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Optimal weight and power parameters of crawler tractors to reduce pressure on the soil

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Abstract. Crawler and wheeled vehicles are used in a variety of soil and climatic conditions. In the Krasnoyarsk region crawler tractors have a number of advantages. They have a higher traction efficiency, low fuel consumption, and low pressure on the soil. Reducing the pressure on the soil helps to preserve its structure and fertility. This fact is relevant for the agro-industrial complex of Siberia. At present, the vehicle fleet of general-purpose crawler tractors is being reduced. This is due not only to economic reasons, but also the lack of justification for their operation. The paper shows the optimal weight and power parameters. The use of triangular crawler track increases traction efficiency by 3.0% and significantly expands the traction range of effective use of the tractor. For tractors of 4 and 5 classes, the optimal range of change in operating power is 140...175 kW, it corresponds to the optimal range of change in weight 8.5...9.5 tons. For tractors of 5 and 6 classes, optimal interval of changing the operating power is 155...210 kW, it corresponds to the interval of weight change 10,5...12,0 tons. Regulation of operating parameters is produced with a change in the coefficient of engine adaptability from 1.2 to 1.4.

1. Introduction

Crawler tractors are used to perform basic agricultural work in combination with mounted, trailed implements and units. In the field conditions of Siberia, this vehicle has advantages over the wheeled one [1]. It is impossible to do without crawler tractors, as 90% of the cultivated area require harrowing of winter crops, and moisture closure is carried out both on winter crops and on spring crops.

Modern agricultural technologies should have an environmental focus. First of all, the condition of the soil and the preservation of its ability to renew [2] should be taken into account. Less impact on the soil will reduce crop losses. The ability to go to the fields earlier in spring and later in autumn will be got. Therefore, the greatest demand will be for vehicles, the design of which allows increasing the contact area of the crawlers with the ground and evenly distributing the pressure over the entire bearing surface. However, currently, there is a reduction in the vehicle fleet of crawler tractors. In the period from 2013 to 2018, prices for the vehicles of the most popular level (3–6 classes) increased by 9-12% [3], and wheeled vehicles began to displace tractors with classic and triangular crawler contours. As a result, the vehicle fleet of crawler tractors in the agro-industrial complex of the region is 13%, while the vehicle fleet of wheeled vehicles is 87% [4].

Manufacturers of agricultural tractors need state support; otherwise they will leave the agricultural market. At the same time, the decline in the market segment of crawler tractors is not only due to

economic reasons. An important condition for increasing demand is the use of optimal operating conditions of tractors to reduce environmental costs due to pressure on the soil.

To reduce the harmful effects on the soil and improve the efficiency of the crawler tractor, it is necessary to solve two problems: to expand the range of operating speeds of the crawler tractor and to reduce the specific pressure on the soil. The analysis of the existing designs of tractor's driving system showed that to improve the performance of the crawler tractor; it is possible through the use of a tractor's driving system with a triangular crawler contour (TCC). Currently, the main factor hindering the introduction of this tractor's driving system is the low level of knowledge and the prevalence of such a configuration.

The aim of this work was to determine the optimal weight and power parameters of crawler tractors in connection with the conditions of their operation and traction class.

2. Materials and methods

The object of the study was the crawler tractor VT-150/200 for general purpose, a product of the Volgograd tractor plant. The vehicle is easy to use, has two power levels and optimal speed characteristics. The great advantage of the model is that it can be used to perform operations with various mounted and semi-mounted units. Therefore, it is necessary to establish traction and coupling parameters on the operations of the main tillage.

Efficiency justification of tractors with a triangular crawler contours was carried out on the basis of the traction efficiency of the tractor mass utilization factor. The dependence of the operational parameters of the crawler tractor on the operations of the main tillage was carried out at different rut length (600...1000 m; >1000 m), as well as taking into account the energy intensity of the technologies used and the technical support of the operation of the main tillage [5].

