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Increasing the Efficiency of Transport and Technological Complexes Used in Crop Harvesting

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Abstract: The efficiency of transport and technological processes of crop harvesting in the Amur Region depends upon a range of cooperating factors: state of traffic infrastructure and load bearing capacity of soil, amount of precipitation during the harvest, yield of agricultural crops, availability of harvesting and postharvesting equipment and transport at farm units and other variables. The harvesting of grain crops in the Amur Region takes place during the period of high precipitation, when the soil on fields has weak load bearing capacity due to excessive water saturation of the surface. The study in hand describes the results of testing of an combination vehicle consisting of the automobile KamAZ-55115 and the trailer NEFAZ 8560-02 and equipped by a trailing weight redistribution device allowing to increase traction-trailing properties by redistributing trailing weight between the driving wheels of the automobile and the trailer.

Key words: KAMAZ-55115, trailer, trailing weight, traction-trailing properties, trailing weight redistribution, energy consumption

INTRODUCTION

An important industry in the economy of the Amur Region is agricultural production in particular, the production of grain crops and legumes. The main leguminous crop of the region is soybean. For the cultivation of this type of crop, the specialists have developed agricultural technologies compliant with its biological and production peculiarities as well as with environmental conditions of the farming areas. The high yield is of course, depends largely on the timely performance of main agricultural works. The important role here is played by the automobile transport which is used for delivery of seed materials, fertilizer and herbicides, transportation of gathered harvest and timely shipments of agricultural products to the consumers or processing plants (Brouwer and Ittersum, 2010; Behnassi *et al*., 2014a; Lichtfouse, 2013).

The fulfillment of the entire amount of transport works supporting agricultural production largely depends on the category and state of roads used. More than 85% of roads of the transportation infrastructure of the region belong to the 4th and the 5th categories (gravel and dirt roads). Their operation highly depends on the seasonal climatic and road conditions. The most important of them are: the state of the roadway pavement, the presence of deformations and structural damage of road surface dressing and its foundations, regime parameters of seasonal and daily temperature fluctuation, the amount of precipitation, the presence of black frost and snow cover (Shchitov *et al*., 2012a, b; Shchitov and Krivuca, 2014a, b).

Issues related to improving efficiency of mobile wheeled vehicles have been covered in numerous research papers by scientists from all over the world (Anonymous, 2006, 2007; Maharjan and Joshi, 2013; Behnassi *et al*., 2014). For instance, improvement of transport and technological support of the agroindustrial complex can be achieved by forming functional complexes of same-type vehicles and increasing their efficiency, as proposed by Evdokimov *et al*. (2012a, b), Hans-Otto and Hwan (2005) and Zakharv (2000). The optimal speed of vehicles and methods for optimization of time of delivery of cargo between the consuming points are covered in (Zakharov, 2000; Brouwer and van Ittersum, 2010; Shchitov *et al*., 2012; Shchitov and Krivuca; 2014a, b).

The researchers of the study (Zakharov, 1996; Shchitov *et al*., 2014) discuss the issue of increasing efficiency of use of vehicles at agricultural enterprises by improving several performance indicators.

The analysis of foreign and domestic sources shows that there is a sufficient number of different methods to increase the traction-trailing properties of wheeled mobile

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energy devices, including: the use of thrown-on chains, devices for automatic dumping of sand and gravel mix under the propulsions, devices for setting up additional wheels, etc. (Bulinski and Niemczyk, 2007; Jordan, 2013). However, those methods are not always acceptable for the operation of vehicles on soils with low bearing capacity. They are also characterized by a sufficiently high metal consumption, structural complexity, low reliability. Their installation and maintenance are economically costly.

Consequently, the main goal of the carried-out research was objectively the search for new engineering and technical solutions that would enhance the traction-trailing properties of wheeled vehicles which constitute important components of the efficiency of transport and technological support for the harvesting process (Wright and Fulton, 2005; Anonymous, 2008).

It has been established earlier (Shchitov *et al*., 2015; Vorokhobin *et al*., 2016) that most effective, reliable and low-cost way of achieving the set goal under conditions of flotation on soils with low bearing capacity and the presence of a solid underlying layer in the form of permafrost or snowdrifts is the rational use of the weight of the transported cargo which can be effectively used for additional loading of the undercarriage of the vehicle and increasing its traction-trailing properties. One more advantage of this method is that it does not increase the total weight of the articulated vehicle.

MATERIALS AND METHODS

Having implemented scientific and patent search, the researchers proposed a new technical solution for rational use of partial weight of the transported cargo to improve traction-trailing properties of combination vehicles a traction-loading device, the novelty of which was confirmed by the Russian Federation unitily patent no. 2493018. Figure 1 and 2 show the principal diagram of the proposed device and its general view (Shchitov and Krivuca, 2011).

The proposed device is especially suitable for increasing the flotation capacity of articulated vehicles on roads with a variable adhesion coefficient, since, in this case the tangential force of the propulsions of the vehicle increases due to the increase in the vertical load on the driving wheels of the car and the adhesion coefficient. The traction-loading device is installed in the undercarriage of the trailer. It allows to redistribute trailing weight between the axles of the trailer and the rear wheeled cart of the automobile (Shchitov and Krivuca, 2012a, b).

