OPTIMIZATION OF MAIN PARAMETERS OF TRACTOR AND UNIT FOR PLOWING SOIL, TAKING INTO ACCOUNT THEIR INFLUENCE ON YIELD OF GRAIN CROPS

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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 plowing. For calculations, we used the energy mathematical model of arable units according to the optimization criterion – total energy costs, taking into account the influence of the tractor and aggregate parameters on the formed crop of grain crops. Calculations using the systemic energy mathematical model of arable units have shown that for a specific combination of operating conditions of the units there is an optimal combination of the tractor weight, engine power, implement width, which remain stable, when most of the main parameters of the system – "tractor – implement – operator – field – soil – crop" (TIOFSC), as well as environmental factors change. The optimal weight of the tractor for plowing, when changing most of the factors of the "TIOFSC" system, changes slightly and remains in the range 130-160 kN, usually 160 kN. A larger value of the tractor weight corresponds to a larger value of the specific traction resistance of the plow of more than 50 $kN \cdot m^{-2}$. Power requirements range from 450 to 590 hp. Tractors with less power are effective with less seasonal load on the unit (less than 250 hectares). The optimal working width of the tillage unit varies from 4.20 to 5.25 m, more often it is in the region of 4.55 m. The decrease in the rational working width is associated with an increase in the resistivity of the plow and an increase in the depth of plowing. The optimal speed can vary from 10 to 12 $km \cdot h^{-1}$, more often within 11 $km \cdot h^{-1}$. The value of rational speed is associated with a change in the physical and mechanical properties of the soil

Keywords: tractor; aggregate; optimization; total energy costs; tractor mass; power; aggregate width; operating speed; yield loss.

Introduction

The efficiency of agricultural production depends on a large number of factors related to - the natural climatic conditions of economic activity, the technologies used, the level of seed development, chemicalization, plant protection products and, importantly, from the level of mechanization of production, scientifically based selection of equipment for technological operations, optimal parameters and modes of operation [1-17]. Technological operations in the production processes of grain cultivation in their energy intensity can be conventionally divided into three groups: low-energy operations (care for plants, etc.); medium-energy operations (surface soil treatment, sowing, etc.); high-energy technological operations (plowing, deep loosening of soil, etc.). In the previous works [18-22], we have proposed a method of justifying the parameters of machine-tractor units taking into account their impact on the yield of grain crops, the optimal basic parameters of the tractor (the mass of the tractor and the power of its engine) are justified, the width of the capture and the speed of the units on their base for surface treatment of the soil and sowing.

The proposed article substantiates the basic parameters of the tractor and arable unit, compiled on its base.

Materials and methods

The main parameters of the tractor, the width of the capture and the speed of the arable unit, are based using a system energy mathematical model of the arable unit, composed taking into account the influence of the parameters of the tractor and arable unit based on the emerging yield of cereals [18-20]. The mathematical model of arable units has features and differs from units for surface treatment of soil in requiring large direct energy expenditure through fuel.

However, deep loosening of the soil up to 28 cm to some extent neutralizes the negative impact of tractor engines on the soil, reduces the compaction of the soil, and therefore, the potential harvest will be lost less. The results of the study were obtained in the course of computational experiments conducted using the said mathematical model of arable units on the criterion of optimization of parameters – total energy costs [18-22].

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

The results of optimization of the main parameters of the tractor as part of the arable unit, working with alternating paddocks for working conditions – the area of the field of 100 hectares, the specific traction resistance of the plough working bodies 40 kN·m^{-2}, the volume of work 400 hectares, are given in Fig. 1.

The original data for calculating the parameters of the arable unit:

- single field area = 100 ha;
- length of the unit run before turn = 1 km;
- moving distance from field to field = 3 km;
- coefficient of strength of the bearing surface = 0.9;
- scope of work = 400 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 0.2) = 0.2 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 = 0.09;
- depth of plowing = 0.26 m.

