

Evaluation of the traction-chain properties of a wheel tractor in dry peat deposit

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Abstract. The paper highlights the results of studies on the creation of a measuring complex suitable for experimental studies of the towing and coupling and dynamic properties of wheeled tractors operated in difficult geological conditions of peat deposits of various degrees of drainage. The conceptual solutions for the layout of the measuring complex, which allows carrying out field measurements of the kinematic and dynamic parameters of machine-tractor units, to measure the hook force and torque on the power take-off shaft, are presented. Solutions are proposed to support the testing process with auxiliary devices that create hook loads on tractors. The requirements for the organization of a technological site for conducting traction tests of wheeled tractors are given. As a result of the research work, a test procedure was developed; the issues of metrological support of research and processing of experimental data were resolved.

1. Introduction

The productivity of machine-tractor units (MTU) in the main technological operations for the extraction of peat depends both on the design parameters of the machines and on the properties of the deposits of the developed field [1, 2, 3, 4,11]. The physicommechanical properties of the peat deposit are decisive in the formation of the tangential traction force by the tractor wheel propulsion. These properties are mainly determined by the type of peat, the degree of decomposition, and humidity along the depth of the peat massif [5, 6,12].

Due to the significant variability of factors that have a direct impact on the cross-country ability of vehicles with wheeled engines in the conditions of a peat deposit, when changing the operating modes of the units, adjusting the technological scheme, changing the type of tires or switching to the use of new machine-tractor units, issues of assessing the patency of wheeled vehicles come to the fore in all operating conditions in the real conditions of the field being exploited. The creation of mobile measuring systems, which allow carrying out field measurements of the kinematic and dynamic parameters of machine-tractor units, to measure the hook force and torque on the power take-off shaft, to develop unified requirements for the organization of pilot sites and the test process as a whole, will make it possible to carry out comparative tests to obtain objective information allowing reasonably make technical and technological decisions, with a guarantee of their applicability in the conditions of a particular enterprise.



2. Materials and methods

In order to conduct research using the available exploration data, five technological sites were selected for milling peat extraction. Three of them are sites on the lowland deposits with a surface layer humidity in the range from 65% to 94%, and two sites with a transitional and upper deposits with an average operational humidity in the range of 78-81%.

Sampling for humidity control was carried out according to the sample scheme shown in (Figure 1). Humidity was determined in laboratory conditions by a standardized method (GOST 278-54). To determine the bearing capacity, a densitometer was used [7,13].

At each of the five sites, five test plots were marked. The lengths of the control sections, as well as the sections for accelerating and stopping the tractor between the experiments were selected according to the available technical requirements for traction tests.

Currently, a wide range of tractor tires with various treads is available. Despite the conditional separation of tires by application depending on design features, the effectiveness of a particular tire in different enterprises in terms of patency is not guaranteed by the manufacturer, and additional field tests are required on a particular wheeled tractor mover.

In the territory of the CIS countries, a major producer of tractor tires is the «Belshina» production association. The tires of this manufacturer are equipped with movers of wheeled tractors of traction classes 1.4 and 2. Tires are very diverse both in external geometric dimensions and tread, and in operational parameters. To carry out comparative traction and technological tests of the MTZ-852 tractor at the peat field under development, three sets of tires were selected that are used to complete the front and rear drive axle propulsors in various modifications: 1) serial: FDA - (8.3 / 8-20) V-105, RDA - (15.5-38) F-2A; 2) experienced: FDA - (16.20-20) F-64, RDA - (18.4-34) F-11; 3) rice-growing: FDA - (16.0-20) F-76, RDA - (18.4-34) F-44. The features of the 2nd and 3rd tire sets compared to the serial are the increased width and outer diameter of the tires, and the difference, including among themselves, is determined by the difference in the height of the lugs and the density of the tread pattern.

Based on the selected three sets of tires, five layout schemes of a tractor propulsion unit with a 4x4 wheel arrangement were created under conditions of peat mining (Table 1).

Table 1. Ways to install wheels on a tractor

Drive axle	Tire Layout Number				
	1	2	3	4	5
Front	(8.3/8-20) V-105	(16.20-20) F-64	(16.0-20) F -76	Dual (1+1)	(16.0-20) F -76
Rear	(15.5-38) F -2A	(18.4-34) F -11	(18.4-34) F -44	Dual (1+1)	Dual (3+1)

The front wheels were doubled according to the 4th scheme by installing the disk of the added wheel directly on the bolts of the main wheel disk in the order: left - to the right, right - to the left. The rear wheels in the 4th and 5th layout schemes were doubled through transitional standard hubs.

