OPTIMIZATION OF MAIN PARAMETERS OF TRACTOR AND UNIT FOR DEEP PROCESSING OF SOIL ACCORDING TO CRITERION - TOTAL ENERGY COSTS

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Abstract. The article is devoted to the substantiation of the main parameters of the tractor (tractor weight and engine power) and the unit for deep soil cultivation (up to 0.6 m). Calculations using a systemic energy mathematical model of soil-cultivating units showed that there is an optimal combination of the tractor weight and engine power, which remain stable, when most of the main parameters of the system "tractor – implement – operator – field – soil – crop" (TIOFSC), as well as environmental factors changed. The optimal weight of the tractor in deep tillage does not change, when most of the factors of the TIOFSC system change, and remains equal to 240 kN. There is a feature in this technological operation – the more the tractor weighs, the lower the total energy costs, which is associated with insignificant crop losses from the negative impact of tractor wheels on the soil. In the calculations, the maximum tractor weight of 240 kN was adopted based on the availability of wheeled tractors in the production (John Deere and New Holland 9000 – series). The revealed optimal engine power of the tractor is related to its weight and in our calculations it is 600 hp. Unlike the main parameters of the tractor, the implement's working width depends on environmental factors (soil hardness, its resistivity, etc.) and ranges from 6 to 8 m (a larger value for light soils). The speed of the unit depends on the parameters of the tractor, the width of the implement and soil properties, it ranges from 8 to 10 km·h^{-1}, which allows to somewhat control the energy efficiency of the unit when changing soil properties. At work with such parameters total power expenses will be in area 4000-5000 MJ·ha^{-1}. The deviation of parameters of the tractor and the unit from recommended conducts to growth of the size of total power expenses.

Keywords: tractor; aggregate; optimization; energy; tractor mass; power; yield loss.

Introduction

In recent years, the agriculture of the Republic of Tatarstan has developed a trend of transition to energy-saving technologies: minimal soil processing technologies, and even no-till technologies. To do this, economic calculations are made and the effectiveness of the transition to these technologies is justified, which is associated with a reduction in the cost of production resources. It does not take into account that in practice the yield of cereals in the first year decreases. One of the reasons for the decline in cereal yields in the first and subsequent years is excessive soil compaction, increasing its density and hardness [1-11]. Therefore, the content of the soil humus on these technologies should be more than 3-3.5 %. Naturally, because of this, there is a need for deep periodic non-field looseness of the soil on the field [12-14].

Periodic deep soil processing improves the culture of agriculture, as it leads to increased soil moisture and, accordingly, increases the accumulation of moisture available to plants. At the same time, the flushing of the top fertile soil from the fields to ravines, rivers and lakes is reduced (every year in the world due to this negative process is withdrawn from the circulation arable land equal in area to the 3rd of territories of the Republic of Tatarstan). The relevance of this technological operation for agriculture of the Republic of Tatarstan and the Russian Federation as a whole is not in doubt.

Equally relevant is the problem of scientific justification for the choice of technology and its parameters for this technological operation [15-16].

Materials and methods

An energy mathematical model of the unit performing this operation was developed. Features of the model used and its novelty are that the criterion for choosing the technique and optimizing its parameters is the criterion – total energy costs, which takes into account the impact of technology and its parameters on the harvest. [16-22].

The energy criterion for optimizing the parameters and operating modes of the tractor and tractor-implement units on seeding as a whole will look as follows [21]:

$$E = E_{m.tr} + E_{m.imp} + E_{rts} + E_{u.c.} + E_{drv} + E_{fo} + E_{agr} + E_{exp} \rightarrow \min, \quad (1)$$

where E – specific total energy expenditure, MJ·ha^{-1};

$E_{m.tr}$, $E_{m.imp}$ – energy spent, respectively, for the manufacture of a tractor and agricultural machine, per 1 hectare, MJ·ha^{-1};
E_{rts} – energy spent on all types of repair and technical service of a tractor and agricultural implement, MJ·ha^{-1};
$E_{u.c.}$ – energy spent on assembling and disassembling the seeding unit, MJ·ha^{-1};
E_{drv} – energy spent by the machine operator on the control of the unit (turning, stopping and starting and shifting gears), MJ·ha^{-1};
E_{fo} – energy spent for fuel, MJ·ha^{-1};
E_{agr} – energy of the crop lost due to violation of the technological terms of the technological operation, MJ·ha^{-1};
E_{exp} – energy of the crop lost due to soil compaction by the tractor wheels, MJ·ha^{-1}.

