

Research on the rational aggregation of a transport tractor

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Abstract. The results of studying the resistance to traction of a tractor train consisting of models Belarus 80.1 tractor and two 2PTC-4-793 trailers, and how this resistance depends on the number of trailers, the load weight G_t , and the speed of movement are specified in the article. Obtained figures indicate that, while the weight of each trailer n remains constant, the force in tractor’s attachment increases as number of trailers increases. Conversely, the resistance coefficient f of support surface's slope angle α and the rolling resistance of the wheels decreases. For investigating the force at tractor trains P_{tf} on soil and gravel roads, it is recommended to use the slope angle 6° of support surface and rolling resistance coefficient values for the specific surface types gravel - $f = 0.03$ and asphalt - $f = 0.018$. At a speed of 35 km/h, maximum traction resistance force for tractor train with total mass of 15720 kg and four trailers reached 2592 N. Usage degree of calculated traction force in Belarus 80.1 tractor and four-loaded trailers of 2PTC-4-793 type train was 17%.

1 Introduction

Most scope of works performed by wheeled tractors in agricultural production consists of transportation, and their annual loading rate reaches 50-60 percent [1-3]. 35-40 percent of cost of produced product is accounted for by transportation cost. Inadequate organizing the transportation activities leads to excessive consumption of fuel and lubricants, ultimately increasing in self cost of product.

It is advisable to apply four-wheeled tractors with low clearance in transport works. They do not always move on smooth roads, they carry out cargo transportation in the field and in various uneven conditions.

Therefore, in order to effective using the load-carrying capacity of trailers and power of transport tractors, it is advisable to widely use modern tractors and tractor trains consisting of two-axle trailers with load capacity of 4 tons and more. Traction resistance of tractor train increases with number of trailers, the weight of load loaded onto them, and speed of

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movement [1], [3, 4]. It is possible to increase efficiency of agricultural transport by justifying the rational composition of tractor trains consisting of tractors and trailers.

2 Materials and Methods

Increasing the efficiency of tractor trains with large carrying capacity and rationalized composition is matter of scientific and practical importance.

$$P_{tf} = m_t(g \sin \alpha + W) + X_0. \quad (1)$$

in this case m_t – trailer mass (1730 kg); g – acceleration run of free fall ($g = 9.81 \text{ m/s}^2$); α – slope angle of supporting level land, °; W – acceleration run of trailer, m/s^2 ; X_0 – resistance to movement of the tractor train, N .

Let's consider movement velocity of the tractor trains as $V = \text{const}$ for calculations (movement velocity of trailers is stable). Thus, acceleration run $W = dv/dt = 0$, inertia force $F_i = m_t W = 0$. $X_0 = fG_t \cos \alpha$ (in this case f – resistance coefficient of wheel rolling, G_t – weight of trailer (17 kN)).

In that event

$$P_{tf} = G_t(\sin \alpha + f \cos \alpha). \quad (2)$$

Number of trailers formula (2) for $n = 1$ is in place.

In the event if number of trailers is $n = 2$:

$$P_{tf} = 2G_t(\sin \alpha + f \cos \alpha).$$

In the event if number of trailers is $n = 3$:

$$P_{tf} = 3G_t(\sin \alpha + f \cos \alpha).$$

In the event if number of trailers is n :

$$P_{tf} = nG_t(\sin \alpha + f \cos \alpha). \quad (3)$$

Out of (3) the formula for determination the number will be formulated [1, 8]:

$$n = \frac{P_{tf}}{G_t(\sin \alpha + f \cos \alpha)}. \quad (4)$$

Values of P_{tf} will be calculated as in the following. For two-wheel drive 4K2 formula tractors [5], [9-12] having operating mass greater than 2600 kg:

$$P_{tf} = 0.373G_T = 0.373m_T g = 0.373 \cdot 1.15m_c \cdot g, (N). \quad (5)$$

in this case G_T – operational weight of tractor, N ; m_c – design mass of tractor, kg;

Using the formulas given above, calculation the values of force at the 4K2 formula tractor hitch and number of trailers at tractor train will be available.

1-option $G_t = \text{const}$, $\alpha = 6^\circ$, $f = 0.03$. Design mass of the 4K2 formula tractor is $m_c = 3620 \text{ kg}$, operational mass is $m_T = 1.15 \cdot 3620 = 4163 \text{ kg}$, due to that $m_T = 4163 \text{ kg} > 2600 \text{ kg}$ let's determine P_{tf} value by means of formula (5):

$$P_{tf} = 0.373 \cdot 4163 \cdot 9.81 = 15232.9 = 15.233 \text{ kN}.$$

From (4):

$$n = \frac{15.233}{48.069(\sin 6^\circ + 0.03 \cos 6^\circ)} = 2.35 \approx 2 \text{ pc.}$$

2-option: $G_t = \text{const}$, $\alpha = 6^\circ$, $f = 0.018$. In this case $P_{tf} = 15.233 \text{ kN}$, $G_t = 48.069 \text{ kN}$ and $\alpha = 6^\circ$ remains as it (unchanged). From (4):

$$n = \frac{15.233}{48.069 (\sin 6^\circ + 0.018 \cos 6^\circ)} = 2.58 \approx 3 \text{ pc.}$$

3-option: $G_t = \text{const}$, $\alpha = 3^\circ$, $f = 0.018$. From (4):

$$n = \frac{15.233}{48.069 (\sin 3^\circ + 0.018 \cos 3^\circ)} = 4.5 \approx 5 \text{ pc}$$

From obtained figures one can see, that the number (n) of trailers containing at tractor train increases with increasing values of force (P_{tf}) at tractor hitch, while weight (G_t) of single trailer remains unchanged, and on contrary, it decreases by increasing the values of slope (α) angle of supporting level land and coefficient of wheels rolling resistance (f).