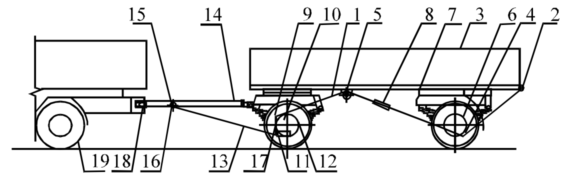

Fig. 1: Principal diagram of the traction-loading device: 1) Flexible cable power connection; 2) Coupling device mount; 3) Trailer; 4, 5) Guide blocks; 6) Rear wheel axle; 7) Trailer frame; 8) Adjustment turnbuckle; 9) High side of the articulated bracket lever; 10) Articulated bracket lever; 11) Air regulator; 12) Front wheel axle of trailer; 13) Cable power connection; 14) Drawbar; 15) Guide block; 16) Bearing; 17) Low side of the articulated bracket lever; 18) Coupling device and 19) Vehicle

Fig. 2: Combination vehicle with the installed traction-loading device

The proposed device operates in the following way. When combination vehicles travel on soils with a weak load bearing capacity and the slippage of the towing vehicle increases, the driver-operator connects connects the air regulator 11 via. a distributor which, when the rod extends, turns the vertical articulated bracket lever 10, pulls the flexible cable power connections 1 and 13, transferring the load of the trailer 3 through the drawbar 14 to the coupling device 18 and the driving wheels of the towing vehicle 19, increasing the vertical load on the propulsions and improving its traction-trailing properties, thus allowing the rig to move around without slippage, performing agricultural and transportation works despite the weak load bearing capacity of soils.

The testing of the experimental combination vehicle equipped with the proposed traction-loading device was carried out in accordance with the recommended general and particular methods using specialized programs for mathematical calculation, experimental simulation and regression analysis methods. The following parameters were measured: travel speed; load-carrying capacity; used transmission of the automobile transmission gear box; fuel consumption; distance traveled; testing period. These parameters were measured using an on-board measuring system and the transport monitoring features of the navigation system GLONASS and GPS. The data obtained during the experiment was processed via. known methods of mathematical statistics on the computer (Shchitov and Krivuca, 2011; Evdokimov *et al*., 2012a, b).

RESULTS AND DISCUSSION

The results of testing of the automobile KamAZ-55115 with the trailer NEFAZ 8560-02 and the device for redistribution of trailing weight. The conducted empirical research and experimental trials of the combination vehicle with traction-loading device confirmed the validity and correctness of the proposed methods for solving the issue by using partial weight of the transported cargo to improve the traction-trailing properties of the vehicle.

Theoretical substantiation of redistribution of partial weight of the transported cargo to the rear wheeled cart of the automobile which involved the application of the Herman-Euler-d'Alembert condition, has confirmed the normal operation and effectiveness of the proposed device, since, according to the data obtained by putting additional load on the towing device the operator can increase the weight transferred to the front driving wheels of the automobile. Furthermore, the study established that the value of this load depends on the load angle • and the distance $l_2$to the point of its application. The effect of the above parameters on the value of the additional load transferred to the driving wheels of the automobile is shown on Fig. 3 and 4.

The conducted research also allowed to establish that the most rational value of these parameters for the trailer NEFAZ 8560-02 is as follows: the load angle • : from 20-30° the distance l_2-6.58 m. Thus, the use of the traction-loading device allows to increase the weight that is supported by the rear driving wheels by and as a result, to improve the traction-trailing properties of the automobile involved in transport operations.

In order to validate the results of the conducted study on the effect of the traction-loading device on operational parameters, the researchers performed experimental trials of the said device both in a static state and in motion (in a combination vehicle). The results of these trials are presented in a graphical form on Fig. 5.

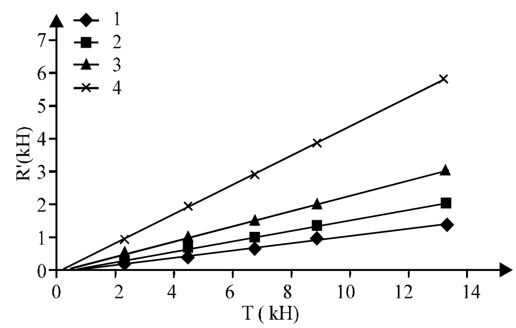

Fig. 3: Dependency of the transferred load R on the load application angle • : 1. • = 7°; 2.• = 10°; 3. • = 15°; 4. • = 30°