Results and discussion

Numerous computational experiments were conducted using the developed energy mathematical model – the results of the calculations are presented in Fig. 1-5. The original data for the calculation:

- single field area = 100 ha;
- length of the unit run before turn = 1 km;
- moving distance from field to field = 2 km;
- seed density = 800 kg·m^{-3}
- coefficient of strength of the bearing surface = 0.9;
- scope of work = 500 ha;
- number of tractors performing the operation = 1;
- number of hours of work per day = 20 h;
- planned productivity of main and by-products = 40 c·ha^{-1};
- pressure in the tires (from 0.08 to 0.20) = 0.16 MPa;
- number of wheels on one side of the tractor (1 or 2 or 3, etc.) = 1;
- coefficient of traction of wheels with soil = 0.7;
- coefficient of resistance to rolling of tractor wheels = 0.08.

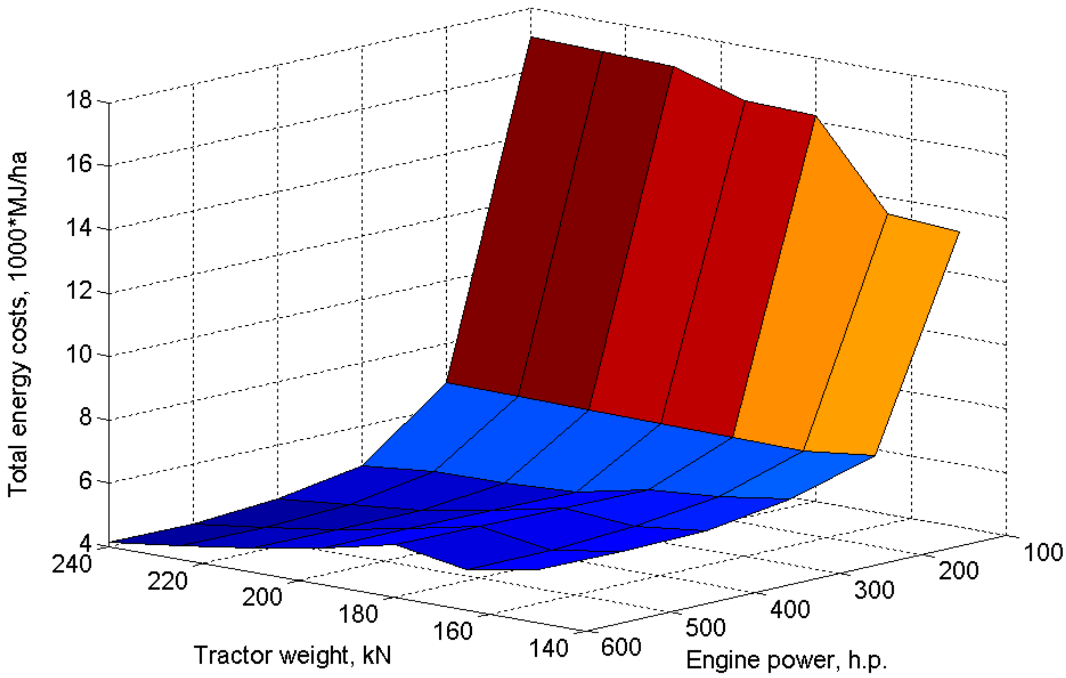

Fig. 1. **Graph of the dependence of total energy costs in thousands. MJ·ha^{-1} from the weight (cn) of the tractor and the power of its engine in hp**

Calculation results:

- B_{opt} = 8 m – optimal for the conditions of calculation of the width of the capture of the unit;

- V_{opt} = 10 km·h^{-1} – optimal for the conditions of calculation of the speed of the unit;
- G_{tiopt} = 240 kN – optimal for the conditions of calculation of the weight of the tractor;
- N_{eopt} = 600 hp – nominal power of the tractor engine;
- N = 589.4 hp – optimal engine power required for the conditions of calculation;
- E_{min} = 3992.3 MJ·ha^{-1} – amount of total energy costs.

Figure 1 assumes that there is an optimal combination of the weight of the tractor and the power of its engine, when the total energy costs of the unit for the performance of the technological operation are minimal. The size of the main parameters of the tractor corresponds to the maximum possible values and is limited by the allowable weight of the tractor and the power of its engine. From the practice of world tractor-building, we limited the weight of the tractor to 240 kN, and the power of its engine 600 hp. At such parameters, the tractor should operate with an 8-metre width deep-thinning at 10 km·h^{-1}.