3 Results

Researches were carried out on tractor trains consisting of Belarus 80.1 tractor of 4K2 formula and 2PTS-4-793 trailers with aggregate load capacity of 4 tons in accordance with the requirements of state standards in trial testing [1], [10-14]. Trailers were implemented separately in each speed transmission of the tractor on asphalt and dirty roads with length of 5000 m. Cargo (cotton) was loaded onto trailers after each arrival of tractor train. In this way, the tensile strength values were increased.

Trial testing was implemented for the Belarus 80.1 tractor with the total mass of tractor train consisting of 4 2PTS-4-793 trailers in unloaded status (no cotton was loaded onto trailers) - 10540 kg (103 kN); 19883 kg (195 kN) was transferred in loaded condition (cotton loaded on trailers).

Values of traction resistance of trains consisting of Belarus 80.1 tractor and 2PTS-4-793 trailers of the 4K2 formula and trailers aggregated to it are shown in table and graph.

Table 1. Values of traction force at hitch of train consisting of Belarus 80.1 tractor of the 4K2 formula and 2PTS -4-793 trailers with assembly of load capacity of 4 tons (design mass of each trailer is 17 kN)

Gearbox	V , m/s	Unladed Belarus 80.1 + 2PTS-4-793 (design mass of each trailer is 17 kN)	
		Unladed Belarus 80.1 + 2PTS-4-793 (design mass of each trailer is 17 kN)	Laded Belarus 80.1 + 2PTS-4-793 (with cargo) (17 kN of cotton is loaded on every trailer)
		P_{tf} , N	
I / II	0.8 / 0.9	418 / 492	988 / 1251
III / IV	1.6 / 2.0	607 / 941	1655 / 1797
V / VI	2.4 / 2.8	927 / 942	1910 / 2059
VII / VIII	3.4 / 4.0	1387 / 1047	2112 / 2269
IX (lowered)	7.5	1158	2373
IX (increased)	9.4	1053	2592

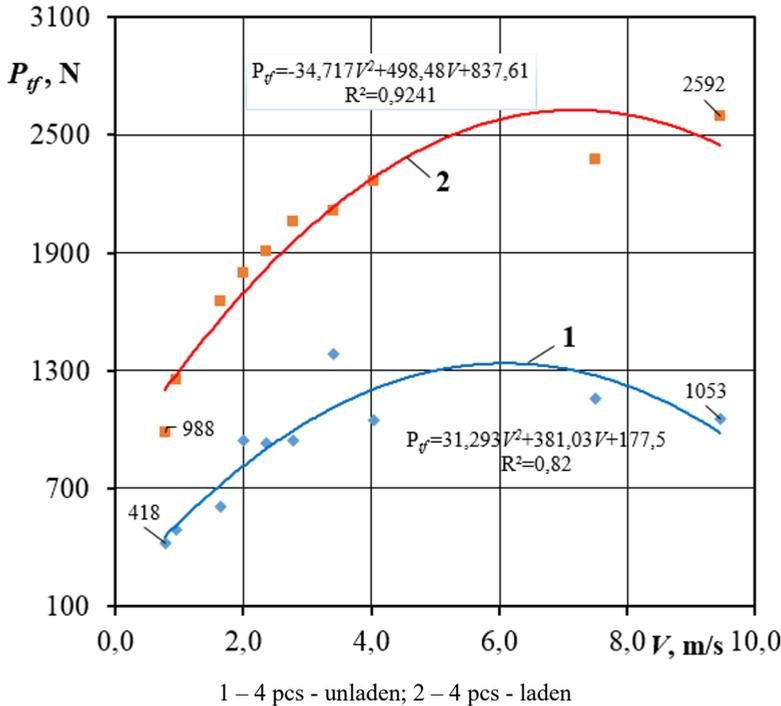


Fig. 1. Graphs of variations in traction force on hitch of the tractor train consisting of Belarus 80.1 tractor 4 unladen (without cargo) and laden (with cargo) 2PTS-4-793 trailer

4 Discussion

After studying the results, it is seen that when 4 laden 2PTS-4-793 trailers having load capacity of 4 tons (design mass of each trailer is 17 kN) are aggregated to Belarus 80.1 tractor of 4K2 formula of the 1.4 class with engine power of 59.6 kW (81 hp): in unloaded condition (no cotton loaded on trailers) - 10540 kg (103 kN); and when loaded (with cotton loaded on trailers) - 19883 kg (195 kN). It was identified that traction resistance forces of tractor train reached the following maximum values at speed of 35 km/h, that is, level of utilization of engine power and maximum traction force on hook when trailers of Belarus 80.1+4 2PTS-4-793 were loaded was 17 % [1, 11, 12].

Traction resistance of tractor train increases by increasing in number of trailers, weight of load loaded on them and the movement speed. Trends of changes in traction resistance values of tractor trains consisting of Belarus 80.1 tractor and 2PTS-4-793 trailers correspond to those laws specified in literature [1, 8, 11, 12]. In case if the movement velocity of 2PTS-4-793 model tractor Belarus 80.1+1 belonging to 1.4 class under 4K2 formula trailer was $V=34$ km/h then we obtain $P_{tf} = 736$ N, in the event if trailers number are $P_{tf6} = 6 \cdot P_{tf1} = 6 \cdot 736 = 4416$ N = 4.416 kN.

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