The pressure in the tires was set as low as possible according to the technical characteristics of the tires: front in the range from 0.14 to 0.16 MPa; rear tires in the range from 1.0 to 1.2 MPa.

One of the additional tasks in the process of traction testing was the development of a method and device for creating a hook load of a tractor. At present, several methods for creating a tractor hook load during traction tests are known and widely used. In particular, the hook load can be realized using the appropriate selection of technological machines that would provide a stepped increase in traction to the maximum realized by the tractor. On solid soils and roads of various categories, transport trucks with variable load are used. In the study of transient and transient modes of operation, as well as in special tests, the hook load is created by braking the mover of the towed tractor. The main task when choosing a method for creating a hook load is the possibility of its stepwise change over a wide range up to the maximum possible in accordance with the traction class of the tractor.

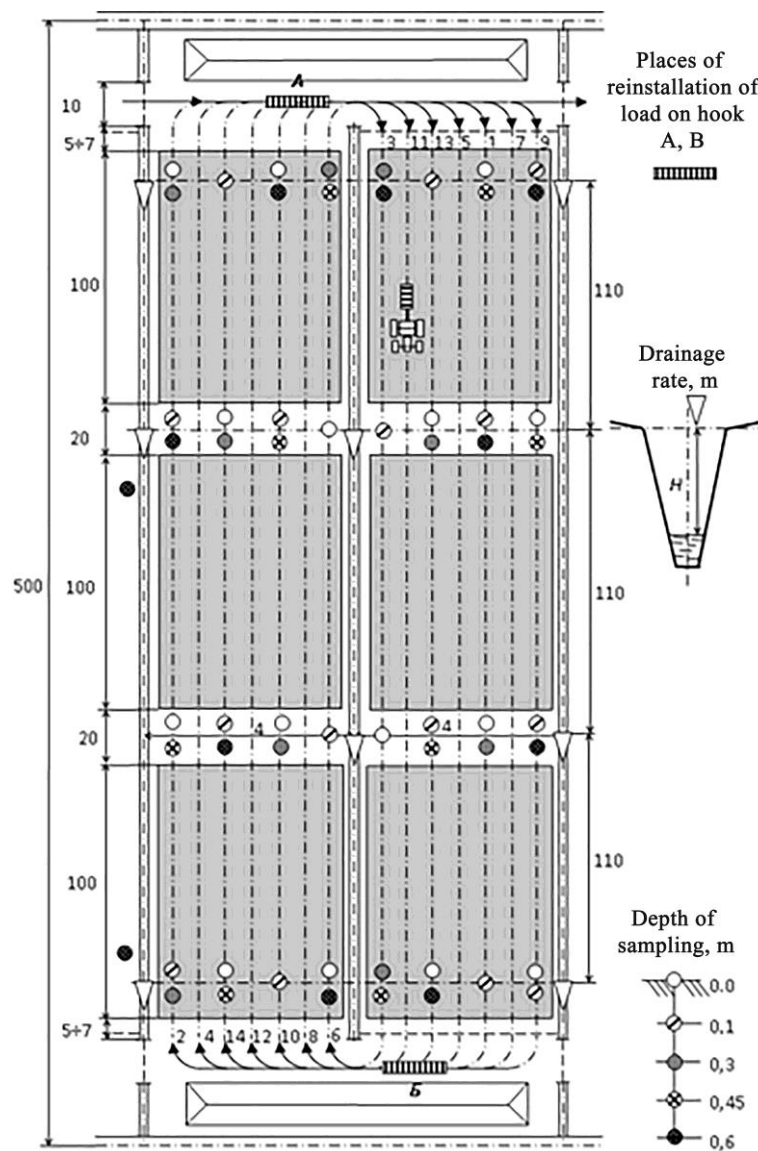


Figure 1. Scheme of the technological site for traction testing of wheeled tractors

During the traction tests of the MTZ-852 tractor at the production sites for milling peat milling of the «Zelenoborskoye» enterprise (Republic of Belarus, Minsk region), the hook load was created by a set of spent track caterpillars of the MTF-43 milling peat harvesting machine. Caterpillar tracks were grouped into seven sets of twenty links, which allowed ensuring the entire range of the hook load realized by the tractor. Link sets 1 (Figure 2) were connected in three rows to the tow hitch 2 and, using steel cables 3 (length 2.5-3.0 m), to the link 4, mounted on the cross-section of the tractor rear linkage.