The question naturally arises: Do these calculation parameters and the mode of operation of the unit remain when the conditions of the work change?

Consider the influence of some of the most important environmental factors of the TIOFSC system (tractor – implement – operator – field – soil – crop), on the optimal values of the parameters of the unit. Fig. 2 shows the dependence of the parameters and modes of operation of the unit for deep loosening of the soil on the area of the field.

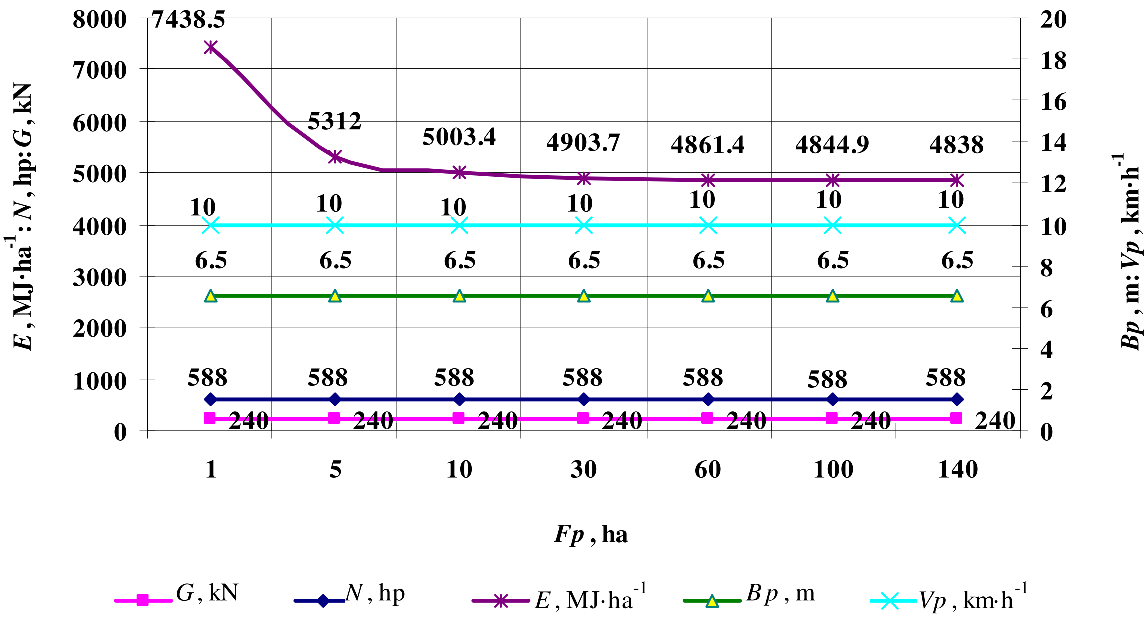

Fig. 2. **Depending on the total energy costs, parameters and modes of operation of the unit from the area of the field being processed**

As it can be seen from Fig. 2, all the calculated parameters of the unit do not depend on the size of the field, but the total energy costs with the decrease in the field area increase in hyperbolic dependence. It is expensive to work on small fields.

This is due to a decrease in the performance of the unit (ha·h^{-1}) in small fields, which naturally leads to an increase in the loss of grain energy from the violation of agrotechnical terms of operation.

Fig. 3 shows that all parameters of the unit remain constant, when the seasonal load changes to the unit in the range of 300 to 600 hectares. At the same time, the total energy costs with the increase in the seasonal load on the unit increase and this is due to the increase in the duration of the technological operation, and therefore, an increase in the energy of the lost crop.

Fig. 4 shows the dependence of the total energy costs and parameters of the unit on the specific resistance of the deep-sliver.

As it can be seen from the picture, with the consistency of the parameters of the tractor itself, the width of the capture of the unit, with the increase of the specific resistance of the loosener from

8 kN·m^{-1} to 16 kN·m^{-1}, tends to decrease. At the same time, the width of the capture of the unit is reduced from 11.5 m to 6 m, almost 2 times, and the optimal speed of the unit varies from 8.5 to 10 km·h^{-1}. With the increase in resistance of the snare within these limits, the total energy costs increase almost twice from 2800 to 5400 MJ·ha^{-1}.

With the increase in hardness of the soil, as seen in Figure 5, the total energy costs increase, the parameters of the tractor remain stable, the width of the capture of the unit is reduced from 6.5 to 5.5 m, the speed depends on the width of the capture unit and varies from 8 to 10 km·h^{-1}.

