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EFFECTIVE AGGREGATING OF TRACTORS FOR TRANSPORTATION

Summary. The paper discusses the importance of tractors for the technological and transportation activities in agriculture. It also presents a methodological approach and an algorithm based on the criteria for the full utilization of the tractors' gravity and power for the successful aggregating of tractors when performing these activities. The offered mathematical model makes it possible to determine the sphere of full aggregation of tractors in transport within the broad range of change of the production conditions' indicators with the help of board computers.

РАЦИОНАЛЬНОЕ АГРЕГАТИРОВАНИЕ ТРАКТОРОВ ДЛЯ ТРАНСПОРТИРОВКИ

Резюме. В статье рассматривается значение тракторов для выполнения технологических транспортных работ в сельском хозяйстве. При этом представляется методический подход и алгоритм для их рационального агрегатирования в ходе выполнения этих операций на основе критерия наиболее полного использования их массы и мощности. Предложенная математическая модель позволяет определить область оптимального агрегатирования тракторов для транспортировки в широких диапазонах изменения показателей производственных условий при помощи имеющихся на тракторах бортовых компьютеров.

1. INTRODUCTION

The agriculture is a sector which is characterized by the high intensity of transport activities. This is due to many reasons but mainly to the fact that the primary means of production is the land. This characteristic of agricultural production leads to the spreading of the production processes over vast territories. On average, per decade of cultivated land in Bulgaria there are 3-4 tons of transported loads. These loads can be classified into approximately 200 groups. 50 of them are loads connected to the main and auxiliary production and wastes from farming and animal breeding while 30-35 groups are loads needed for the realization of the production processes in these spheres. In addition, for the normal functioning of any farm it is necessary to transport 75-85 groups of loads that are not directly related to immediate realization of the production processes [5].

2. PREREQUISITES AND SOLUTION OF THE PROBLEM

When carrying out transport activities under certain production conditions effective aggregating of the tractor means its appropriate selection and combination with a trailer (or trailers) with a certain total weight and load capacity corresponding to the full utilization of the tractor's towing capacity based on the engine power and the cohesion of the drive wheels with the road. This definition is in the basis of the methodological approach for calculating the effective aggregating of tractors used for transportation.

The towing resistance of the trailer (trailers) R is determined in *kN* under a determined working mode of the tractor:

$$R = G_P\left(f_P \pm \sin\alpha\right) \approx G_P\left(f_P \pm \frac{i}{100}\right), \tag{1}$$

where: G_P is the total gravity of the trailer (trailers) with the load, *kN;*, f_P - resistance coefficient for moving the trailer along the road; α - angle of the road slope, *rad*; i - slope of the road, %.

When using one – axle trailers or semitrailers part of the weight of the loads transmitted to the tractor. This improves its cohesion capacity and reduces towing resistance of the trailer. Nevertheless, this increases the resistance for moving the tractor which reduces by the respective value the tractor's towing power. For this reason when calculating the towing resistance of the semitrailers the formula used for calculating the trailers' towing resistance is also used.

The calculated value of the towing resistance R of the trailer based of the towing characteristic of the tractor for the respective soil background of the road conditions is used to determine the closest, higher value of the necessary towing power P_T, namely $P_T>R$.

The speed under which the value of P_T is obtained is approximately equal to the movement speed of the tractor transportation aggregate.

For the tractor transportation aggregate the highest towing power is necessary for starting from position and particularly for moving along slopes. The take-off force in starting $R_{П}$ in kN is calculating using the formula:

$$R_{П} = G_P\left(f_P.a_P + \frac{i}{100}\right) + G_E\left[f_T\left(a_T - 1\right) + \frac{i}{100}\right], \tag{2}$$

where: G_E is the gravity of the tractor, kN; a_P, a_T - coefficients for increasing the resistance of the tractor and the trailer when the aggregate takes off.

These coefficients are used to describe the increase of resistance when accelerating the aggregate when it starts from a position. The following values have been experimentally determined (see Table 1) [2].

