Rationale for vehicle parameters for the transportation of straw and hay

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Abstract. Vehicles for the transportation of straw and hay in loose and pressed forms are considered. A scheme of a transport vehicle for the transportation of straw and hay, a haystack truck, is proposed. The haystack truck consists of a frame, wheels, a trailer device, a finger platform, a mechanism for lowering-lifting the front part of the platform, sides, a mechanism for lowering-lifting the rear part of the platform. The results of studies to determine the physical and mechanical properties of straw and hay, necessary to rationale the parameters of the haystack platform, are presented. The dependence of the coefficient of friction of oat straw, barley, winter wheat, millet, buckwheat and alfalfa hay and awnless brome on the fingers of the haystack and loading and unloading surfaces: soil, sod, asphalt, straw, crushed stone on the load and speed is presented. The dependence of the resistance to the introduction of the finger tip of the haystack platform into the straw on the density of the material and the dependence of the load resistance of the vehicle on the angle of inclination of the platform are shown. The results of determining the angles of inclination of the haystack platform during loading, transportation and unloading of straw and hay stacks are presented. Recommendations on the use of a self-loading haystack truck for transporting straw and hay in loose and pressed form are given.

1. Introduction

Transport operations are the most important links in agricultural production. The organization of transport works has a significant impact on labor productivity, operating costs of funds in the production of agricultural products [3].

In recent years, the operation performance of cars and tractors in transport operations has been improved, the load capacity of rolling stock has been increased, and the production of specialized vehicles for the transportation of various goods has been mastered. However, an increase in the number of tractor transport fleets cannot provide a necessary increase in the efficiency of transportation. It is necessary to introduce advanced methods of organizing transport works, improve the use of equipment, and reduce transport costs.

For the transportation of straw and hay from the haystacks to the places of consumption in farms, tractor transport units with general purpose trailers of various load capacities, cars, as well as specialized rolling stock are used. A vehicle with a replaceable body for the transportation of agricultural goods, a cargo platform for the transportation of hay rolls or straw on the basis of a truck are proposed [4,5]. Downtime during loading and unloading has a significant impact on vehicle performance. For short travel distances, downtime during loading and unloading reduces the productivity of vehicles with an increase in their load capacity [2]. Therefore, it is proposed to use a self-loading transport vehicle – a haystack truck for the transportation of straw and hay.

2. Materials and Methods

To determine the coefficients of sliding friction of straw and hay on the platform of the haystack truck, the resistance to moving the chamber with the material on two fingers was measured. The diameter of the fingers was 24, 40, 57, 76 and 89 mm. The speed of movement of the straw/hay chamber was 0.1, 0.2, 0.3, 0.4, and 0.5 mps. The experiments were carried out on straw of barley, winter wheat, oats, buckwheat, millet, as well as on hay of alfalfa and awnless brome. The moisture content of rough fodder is 16-18 %, the length of the stems is 400-700 mm. The distance between the fingers is 430 mm.

The coefficient of sliding friction of straw/hay was determined from various backgrounds: soil, sod, straw, gravel and asphalt.

Research has been conducted to determine the resistance to the introduction of finger tips into straw. Finger-tip cone angle: 150, 200, 250, 300, 350 and 400; straw density– 30, 40, 50, 60, 70 $kgpm^3$; tip movement speed – 0.1; 0.2; 0.3; 0.4 and 0.5 mps.

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3. Results and Discussion

A design feature of the proposed haystack truck is the presence of a movable platform consisting of fingers (Figure 1).