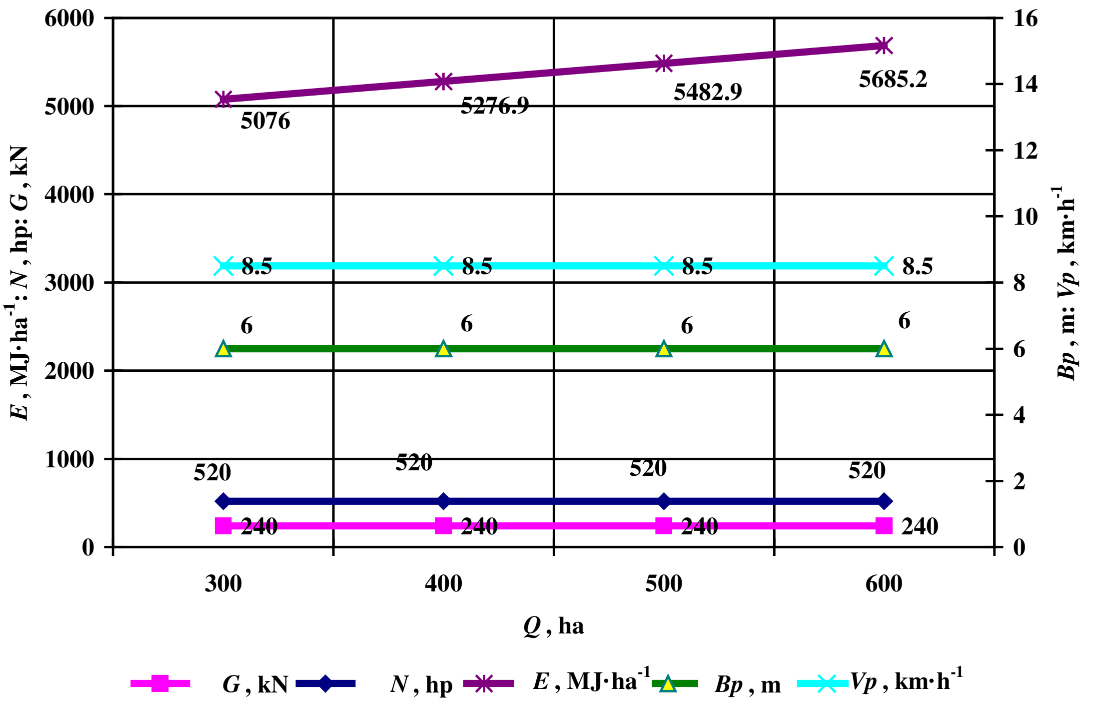

Fig. 3. **Depending on the total energy costs, parameters and modes of operation of the unit on the annual load of the snarl**