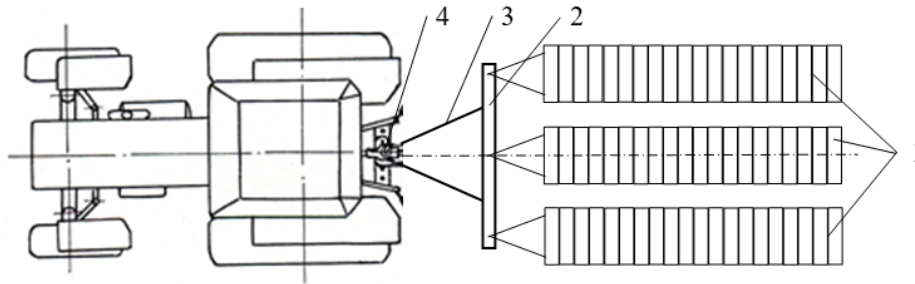


Figure 2. Scheme of formation of the hook load of the tractor using sets of links of the caterpillar chain

The track links of the MTF-43 machine do not have lugs, which made it possible to carry out traction tests for a long time without significant disturbance to the relief and surface structure of technological platforms, on which milling peat extraction machines operated simultaneously.

3. Results and Discussions

During the traction tests of the MTZ-852 tractor on a peat base, tractor operating modes were created that made it possible to more fully study the traction and coupling characteristics of the propulsion device, as well as the tractor's energy capabilities when aggregating it with the main technological machines. These modes were provided by tests of a tractor equipped with alternating propulsors in accordance with the accepted layout schemes (table 1) at five technological sites under conditions of variation of parameters in terms of humidity and bearing capacity of the peat base. The change in operating modes was achieved by connecting the front drive axle automatically or forcefully, as well as automatically locking the differential of the wheels of the rear drive axle, in the range of tractor speeds provided by gears from the 3rd to the 7th gear change box with the reduction gear turned off.

Traction tests were carried out in series with the equipment of the tractor mover according to one of the layout schemes (table 1).

During the testing the following processes were carried out:

1. Registration of controlled parameters of the machine during forward and reverse tractor movement in five control sections and in five gears from 3rd to 7th with automatic inclusion of the front drive axle without hook load. After this, the front drive axle was forcibly turned on and a series of experiments was repeated.
2. Repeat a series of experiments with successive loading of the tractor with hook force due to the connection of one, two, three, etc. sets of loads up to the limit values for the traction class of the tested tractor. These experiments were carried out before loading the tractor with the maximum possible hook force in this mode.
3. Registration of tractor idle motion parameters when towing it by another tractor.
4. Conducting experiments on points 2 and 3 on the remaining four sites.
5. Sequential equipment of the tractor by the movers of the remaining layout schemes (table 1) and the repetition of the experiments in paragraphs 2, 3, 4.
6. Conducting experiments according to paragraphs 2, 3, 4 with the layout schemes of the propulsion device 3, 4, 5, which ensured the patency of the tractor at the same five technological sites with a surface layer moisture depth of 100-250 mm up to 94%, and in some cases more.

The layout schemes of the mover were completed in the sequence 1, 2, 3, 5, 4, which is due to the smaller amount of work on the installation, dismantling and re-installation of elements of the movers.

Processing of experimental data was carried out in two stages. At the first stage, the values

calculated by the procedure were calculated from the measurement results. The necessary statistical analysis of the data was carried out in the second stage.

The kinematic characteristics of tractor movement in both traction and technological tests were established in the following sequence:

- the actual speed of movement $v = L/t$ was determined, where $L = 2\pi Rn$ is the distance traveled, measured using the "fifth" wheel; R - is the kinematic rolling radius of the "fifth" wheel; n - is the number of revolutions of the "fifth" wheel during the experiment t ;

- determined the theoretical speed of the tractor in a given mode. The speed value was taken equal to the actual speed when the machine moves without load (idle tractor passage):

$$v_t = v_r = \frac{2\pi R n_0}{t_0} \quad (1)$$

where n_0 , t_0 - the number of revolutions of the "fifth" wheel and the experiment time at idle tractor, respectively;