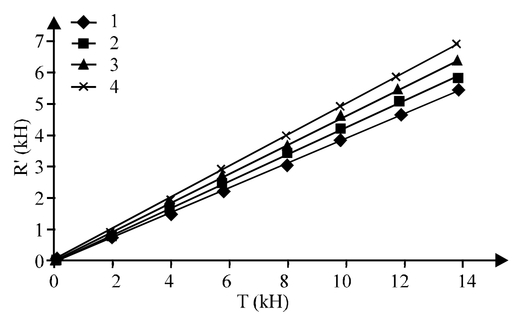

Fig. 4: Dependency of the force response on the additional load application angle (• = 30°): 1. l_2 = 5.5 m; 2. l_2 = 6.0 m; 3. l_2 = 6.5 m; 4. l_2 = 7.0 m

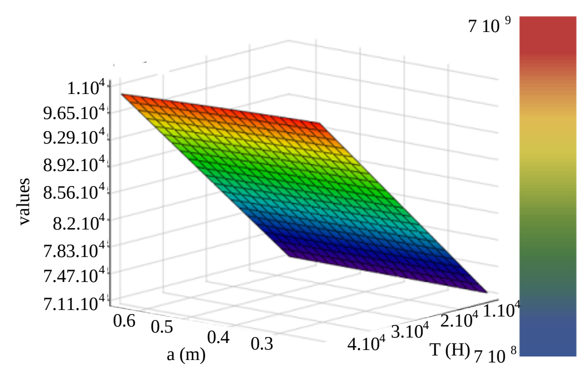

Fig. 5: Dependency of the automobile trailing weight y_B on the device mounting distance and the tension force in the flexible connections of the traction-loading device

The analysis of the graphical dependencies shows that due to the use of the traction-loading device, the trailing weight of the automobile has increased from 71.3-97.8 kN, i.e., by 37%. Thus, the use of traction-loading device when driving an automobile with

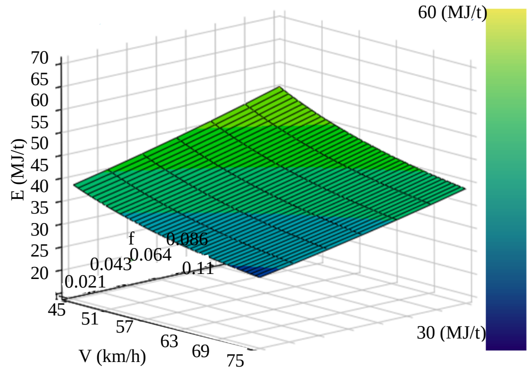

Fig. 6: Dependency of the total energy costs of the automobile KamAZ-55115 with the trailer NEFAZ-8560-02 on the travelling speed and the category of roads when using the traction-loading device

a trailer will result in an increase of the tangential force of the traction along the clutch (a 1.5-time increase, if the road condition coefficient k_c, equals 0.67) and a subsequent increase in working travel speeds and the performance of the combination vehicle.

Field experiments have proved the possibility of increasing the load on the propulsions in cases when the traction-loading device is used and its mode parameters are determined. The authors recommend to put the weight redistribution device into operation only then the coefficient of adhesion of wheels and the soil decreases. In this case, a short-term use of the traction-loading device on starting-off or while driving off-road will allow to continue safe operation of the combination vehicle.

The fuel and energy evaluation of the use of the automobile KamAZ-55115 with the trailer NEFAZ 8560-02 and the traction-loading device for the redistribution of the trailing weight showed that the implementation of the loading device reduces the total energy costs of the vehicle (Fig. 6) (Shchitov and Krivuca, 2012a). The study also established that the use of the traction-loading device allows to decrease total specific energy costs when driving the vehicle on when driving the vehicle on gravel roads (by 13.3%) and on dirt roads (by 20.2%) (Shchitov *et al*., 2014).

The validity of the obtained data is further confirmed by the convergence of the theoretical substantiations and experimental values received under actual operating conditions involving the automobile KamAZ-55115, the trailer NEFAZ 8560-02 and the trailing weight redistribution device. The comparison of these results with the data previously obtained by the researchers (Evdokimov *et al*., 2012a, b; Shchitov *et al*., 2012) proves the effectiveness of the proposed solution which has not been considered by the applied science in its entirety before now.

CONCLUSION

Based on the results of the above study, it can be concluded that the use of a traction-loading device for a partial redistribution of the weight of the transported cargo makes it possible to change the traction-trailing properties of a combination vehicle in motion and reduce the total energy costs per unit of work performed. Consequently, the proposed device is a highly efficient, that implements original ideas and has a proven scientific and engineering novelty. It provides for the rational use of the partial weight of the transported cargo to affect and improve the traction-trailing properties of an automobile.

The results of the conducted empirical research and experimental trials have been approved and recommended for application by the expert committee under the Ministry of the Agriculture of the Russian Federation, Administration of State Vehicular Control in the Amur Region and the Research and Technology Board of the Amur State Regional Machine Testing Station all seeking to introduce latest scientific and technical developments and best practices into agribusiness. The proposed devices were implemented and are widely used in the plant cultivation technology of ZAO T3 "Agrofirma "Partizan", OAO "Pogranichnoe", SK Collective farm "Dim". The methodological and mathematical solutions are used in the educational process of the Federal State Budget Educational Institution of Higher Education "Far Eastern State Agrarian University".

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