ABSTRACT

Gaponov O.O. Improving the efficiency of multi-scraper chain trench excavators based on critical depth soil blocked cutting.

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The dissertation is devoted to the solution of the topical scientific and applied problem of increasing efficiency of multi-scraper chain trench excavators at the expense of critical depth soil cutting with its cutters.

The dissertation substantiates the relevance of the topic, formulates the object, subject, purpose and objectives of the study, describes the research methods, as well as the association of the paper with the scientific programs, plans, and topics. It also provides information on testing and publication of research results.

Since the soil development with cutters in conditions of critical depth cutting can reduce energy consumption of the trenching process and increase the productivity of chain trench excavators, the topic of this dissertation should be considered relevant.

The scientific novelty of the obtained results lies in the development of generalized theoretical dependences, which were first obtained to determine the basic parameters of the working body and operation modes of a chain trench excavator whose cutters work in conditions of critical depth cutting. In particular, the following results were obtained for the first time:

– the preconditions for increasing the efficiency of chain trench excavators due to critical depth soil cutting are substantiated and the length of the ploughshare of the extreme side cutters for these conditions is determined;

– the main parameters of the working body and the operation modes of the excavator are determined, which are: the angle of lateral extensions of the cut to the horizon, the distance between adjacent ground-excavating bodies, the number

of cutting lines and the number of cutters in the face, the height of the scrapers, the speed of cutting and feeding, cutting strength and others;

- the technique of carrying out experimental check of theoretical positions is developed and natural samples of a working body cutters and their combinations for the test in the soil channel and in field conditions are created;

- the algorithm of engineering calculations is developed and the nomograms for definition of the basic parameters and operating modes of excavators depending on geometrical parameters of cutters, parameters of a trench and soil conditions are built;

– the calculations confirm the economic efficiency of modernization of chain trench excavators with critical depth soil cutting due to the reduced energy costs of the process of soil development and increased productivity of trenching and the pace of work on laying underground utilities.

The efficiency of chain-scraper excavators is ensured by the minimum energy consumption of the working process and the maximum productivity of the machine, which in turn depend on the shape of the cutters, their number and arrangement.

It is known that when the depth of soil cutting with blades increases to critical, the energy consumption of the working process multiplies, because the intensity of the increasing resistance to cutting is less than the cross-sectional area of the cut. In supercritical cutting, the resistance of the soil to cutting with a blade increases due to the soil pressing into the side walls of the cut, and the area of the fracture zone remains unchanged because it is impossible to affect the process of soil destruction of the day surface. As a result, energy consumption of the work process gets bigger.

The existing analytical and experimental models of interaction of multi-scraper chain trench excavators with soil do not determine the technological parameters of the machine considering soil cutting with the cutters at the level of critical depth. Thus, the existing recommendations for the design of machines do

not provide the minimum energy consumption and maximum productivity of the work process.

In order to determine the geometric parameters of the ploughshare, which performs asymmetric blocked soil cutting, the characteristic shape of the body of the chipped soil for this case and the forces acting on it when interacting with the soil were considered. From the obtained calculated dependences it was found that the relative length of the ploughshare depends on the scheme and cutting angle of the cutters and the physical and mechanical properties of the soil. Thus, when changing the cutting angle of the cutters from 20° to 50°, the relative length of the ploughshares decreases: for the scheme of asymmetric blocked cutting with extreme side cutters from 3.52 to 1.63 for semi-hard loam and clay and from 2.52 to 0.93 for hard sand; for the scheme of semi-blocked cutting with medium cutters from 33.3 to 6.66 for semi-hard loam and clay and from 47.2 to 7.27 for hard sand; for the scheme of semi-blocked cutting with extreme side cutters from 1.8 to 1.5 for semi-hard clay, from 1.33 to 1.12 for semi-hard loam and from 0.87 to 0.66 for hard sand.

The dependences obtained in determining the critical depth forces of soil cutting and energy consumption of the trench digging process with a continuous scraper excavator provide an opportunity to supplement the calculations and create a comprehensive method of calculating the machine based on the principles of the most effective soil destruction of blocked and semi-blocked soil cutting by cutters of the working body of the excavator. It is established that the energy intensity of the working process takes the minimum values at the cutting angles of the cutters α_p=20…30°, increasing in direct proportion with the increase of the trench width. Also, the energy consumption decreases with the increasing width of the cutters.

The specific digging force (at the critical depth of cut) is numerically equal to the energy consumption of one cubic meter of soil and for semi-hard loam (category II soil) varies from 147.7 kPa for $\alpha_p = 20$ ° to 225.8 kPa for $\alpha_p = 50$ °.

To substantiate the efficient modes of operation for many scraper excavators and the width of their extreme side cutters, the conditions of effective unloading

were determined and the parameters of the dependence of the change of soil movement on the surface of unloading scrapers on the unloading time were established. For the same purpose, the dependences of the speed of blocked cutting on the width of the trench were determined. After that, the technical performance of the excavator was found on the basis of determining the bearing capacity of the soil of one group of cutters operating in conditions of critical depth of soil cutting, taking into account the physical and mechanical properties of the soil. The determined conditions allowed establishing the width of the extreme side cutters that carry out asymmetric blocked cutting of soils.

It was established that the time of soil unloading from scrapers virtually does not depend on the angular velocity of the drive sprocket of the chain within its change within 5… 9 rad/min in the unloading area. At the same time, increasing the width of the knife, for example, from 0.02 m to 0.03 m when digging a trench in the loam requires reduction in cutting speed by 1.5 times.

The obtained calculation dependences for calculating the technical productivity of the excavator were obtained by determining the bearing capacity of the soil of one group of cutters operating in critical cutting depth, which made it possible to establish the width of the extreme side cutters performing asymmetric blocked cutting. For example, for semi-hard loam, it should be larger than the width of the middle cutters.

The obtained results take into account both the technological aspects of the excavator operation and the physical and mechanical properties of the soils developed by the cutters in the conditions of the critical depth of their cutting. This distinguishes the research conducted in the paper from the previous ones. The obtained calculated dependences make it possible to consider and analyze the main factors affecting the processes of trench development and substantiate the parameters of the machine and its working equipment, which provide minimum energy consumption and maximum productivity of the excavator taking into account physical and mechanical properties of soils.

Thus, it can be affirmed that an applied aspect of the use of the obtained scientific result is the possibility to improve the working equipment for designing more efficient scraper trench excavators. Reducing energy consumption and increasing productivity are important technical indicators that determine the cost of not only digging a trench, but also of laying linear-long sections of underground distribution utilities on the whole.

The practical significance of the obtained results of the work includes the development of a methodology and creation of algorithm for determining the parameters and operating modes of chain-scraper trench excavators on the basis of critical deep cutting of soils. On the basis of the received engineering calculations the technical task for modernization of the ETC-208 excavator which was accepted in production by LLC SPE "Gaztekhnika LTD" and LLC SKTB "Hydromodul" was made. The machine was used in the development of trenches for laying underground communications by a specialized construction company "Kharkivspetsbud-1".

The results of the research are used in the educational process, in particular, in lectures, practical classes, laboratory works and course designing in the disciplines "Earth-moving machines", "Dynamics of construction and road machines" for the students of bachelor and master educational levels in knowledge area 13 "Industrial Engineering" in specialty 133 – "Lifting and transport, construction, road, reclamation machines and equipment".

Key words: trench digging, trench excavator, scraper excavator, scraper, cutter, critical depth, soil cutting.

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