These operations were divided into three groups: moldboard plowing and deep tilling to a depth of 0.21...0.23 m and 0.40...0.50 m, respectively, with K_{01} = 11.00...13.65 kN/m, $\Delta \bar{K}_{01}$ = 0.15...0.18 s²/m², $v_{\bar{K}01}$ = 0.10 and V_1 = 1.8...2.1 m/s; post-harvest subsurface combined treatment (continuous cultivation) and chisel plowing to a depth of 0.14...0.16 m and 0.20...0.30 m, respectively, with K_{02} = 4.70...6.50 kN/m, $\Delta \bar{K}_2$ = 0.10 s²/m², $v_{\bar{K}02}$ = 0.07 and V_2 = 2.1...2.8 m/s; post-harvest surface treatment (stubble peeling), pre-sowing treatment, treatment and sowing by zero technology to a depth of 0.06...0.12 m at K_{03} = 3.10...5.10 kN/m, $\Delta \bar{K}_3$ = 0.06 s²/m², $v_{\bar{K}03}$ = 0.07 and V_3 = 2.8...3.8 m/s.

Modeling of parameters was carried out on the basis of tests in traction hitch properties of tractors with classic and triangular crawler contours. The relationship of the index of slipping of the mover δ with the coefficient of weight use $\varphi_{\kappa r}$ is established by the dependence [6] (a, b – empirical coefficients):

$$\delta = (a \times \varphi_{\kappa r}) / (b - \varphi_{\kappa r}) \tag{1}$$

Traction efficiency of the tractor at known values of efficiency of transmission of $\eta_{\text{тp}}$, slipping η_6 and rolling η_f was calculated by the formula:

$$\eta_{\text{т}} = \eta_{\text{тr}} \times [\varphi_{\kappa r} / (\varphi_{\kappa r} + f] \times [1 - \delta] \tag{2}$$

The operational power (N_{ji}) and weight(m_{ji}) of the tractor were determined from the expressions [6]:

$$N_{ji} = W_i \times K_{0i} \times \mu_{Ki} / \eta_{THi} \times \xi_{\bar{N}ji} \tag{3}$$

$$m_{ji} = W_i \times K_{0i} \times \mu_{Ki} / V_{Hi} \times \varphi_{kri} \times \Delta R \tag{4}$$

where: W_i – the net capacity of the unit, m²/s; K_{0i} – the resistivity of the unit, kN/m; μ_{Ki} = $1 + \Delta K_i$ ($V_H{}^2 - V_0{}^2$); ΔR is the increment of the speed of K_0, s²/m²; $\xi_{\bar{N}ji}$ – coefficient of power use with fluctuating traction load.

3. Results and discussion

Figure 1 shows the dependence of the traction efficiency on the utilization factor of the tractor weight with a classic and triangular crawler contour. Equipping the tractor with a triangular balanced suspension allows to increase the traction efficiency by 3.0% [7] and to expand the area of effective use from $\varphi_{kr1} = 0.40...0.66$ to $\varphi_{kr2} = 0.30...0.70$.

Taking into account the rational values of the operating speed for the operations of the main tillage of different groups (2.1, 2.45 and 3.30 m/s), the intervals for regulating the operating power and weight of the tractor for the prevailing classes of the rut length (600...1000 m and more than 1000 m) are determined. According to the dependence of the values of weight and power parameters on the operations of the main tillage of the prevailing classes of the rut length, $\varphi_{kr\ opt}$ and $\varphi_{kr\ max}$ were determined taking into account the dependence of the weight utilization factor for the classical and triangular crawler contour [8]. Taking into account the natural and industrial conditions, the new vehicle fleet of crawler tractors should be represented by mobile energy facilities with variable weight and power parameters on a single element aggregate base of the two main models.
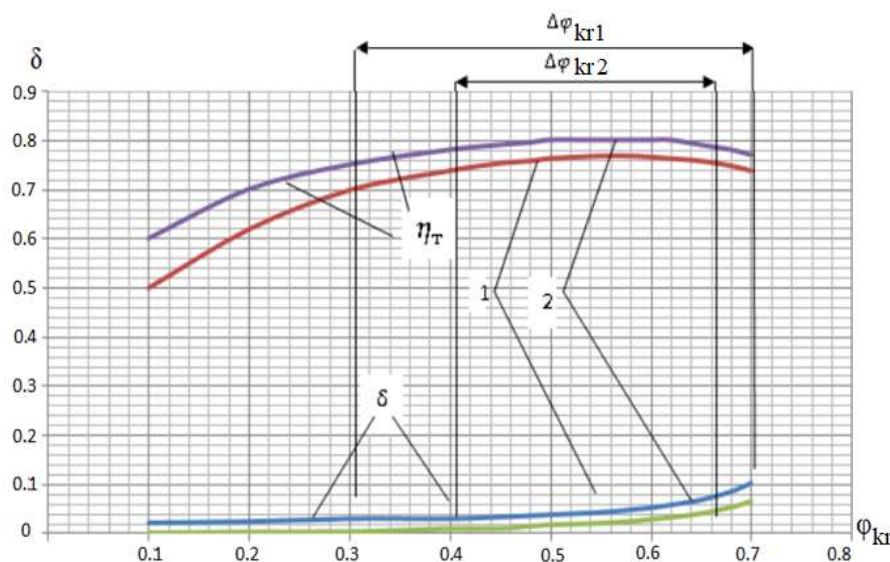