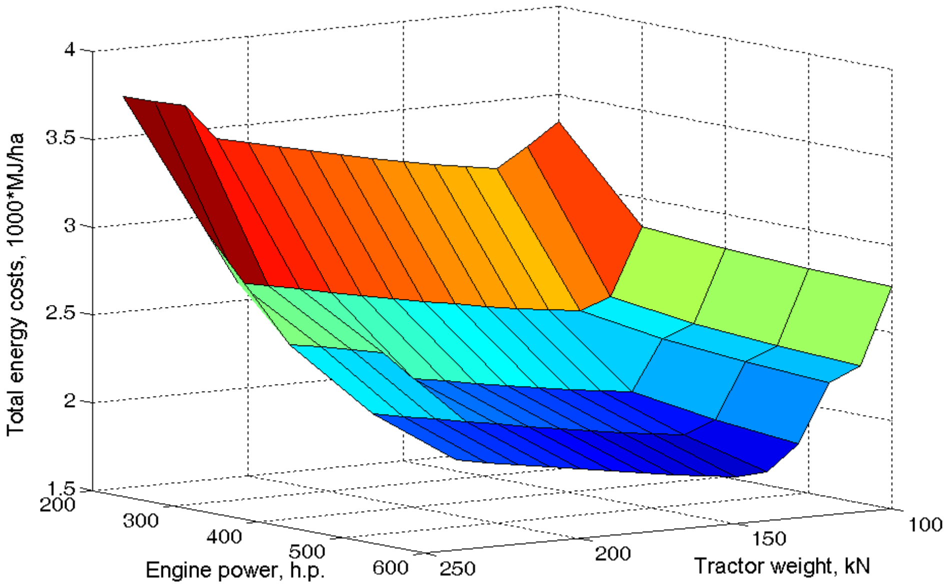

Fig. 1. **Change in the total energy costs of the arable unit from the ratio of weight and engine power of the tractor**

Calculation results:

- width of the tillage implement B_{opt} = 5.25 m;
- working speed V_{opt} = 12 km·h^{-1};
- weight of the tractor G_{tiopt} = 130 kN;
- engine power N_{eopt} = 517 hp;
- total energy costs E_{min} = 1625.9 MJ·ha^{-1}.

We assume that the optimal values of the main parameters of the tractor and the unit may change, when the values of factors that affect the operation of the unit are brewed. Consider the effect of such a factor as specific resistance of the soil to the working bodies of the plough – *k*, kN·m^{-2} on the estimated optimal values of the weight of the tractor – *G*, the power of the tractor engine – *N*, the width of the plough capture – *B*, the speed of movement during the technological operation – *V* and the amount of total energy costs – *E*, see Fig. 2.