- the conditional coefficient of tractor slipping was determined by the formula:

$$\delta = \frac{v_t - v}{v_t} \cdot 100\% \quad (2)$$

- slip coefficients for the drive wheels, or slip for the driven wheels were calculated by the formulas:

$$\delta_k = \frac{L_t - L}{L_t} \cdot 100\%, \quad \varepsilon_k = \frac{L - L_t}{L} \cdot 100\%, \quad (3)$$

where $L_t = 2\pi R_t n_r$ - is the length of the path that the wheel would go, making n_r revolutions, with a rolling radius equal to the rolling radius R_t at idle; n_r is the number of revolutions of the wheel during the working passage;

- traction power and traction efficiency of the tractor were determined by the formulas:

$$N = P v, \quad \eta = \frac{N}{N_e} \quad (4)$$

where P - is the mathematical expectation of the hook effort in the experiment; N_e - is the installed power of the tractor engine.

Statistical processing of experimental data was carried out in order to calculate estimates of the mathematical expectation and standard deviation of the values of the determined values, as well as to test hypotheses about the laws of their distribution. This part of the data processing was carried out according to standard programs from the computer software.

In order to ensure field testing of tractors, a measuring complex was developed that is installed directly on the test machine with the ability to control and perform control functions at the workplace of the machine operator.

For testing the MTZ-852 tractor in conditions of peat mining, the measuring complex included a power source, a control panel, a personal computer, distribution blocks, current collectors, strain gauge sets, strain gages and traction strain gages, angular velocity sensors, pulse and potentiometric sensors, devices for installing devices on the tractor, as well as connecting cables. For the purpose of unification, measuring channels were included in the structure of the measuring complex for recording the stress state of the parts, their rotation frequency, and also the relative angular displacement of the mating parts [8, 9]. Such a layout of the complex made it possible to carry out remote synchronized measurements of the recorded parameters using sensors located at different points of the MTU.

The measuring channels of the complex are formed as follows.

The channel for determining the loads according to the stress state of the parts includes a strain gauge bridge with additional and adjusting resistances. It is used to measure the torques on the wheels and the power take-off shaft. In the strain gauge connection schemes, balanced four-arm bridges are used, the loads are determined by the unbalance value of which. To ensure operation on an amplifier-free circuit, the shoulders of the bridge are active, several strain gages are connected to each of them.

The measurement of the rotational speed of the tractor wheels and the "fifth" wheels is made by pulse sensors, which together with the resistance to adjust the second type of measuring channel. The third type of measuring channel serves to measure the speed of the power take-off shaft. It uses a

tachogenerator.

The registration of the hook load during the tests was carried out using a special traction link, in which the sensor is a potentiometer. It makes up the measuring channel of the fourth type.

Figure 3 shows the installation diagram of devices and measuring and recording equipment on a wheeled tractor.

As a power source used batteries 1 large capacity, providing a stable voltage on-board network. To configure and adjust the measuring channels, turn the equipment on, the control panel 2 is used. The information received from the measuring channels is displayed and stored on a personal computer 3.

The torques on the wheels of the front and rear driving axles are measured by tensor 4 and 5, and the wheel speeds are measured by impulse sensors 6 and 7. The load on the hook is measured by traction link 9, the torque on the power take-off shaft and its speed by sensors 8. The tractor moves cornering is fixed by a sensor 10 mounted on the elements of the steering trapezoid of the front wheels.

Measuring instruments are mounted on damping devices in the form of spiral springs and rubber gaskets.

To fix the kinematic parameters of tractor operation, the system includes two piano-type wheels 15 (fifth wheels), which are mounted on the tractor frame using articulated parallelograms 12 and extendable transverse pipes 11. The forks of the "fifth" wheels are equipped with impulse sensors 14, which are wheel revolution counters and are used to measure the distance traveled. On the tractor frame there are pulse sensors 6 and 7 for reading the number of revolutions of the wheels of the front and rear axles. According to the readings of these sensors and a time counter, the actual speed of movement and slipping of the propulsion device are determined. In the vertical hinges of the "fifth" wheels, potentiometric sensors 13 are fixed, which register the angular deviations of the wheels, which makes it possible by conversion to find the kinematic characteristics of the movement of the MTU in the corner. The deformation of the carrier base of the mover is determined by the readings of potentiometric sensors 16 located in the horizontal joints of the movable parallelograms 12.