Figure 1. The dependence of the slipping crawler tractor (δ) from the coefficient.

of the weight utilization ($\Delta\varphi_{kr}$): 1 – classic contour; 2 – triangular contour.

The influence of the rut length and soil treatments on weight and power parameters of the crawler tractor is determined by the value of pure performance W^*, characteristics of specific resistance of the unit K_o and $\mu_{\text{н}}$, operating speed V^*_{opt} and initial traction mode of using $\eta_{\text{тн}}$ and $\varphi_{kr\ н}$.

Table 1 shows the results of calculating the dependence of the averaged values of weight and power parameters of crawler tractors on the operations of the main tillage on the rut length for the two models, respectively, when $\varphi_{kr\ н} = \varphi_{kr} = 0{,}5\ (\varphi_{kr\ opt} + \varphi_{kr\ max})$.

Table 1. Averaged values of weight and power parameters of crawler tractors
for tillage at different rut length

Types of related operations	V^*_{opt} (V^*_{max}), m/s	Rut length class	
		600…1000(m)	>1000 (m)
		$\varphi_{kr\ opt}/\varphi_{kr\ max}$	$\varphi_{kr\ opt}/\varphi_{kr\ max}$
Tillage and deep tillage	1.8	7.1 104.6	9.2 135.9
	(2.1)	8.3 143.4	10.8 186.9

Combined processing (continuous cultivation) and chiseling	2.1 (2.8)	7.1 104.6 8.7 149.5	9.2 135.9 11.0 190.0
Surface treatment and seeding	2.8	7.7 182.0	9.1 215.6

The first model of 4–5 classes with a capacity of 140–175 kW and an operating weight of 8.5–9.5 tons is the most rational on the main soil treatment at a length of 600–1000 m rut. The second model of 5–6 classes with a capacity of 155–210 kW and a weight of 10.5–12.0 tons is used to work with a rut length more than 1000 m. The specified operational parameters correspond to the new models of the standard size range of tractors of JSC "Volgograd tractor plant" with a triangular crawler contour.

Taking into account the natural and industrial conditions, the new vehicle fleet of crawler tractors should be represented by mobile energy facilities with variable weight and power parameters on a single element aggregate base of the two main models. The first model of 4-5classes with a capacity of 140–175 kW and an operating weight of 8.5–9.5 tons is the most rational on the main soil treatment at a length of 600–1000m rut. The second model of 5–6 classes with a capacity of 155–210 kW and a weight of 10.5–12.0 tons is used to work with a rut length more than 1000 m. The specified operational parameters correspond to the new models of the standard size range of tractors of JSC "Volgograd tractor plant" with a triangular crawler contour.

4. Conclusion

In contrast to wheeled vehicles, crawler tractors allow the use of rational soil treatment technologies. The current reduction in the fleet of general-purpose crawler tractors is due not only to economic reasons, but also to insufficient justification of their use. To avoid displacement of crawler tractors of different classes from the market of agriculture, it is necessary to use the optimal weight and power parameters.

It is shown that the use of triangular crawler tractors increases the traction efficiency by 3.0% and significantly expands the traction range of tractor effective use. For the prevailing classes of the rut length and the technology of the main tillage, the weight and power parameters of crawler tractors of two sizes with a triangular crawler contour are justified. For tractors of 4 and 5 classes, the optimal operating power in change interval is 140...175 kW, it corresponds to the optimal weight change interval of 8.5...9.5 tons. For tractors of 5 and 6 classes, the optimal operating power in change interval is 155...210 kW, it corresponds to the optimal weight change interval of 10.5...12.0 tons. Regulation of operational parameters is made by changing the coefficient of adaptability of the engine from 1.2 to 1.4 by adjusting the fuel supply and the installation of ballast weights in the front of the tractor.

Therefore, the use of general-purpose tractors with a triangular crawler contour can increase by 4 – 5% technical performance and reduce up to 7% of the operating costs in the performance of operations of the main tillage.

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