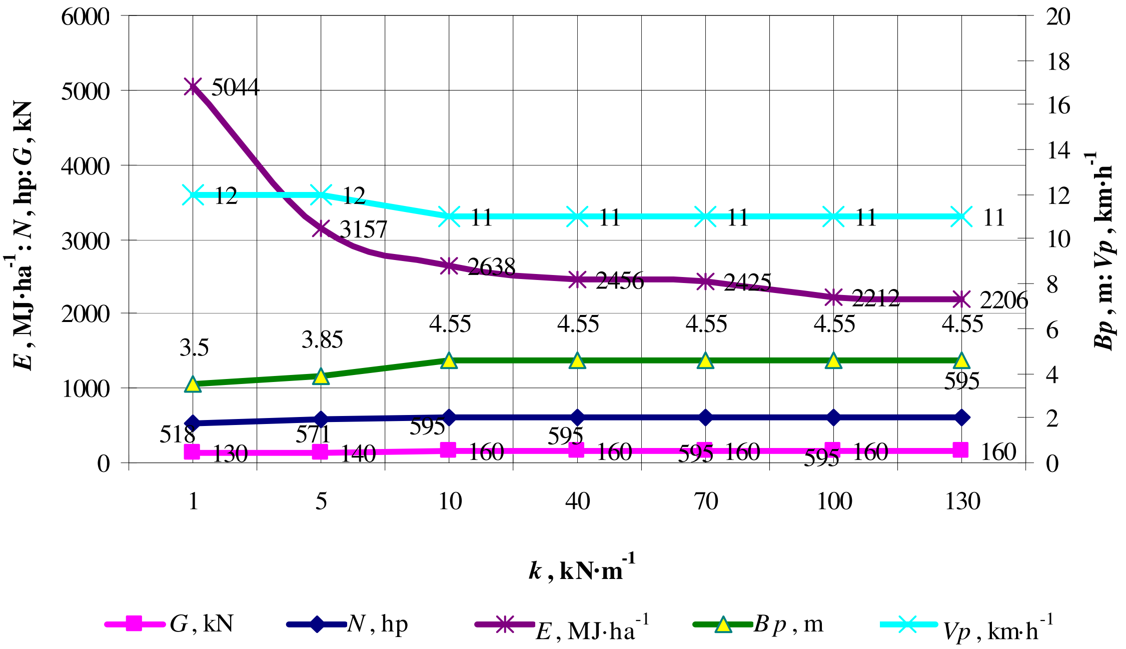

Fig. 2. **Depending on total energy costs, parameters and modes of operation of arable unit on specific resistance of soil**

As it can be seen from Fig. 2, the weight of the tractor – G, when the specific resistance of the soil changes from 50 to 65 kN·m^{-2}, remains constant and equal to 160 kN, At the same time, the required engine power – *N* fluctuates in the region of 600 hp. If the specific resistance of the soil exceeds 55 kN·m^{-2}, it is necessary to reduce the size of the width of the grip – B from 5.25 m to 4.20 m with the specific resistance of the soil equal to 65 kN·m^{-2}. The optimal amount of the working speed of the arable unit – *V* varies between 10-12 km·h^{-1}. The growth of the specific soil resistance leads to a constant increase in total energy costs - E, both due to the increase in direct energy costs through fuel and indirect energy costs, due to the reduction of the productivity of the arable unit.

Consider the impact on the optimized parameters of the arable tractor and the unit in its composition of the factor characterizing the size of the field being processed – the area of the field. The results of computational experiments are shown in Fig. 3. As it can be seen from Figure 3, the change in the size of the field being processed affects all the parameters of the unit. However, when working on fields of more than 10 hectares, all the parameters of the tractor and unit are stabilized and remain constant: the weight of the tractor is 160 kN; The tractor engine capacity is 600 hp; The width of the capture unit is 4.55 m. At the same time, with the increase in the area of the field, the amount of total energy costs decreases. The reduction of total energy costs with the growth of the field area is more intense in the fields from 1 to 10 hectares and this is mainly due to the intensive increase in the performance of the arable unit.

The amount of arable unit work during the season depends on the duration of the technological operation, which means the amount of energy of the crop lost due to the violation of this period. Therefore, let us consider the effect of seasonal load on the arable unit on its optimal parameters. The results of computational experiments are shown in Fig. 4. As it can be seen from Fig. 4, all parameters are stabilized when loaded on a tractor – 300 hectares. At the same time, the weight of the tractor is 160 kN, the engine capacity is within 600 hp, the width of the plough capture 4,55 m, the speed of the unit 11 km·h^{-1}. With the increase in seasonal load on the arable unit, the total energy costs increase, which is due to the increase in the duration of the operation and, accordingly, the loss of the harvest.