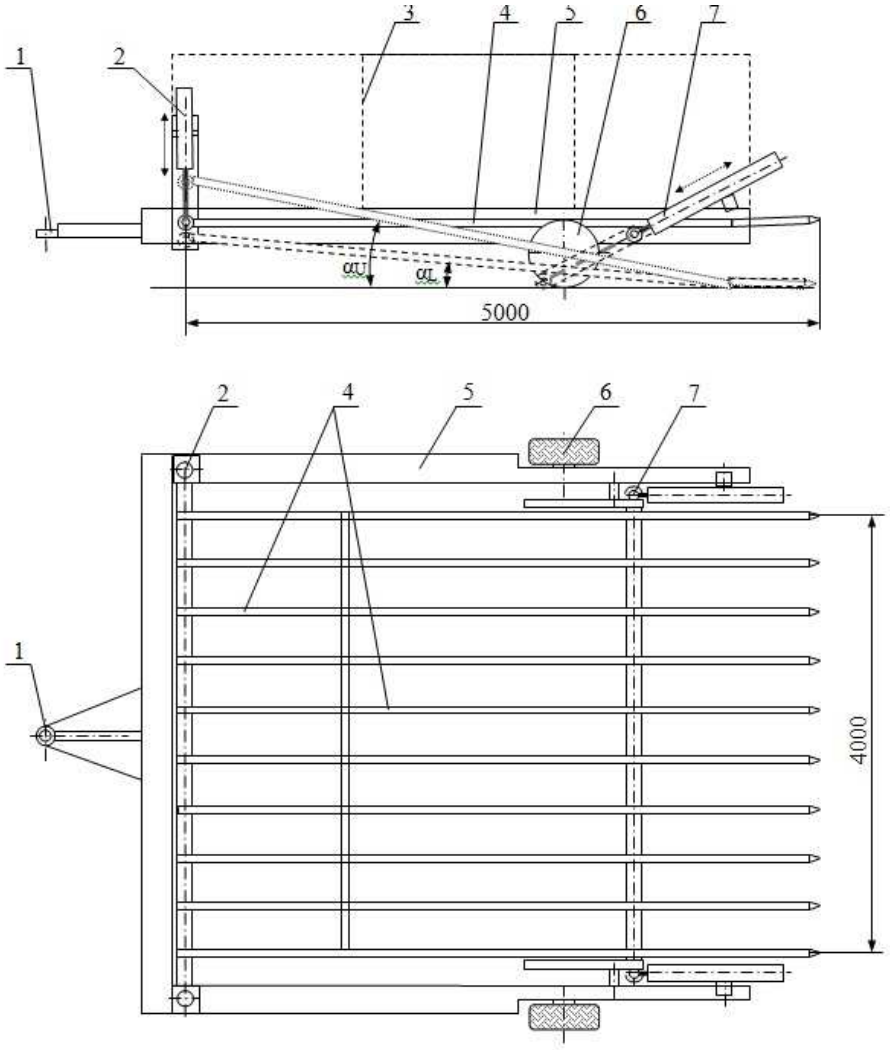

Figure 1. Haystack truck diagram: 1 – trailer device; 2 – mechanism of lowering-lifting of the front part of the platform; 3 – board; 4 – finger platform; 5 – haystack truck frame; 6 – wheel; 7 - lifting and lowering mechanism of the rear part of the platform

The haystack truck in the loading position is driven backwards by the tractor to the haystack, the fingers of the haystack platform are inserted under the straw/hay stack at an angle of α_L, then the platform is raised to the transport position by means of lowering-lifting mechanisms. When unloading, the rear part of the platform is lowered to contact with the unloading platform, and the front part is raised to provide the necessary angle of unloading α_U, and the movement of the unit forward is pulled out from under the stack. The load capacity of the haystack truck is 5 tons. The dimensions of the haystack platform, length and width, were determined taking into account the size and weight of the haystacks, which can be formed by straw/hay in loose form (Figure 2a) and pressed (Figure 2b).

The correlation dependences of the coefficients of sliding friction of straw and hay on the fingers of the haystack truck on the load and speed are obtained.

Figure 3 shows the dependence of the friction coefficient f_s of barley straw (with a moisture content of 16 – 18 %) on the steel fingers of the haystack truck on the load q (kNpm) and speed V (mps).