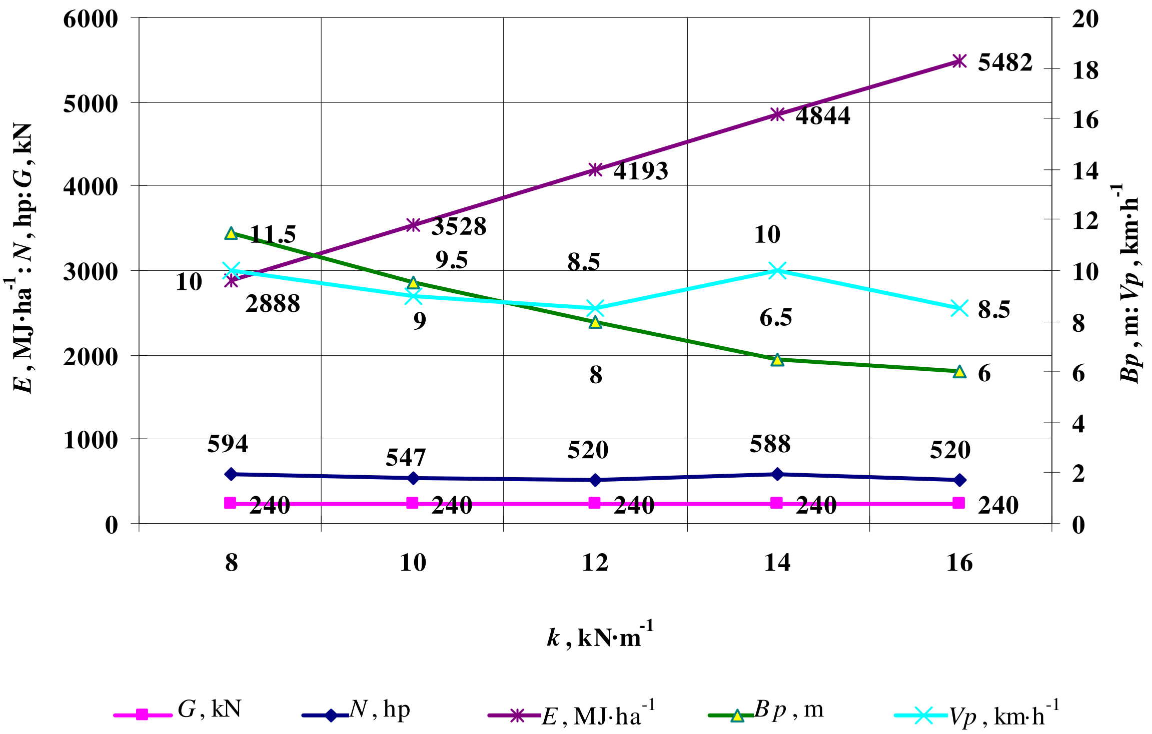

Fig. 4. **Depending on the total energy costs, parameters and modes of operation of the unit on the specific resistance of the soil snarl**

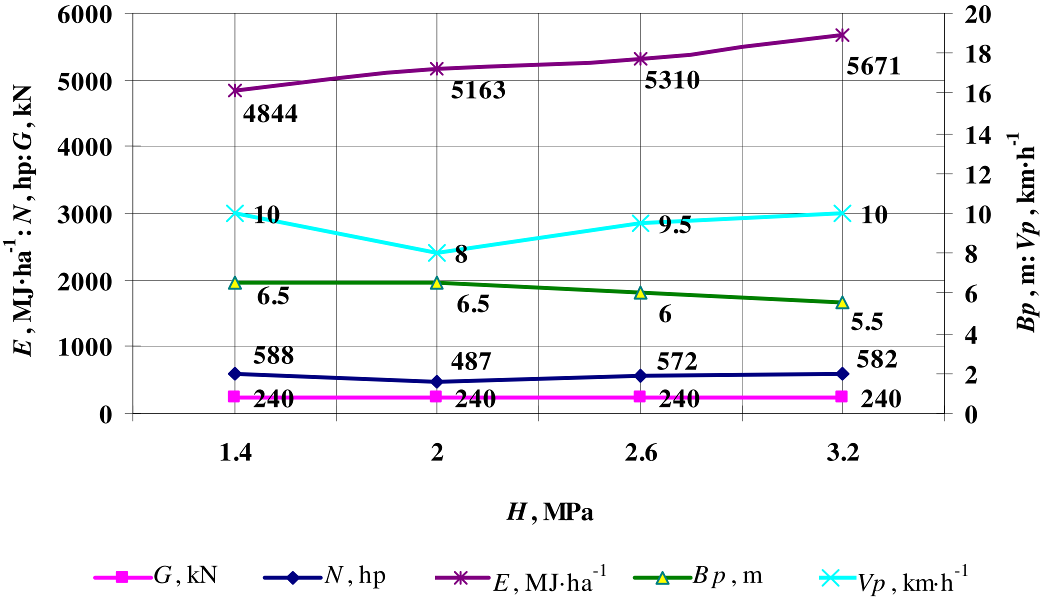

Fig. 5. **Depending on the total energy costs, parameters and modes of operation of the unit on the hardness of the soil**

Conclusions

1. The developed method of scientific justification of parameters and modes of operation of units for deep loosening of the soil is workable.
2. Computational experiments to optimize the parameters of the unit for deep loosening of the soil produce results comparable to the results obtained in practice. This section should only contain the main conclusions based on the present research.
3. Optimal parameters of the tractor working as part of the unit for deep loosening of the soil are as follows: the weight of the tractor 240 kN; 600 hp tractor engine power (John Deere tractors and New Holland 9000th series). The width of the capture of the unit depends on the factors of the environment (the hardness of the soil, its specific resistance, etc.) and varies between 6 and 8 m (greater importance for light soils). The speed of the unit depends on the parameters of the tractor, the width of the capture of the unit and the properties of the soil, it varies between 8 and 10 km·h^{-1}. Using an assembly with these parameters, we get a minimum total energy cost in the region of 5000 MJ·ha^{-1}.

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