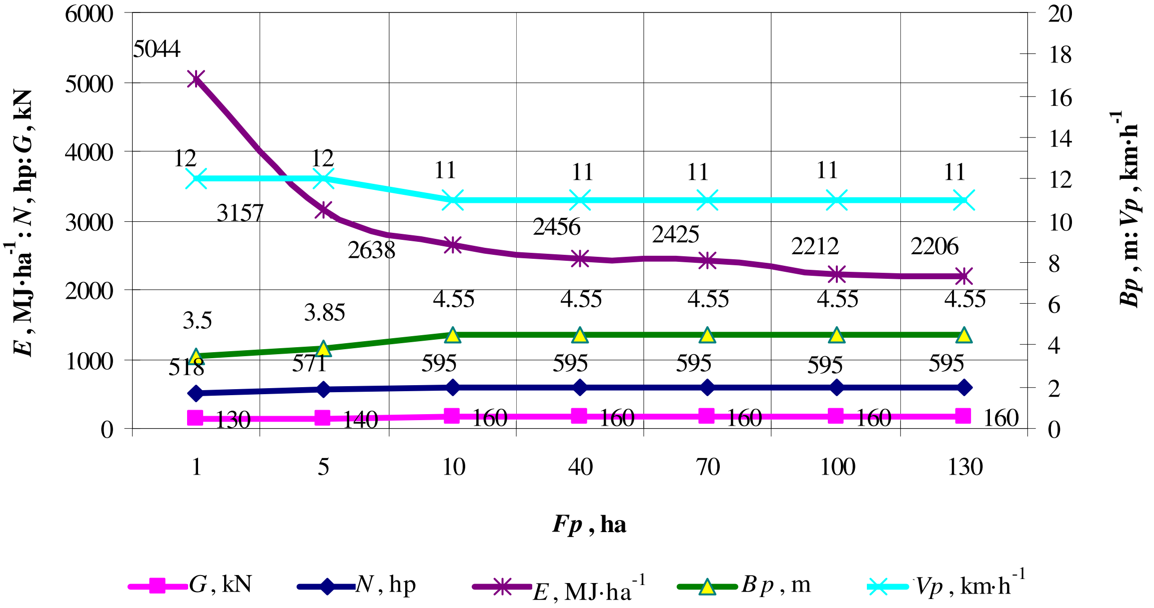

Fig. 3. **Depending on the total energy costs, parameters and modes of operation of the arable unit from the area of the field being processed**

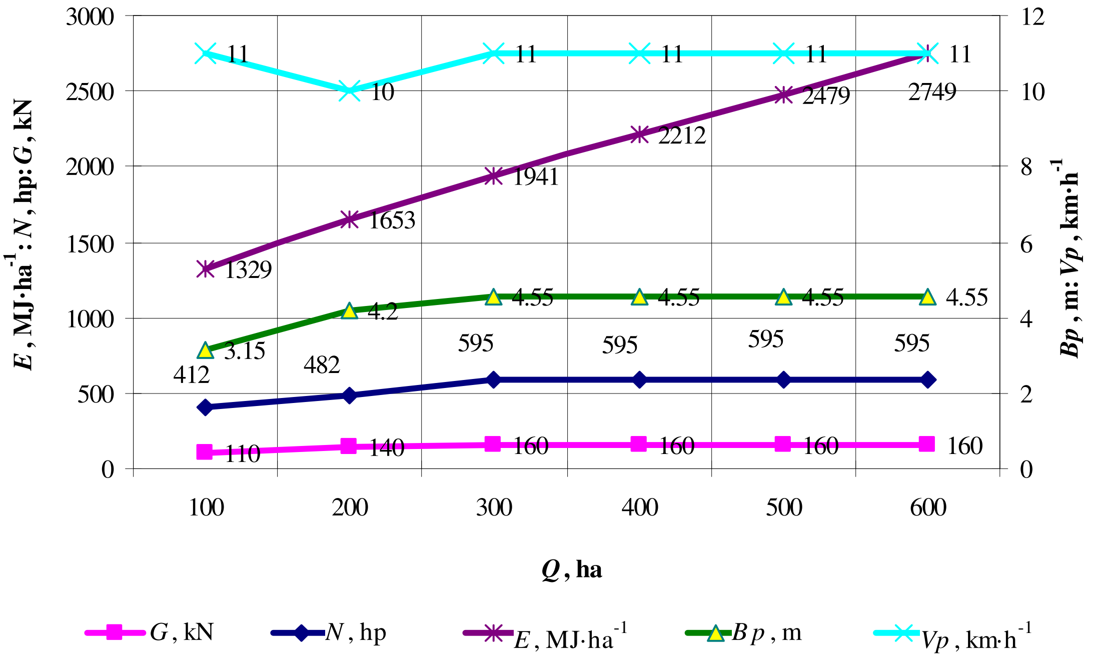

Fig. 4. **Depending on total energy costs, parameters and modes of operation of the arable unit in seasonal load**

Changing the depth of soil processing does not affect the optimal weight value of the tractor – it remains equal to 160 kN, see Fig. 5. Engine power varies between 600 hp and with a depth between 0.20 and 0.28 m, the optimal width of the plough capture decreases from 5.25 m to 4.20 m. The operating speed remains stable at 11 km·h^{-1}. Due to increased direct energy costs through fuel and reduced performance of the plough, the total energy costs of one ploughing unit increase.

