 6 analog (tensometric) channels and 8 discrete channels with a choice of recording time of 7.5; fifteen; thirty; 60; 120 and 240 seconds. The equipment also provides the ability to take measurements with an arbitrary choice of time - the "stop" mode. This is achieved by recording the readings of the measuring and time channels with the subsequent calculation of the average value of the measured parameter in proportion to the standard values of the recording time or one minute [3].

In accordance with the work program, pressure measurements were carried out using TDD-200 strain gauge pressure sensors manufactured by NATI and VISKHOM (Russia). The sensors were calibrated on an MP-600 calibration unit (Pic.2) using an exemplary pressure gauge of 250 kg/cm2.

**Pic.2. Test installation MP-600**

The results of the initial and final calibrations of the pressure sensors showed that the reduced and total error of the measuring channels are within acceptable (+ 2.5%) limits. Using an adapter, the sensor was installed on the pump station NSh-100-3 (Pic.3). An analysis of the kinematic diagram of excavation equipment shows that in order to estimate the rotation speed of the drive shafts of all hydraulic pumps, it is enough to measure only the rotation frequency of the engine crankshaft and, from a technical point of view, measuring this rotation speed is simplest and inexpensive. At the same time, the drive of the pumping station NSh32M-4 has a gear ratio. This at a nominal engine speed of 2100-2200 min-1 provides the following rotational speeds: pump station NSh-32-M-4 - 32.3 s-1 (1940 min-1) and pump NSh-100-3 - 22.5 s-1 (1348 min-1) [1].

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**Pic.3. Strain gauge pressure sensor TDD-200**

To measure the engine speed, a magnetically controlled contact - reed switch was used. To do this, two magnets 2 were installed on the pulley for the drive of the cooling and power supply system installed in the crankshaft of the engine, and a bar was installed in the bars of the left and right tractor spars, into which the connector 4 ShP20 P4 was screwed onto the legs, on which the reed switch was installed. Reed switch using a cable (Pic.4) was connected to the discrete input of the EMA-P equipment. when the engine crankshaft rotates, magnets passing under the reed switch cause its contacts to close, the number of which is calculated by a discrete channel [7].

**Pic.4. Magnetically operated contact - reed switch assembly**

The temperature of the oil in the tank was measured by a digital electrothermometer FLUKE-52 (USA) and it was in the range 52-56 ° C during the experiments. The measuring equipment was installed on the table and the length of the connecting cables provided the possibility of carrying out technological operations in the required volumes. The EMA-P equipment was powered from the power source of the TTZ-80.10 tractor.

**Field test conditions and experimental data processing**.

The tests were carried out on the territory of Kuyi-Chirchik district using a prototype machine based on the TTZ-80.10 tractor when digging a trench, cleaning irrigation networks with excavation equipment Pic.5 and 6). The air temperature was within 16 limits 18·C, clear cloudless weather, no precipitation and no wind loads.

The developed soil was a mixture of sand and gravel with inclusions of tree roots and other plants of category 3 stronger.

**Pic.5. The work of the prototype machine based on the TTZ-80.10 tractor when digging a trench.**

**Pic.6. Operation of a multi-purpose machine based on the TTZ-80.10 tractor when cleaning an irrigation canal**

Test conditions for a multi-purpose machine, especially when cleaning the canal, should be classified as difficult, which is confirmed by the control weighing of soil from the bucket of the excavator with a volume of 0.3 m3. The weight of the soil with a bucket filled with a “cap” ranged between 500-550 kg, and its density reached 1.66-1.83 g / cm3, while the density of the compacted soil, typical for Uzbekistan, does not exceed 1.4-1, 5 g / cm3 [2]. The tested excavator refers to machines with a cyclic mode of operation and therefore the measurements were carried out mainly on the “stop” mode of the EMA-P equipment. in this operating mode, in accordance with GOST 300067-93, for subsequent calculations, it is necessary to determine the average value of the measured parameter for the time interval of one second or one minute according to the formulas [7]:

$$P = \frac{m}{t}K \quad \text{or} \qquad (3)$$

for one minute:

$$P = 60\frac{m}{t}K \qquad (4)$$

where: $m$ - digital indication of the measurement channel of the equipment.

## V. EXPERIMENTAL RESULTS

As a result of field tests, data were obtained that characterize the performance of the MM-1 multi-purpose machine with excavation equipment. The data obtained show (Table II) that among the operations performed by excavation equipment, more time is spent on soil collection, which averages 14.4 s, and the smallest time, i.e. within 2.3-2.5 s, it is spent on turning the boom to unload the soil from the bucket, as well as to lower the bucket back to the bottom.

The rest of the work cycles have practically the same time costs and fluctuates on average between 4.0-5.0 s. Measurement of the pump pressure during the operations of soil collection by the bucket, lifting the filled bucket, turning the boom with the filled bucket, extending the boom, unloading the soil from the bucket, turning the boom back to the bottom and lowering the bucket with it showed that the highest pump pressure of 12.37 MPa appears when lifting a filled bucket with soil. This is due to the fact that the gravity of the boom, stick and filled bucket more affects the energy costs of the equipment. With a change in the load on the operations performed, although not significantly, the pump speed also changes. The change in pump speed occurs within 28.25-30.15 s-1. Based on the indicators of the measured parameters in technological operations with excavation equipment, the results of the energy assessment of the multi-purpose machine MM-1 are derived (table III).