The determined take-off force $R_{П}$ should be lower than the highest possible towing power P_T of the tractor at the lowest gear. If this requirement is not met it is not possible for the tractor to start. Thus, the condition for taking-off of the aggregate is realized in the inequality: $P_T > R_{П}$

In order for the aggregate to be towed it is necessary for the cohesion force $P_{CП}$ of the tractor to be higher than its necessary movement force, i.e.

$$P_{СЦ} \geq G_P\left(f_P.a_P + \frac{i}{100}\right) + G_E\left(f_T.a_T + \frac{i}{100}\right) = R_a, \tag{3}$$

where: R_a is the resistance of the aggregate when it takes off, kN.

When calculating the cohesion force of the 4X2 tractors combined with one-axle trailers or semitrailers, their cohesion weight is calculated using the formula:

При изчисляване силата на сцепление на тракторите от типа 4X2, агрегатирани с едноосни ремаркета или полуремаркета, сцепното им тегло се изчислява по формулата:

$$G_{СЦ} = G_E.K_G\,\frac{L_T + \ell}{L_T}\Delta G, \tag{4}$$

where: L_T is the wheel base, m; ℓ - is the distance from the towing hitch to the vertical plane going through the axle of the driving wheels of the tractor, m; K_G- is the coefficient of cohesion weight of the tractor, $K_G \approx 0,7$ for wheeled tractors 4x2 [5]; ΔG-part of the semitrailer'sgravity that is transferred to the tractor, kN.

Table 1

Resistance coefficients values of the motion of the tractor and trailer under different road conditions

Road surface	Coefficient for increasing the resistance of the tractor's movement	Coefficient for increasing the resistance of the trailer's movement
For asphalt, asphalt concrete	a_T =4,35	a_P =3,35
For dry well-trodden road	a_T =2,48	a_P =1,80
For over-wet dirt road	a_T =1,84	a_P =1,76
For a plowed field	a_T =1,84	a_P =1,42

The allowed size of ΔG, transferred to tractors is within the following limits [5]:
Allowed size of the proportion of the semitrailer's weight according to the tow class of the tractor:

- ✓ For tow class 0,6 - ΔG =5,0 kN;
- ✓ For tow class 1,4 - ΔG =12,0 kN;
- ✓ For tow class 3,0 - ΔG =20,0 kN;

With their total weight the semitrailers load the tractor respectively:

- ✓ One-axle 8-ton trailer - ΔG =20,0 kN;
- ✓ Two-axle 8- ton trailer - ΔG =8,0 kN;
- ✓ One-axle 9- ton trailer - ΔG =17,0 kN;

3. RESULTS AND DISCUSSION

The algorithm for determining the effective tractor aggregates for transportation uses can be summarized as follows:

1. Determining the correct parameters of the task – the make of the trailer, its load capacity q and total weight Q, the characteristics of the road (the type of pavement, condition, slope, etc.) are determined for the particular tractor.
2. Determining the towing resistance of the trailer R under the specified working mode of the tractor using formula (1). The inequality $P_T>R$ is used to determine the possible speed of movement.
3. Determining the strength of the take-off force R_{II} for the most difficult part of the road using formula (2) and checking the conditions for starting $P_T>R_{II}$ for the strongest possible force P_T of the tractor, that is the lowest gear.
4. Determining the strength of the P_{CII} force of the tractor for the part of the road with the lowest cohesion, that is the possibility for the tractor to take off regardless of the increased skidding.

In some cases it is necessary to solve the opposite problem, namely to determine the highest possible value of the total weight of the trailer G_P in order to choose the best trailer with regard to its towing capacity and make on the basis of the particular tractor with take-off conditions determined by the sufficiency of its nominal power (2) and cohesion (3).

A key element in determining the effective tractor aggregating for transportation uses is the compliance with the legal requirements of the country where the aggregates operate so that their movement along the road meets the safety traffic requirements.

4. CONCLUSION

The theoretical argumentation of the effective aggregating of tractors used for transportation purposes provides sufficient grounds for the following conclusions:

1. The designed mathematical model for studying the optimal aggregating of tractors for transportation purposes can be universally applied. When the aggregating is carried out with specific makes of tractors under specific production conditions the numerical values of the coefficients in the analytical dependence of the model are determined.
2. The offered mathematical model makes it possible to determine the area of effective aggregating of tractors for transportation uses within a broad range of changing the production condition with the help of the tractors' board computers.

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