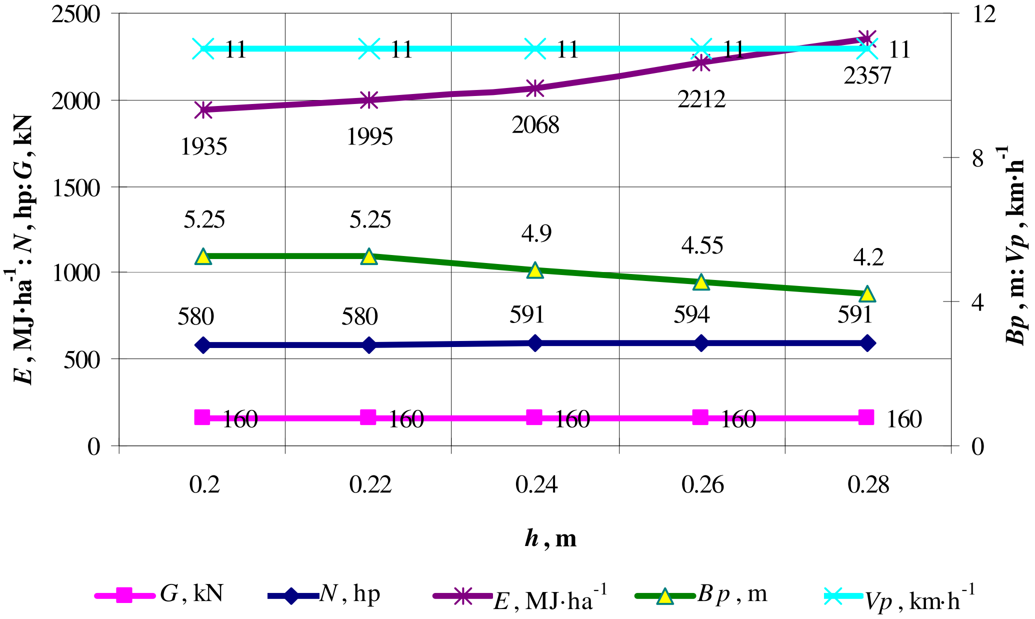

Fig. 5. **Depending on the total energy costs, parameters and modes of operation of the arable unit from the depth of the plough**

Conclusions

1. The developed method of justifying the basic parameters of the tractor and the unit, compiled on its base, through numerous computational experiments, allowed to identify the optimal (rational) values of the basic parameters of the arable tractor (the weight of the tractor and the power of its engine) and the unit, composed on its base (the width of the plough capture and the working speed of the unit).
2. The most rational weight of the tractor is the weight of 160 kN and it is maintained, when the specific resistance of the soil to the plough changes in the range of 46 to 66 kN·m^{-2}, when the field area changes from 10 to 130 hectares, When the seasonal load changes from 250 to 600 hectares, the depth of plowing changes from 0.20 to 0.28 m. At the same time, the required power of the tractor engine is in the range of 570-595 hp. With a specific traction resistance equal to 60 kN·m^{-2} and a depth of plowing equal to 0.26 m, the rational width of the capture of the arable unit is 4.55 m and remains constant with changes in the size of the field from 10 to 130 hectares and seasonal load of the unit from 250 to 600 hectares. If the specific traction resistance of the plough is reduced below 58 kN·m^{-2} and the depth of the plough below 0.25 m, it is necessary to use more widely captured ploughs. The most rational is the working speed of the unit equal to 11 km·h^{-1}.

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