**Table II. The parameters of the measured parameters when performing technological operations of the multi-purpose machine MM-1 (Option - excavator)**

| № п/п | Performance | Pumping Station | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Soil set | Bucket lift | Boom rotation | Extension. booms | Unloading the soil | Turning the boom (back) | Lowering the bucket |
| 1 | Time | | | | | | | |
| | $t_{\max}$, c | 15,0 | 4,1 | 2,7 | 5,9 | 6,3 | 2,4 | 4,4 |
| | $t_{\min}$, c | 13,9 | 1,8 | 2,1 | 2,4 | 4,1 | 2,1 | 4,1 |
| | $t_{mid}$, c | 14,4 | 2,6 | 2,5 | 4,0 | 5,0 | 2,3 | 4,3 |
| 2 | Pump pressure | | | | | | | |
| | $P_{\max}$, MPa | 11,20 | 15,30 | 8,97 | 10,42 | 11,07 | 3,88 | 7,52 |
| | $P_{\min}$, MPa | 10,35 | 11,15 | 6,51 | 9,58 | 9,16 | 3,60 | 7,25 |
| | $P_{mid}$, MPa | 10,70 | 12,37 | 7,68 | 10,12 | 9,63 | 3,74 | 7,34 |
| 3 | Pump speed | | | | | | | |
| | $n_{\max}$, $c^{-1}$ | 29,91 | 29,0 | 30,22 | 29,61 | 29,55 | 30,21 | 30,0 |
| | $n_{\min}$, $c^{-1}$ | 28,77 | 25,93 | 29,10 | 27,45 | 28,55 | 20,11 | 29,6 |
| | $n_{mid}$, $c^{-1}$ | 29,46 | 28,25 | 29,79 | 29,35 | 29,16 | 30,15 | 9,8 |
| 4 | Power spent on pump station drive | | | | | | | |
| | $N_{n\max}$, kWt | 26,82 | 35,46 | 21,06 | 26,1 | 26,0 | 9,45 | 18,0 |
| | $N_{n\min}$, кWт | 24,93 | 23,31 | 15,57 | 22,77 | 21,33 | 8,82 | 17,37 |
| | $N_{n\,mid}$, кWт | 25,56 | 28,26 | 18,45 | 22,68 | 22,68 | 9,09 | 17,64 |

**Table III. The results of the energy assessment of the multi-purpose machine MM-1 (option - excavator)**

| № | Indicators | Soil set | Lift | Turn of an arrow | Extension. booms | Unloading | Turning the boom (back) | Lowering |
|---|---|---|---|---|---|---|---|---|
| 1. | Oil pressure at the outlet of the pumping station, MPa | 10,76 | 12,38 | 7,68 | 10,12 | 9,63 | 3,74 | 7,35 |
| 2. | Station pump speed, s-1. | 29,46 | 28,25 | 29,79 | 29,35 | 29,16 | 30,15 | 32,8 |
| 3. | Power expended on the pump station drive, kW | 25,5 | 28,2 | 18,4 | 24,3 | 22,6 | 9,9 | 18,7 |
| 4. | Effective engine power, kW | 27,7 | 30,7 | 20,0 | 26,1 | 24,6 | 11,4 | 20,6 |
| 5. | Engine operational power utilization factor | 0,48 | 0,53 | 0,35 | 0,45 | 0,43 | 0,20 | 0,36 |

Tests have shown that when collecting soil, the pump pressure was 10.76 MPa, and its speed was 29.46 s-1. At the same time, 25.5 kW of power is spent on the set of soil, and the effective engine power is 27.7 kW. When the operational power of the D-245 engine of the TTZ-80.10 tractor is 57.4 kW, the coefficient of use of the engine's operational power is 0.48.“Max” energy losses and were noted when lifting a bucket with filled soil and energy consumption amounted to 28.2 kW, and the utilization factor of the engine’s operational power was 0.53.Almost the same power costs were obtained by extending the boom with a full bucket and unloading the soil from the bucket, which are, respectively, 24.3 and 22.6 kW. The utilization factor of the operational power of the engine during these operations is 0.45 and 0.43, respectively."Min" power, i.e. 9.9 kW is expended on the operation of turning the boom back to the bottom, while the utilization factor of the operational power of the engine is 0.20.Preliminary tests of bulldozer equipment during cutting operations, soil recruitment and transportation, power costs amount to 23.42·0.2 kW, which corresponds to an engine operating capacity utilization factor of 0.41.

Field tests made it possible to draw a conclusion on the operability of the developed design, as well as on the compliance of the operational power of the engine of the base machine - the TTZ-80.10 tractor with the resistance to arising during the technological operations of the multi-purpose machine MM-1

## VI. RECOMMENDATION AND CONCLUSION

1. The developed mechanism for hinging mounted working bodies expands the range of operation of all types of equipment, which, when operating an excavation and drilling working body, allows to increase the depth of penetration and the height and range of unloading by 12 - 18%, and also provides quick release and easy interchangeability of interchangeable working bodies.
2. Tests of a prototype of a machine equipped with a bulldozer and excavating working bodies in the field showed the efficiency of the developed structures and the drive of the working bodies.

Wherein:
1) "max" pressure in the hydraulic system - 10.76 MPa;
2) Energy consumption for digging with an excavator bucket - 25.5 kW;
3) Energy costs for lifting a loaded bucket - 28.2 kW;
4) Energy costs for soil development with a bulldozer blade - 23.42 kW;
5) Energy costs for transportation of soil dump - 22.3 kW.

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## AUTHORS PROFILE

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