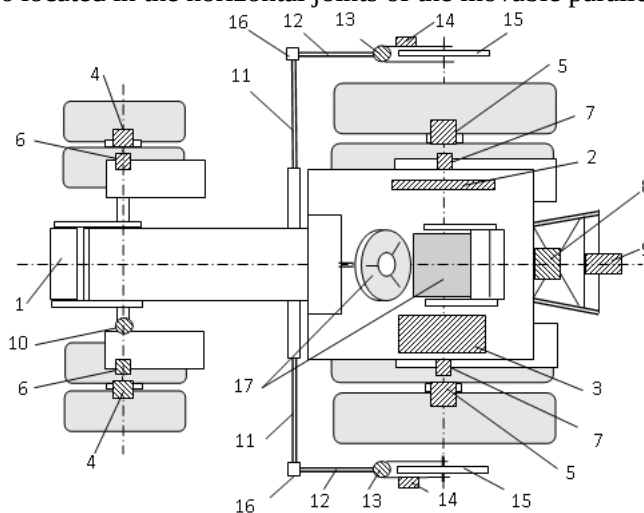


Figure 3. Layout of measuring and recording equipment on a wheeled tractor

The tractor is controlled and the measuring system is operated from the driver's workplace 17, which is played by an experimental engineer with a license to operate the tractor.

Processing of experimental data is performed on a computer using PowerGraph software [10, 14]. PowerGraph software supports a wide range of digital measurement equipment. A high-quality and productive system of information visualization, mathematical processing of analysis, import and export of data allows organizing an effective data recording system with automatic control.

The hook force in the process of traction and technological testing was measured by a specially made traction link.

The main elements of the traction link (Figure 4) are a coil spring 1, a body and a rod, and a potentiometer. The housing consists of a main fork 2 with four studs 3, on which the thrust wall is fixed 4. The rod 5, with the front wall 6 and the hooked fork 7 fixed thereon, makes up the movable part of the device. A potentiometer 8 is fixed on the abutment wall 4, on the input shaft of which is mounted a gear 9, which engages with a rack 10 mounted on the front wall. The potentiometer is connected to the measuring circuit with a connector 11 fixed to the fork 2. The traction link from the side of the main fork with two fingers 12 is mounted on the diameter of the tractor hitch. The towing fork with the help of the pivot 13 is the coupling of the tractor with the trailed machine.

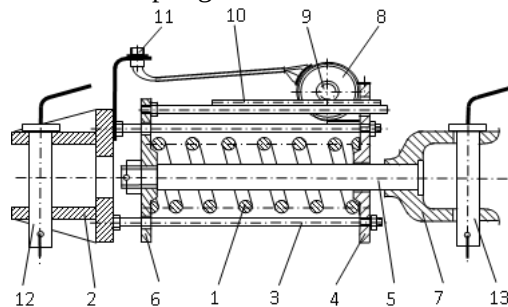


Figure 4. Traction link

The traction link developed for the measuring complex works as follows. Under the action of the hook load, the rod acts on the spring 1 and compresses it. In this case, the distance between the front and persistent walls changes by the amount of spring deformation. Together with the front wall, the rail 10 mounted on it moves, rotating the gear of the potentiometer mounted on the thrust wall [15, 16].

To measure the torque on the power take-off shaft and its rotation frequency, device 8 was used (Figure 3), consisting of an intermediate shaft placed between the PTO shaft and the driveshaft, with load cells glued on it, connected by a bridge circuit, and also connected in parallel with flexible transmission of the tachogenerator. To feed the circuit and remove the electric signal from the rotating shaft, a continuous mercury-amalgamated TRAP type current collector was used.

Torque measurements were carried out when aggregating a tractor with a MTF-13 milling drum, as one of the most energy-intensive trailed machines.

4. Conclusion

To ensure field testing of tractor units in difficult mining and geological conditions of peat deposits of various degrees of drainage, a concept has been developed and a mobile measuring system has been created that allows field measurements of the kinematic and dynamic parameters of the tractor, hook force and torque on the power take-off shaft. Methodological support was developed for testing tractors at standardized experimental sites. As a result of the research work, the issues of metrological support of research and processing of experimental data were resolved. The research results were tested in the conditions of the existing «Zelenoborskoye» peat enterprise (Republic of Belarus, Minsk region).

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