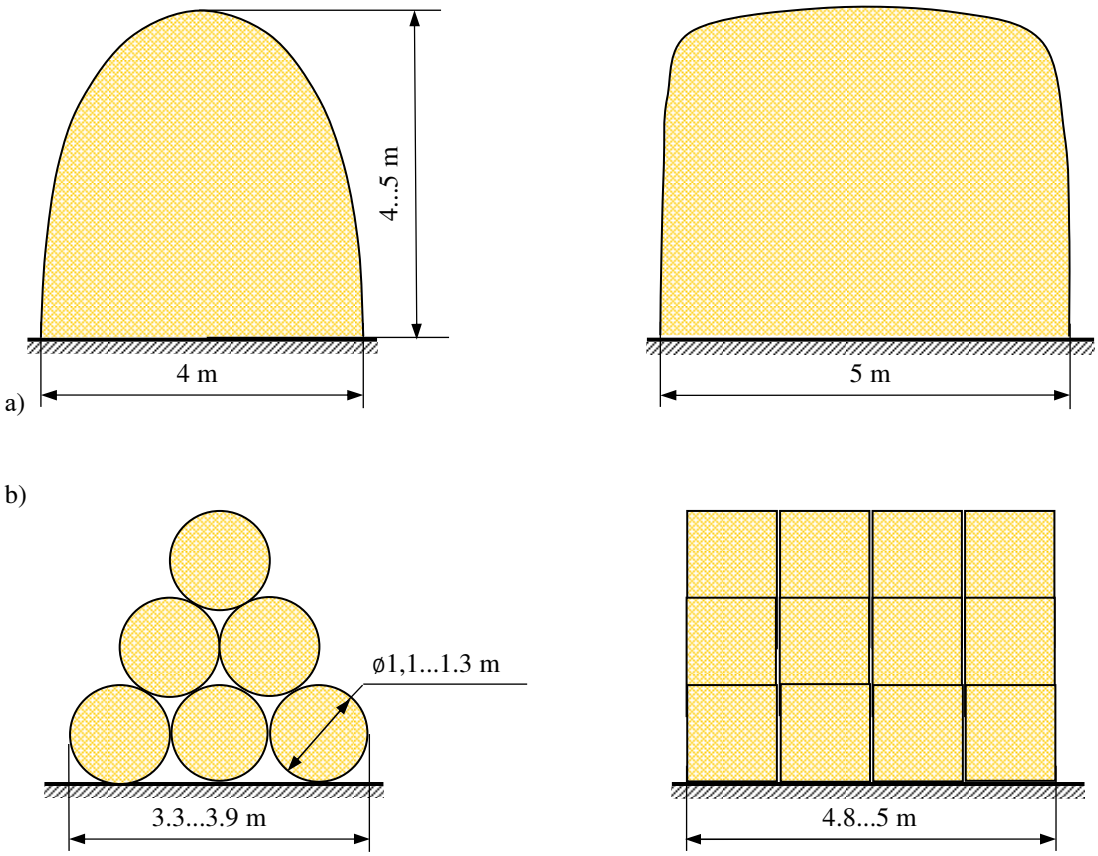

Figure 2. Options for forming straw/hay stacks for transportation on a haystack truck

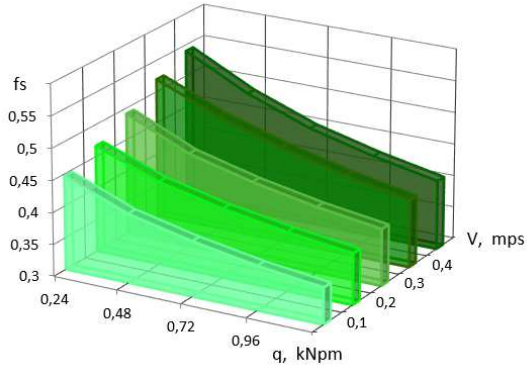

Figure 3. Dependence of the coefficient of friction f_c of barley straw on the fingers of the load q (kNpm) and the speed V (mps)

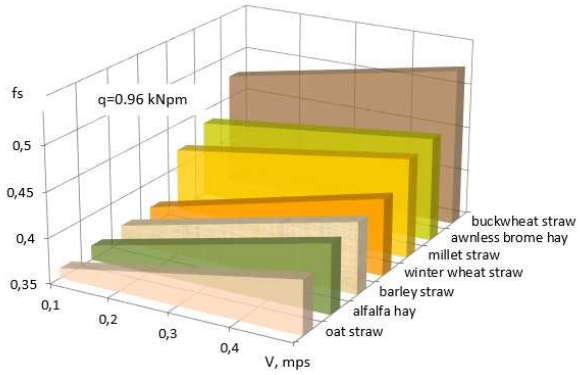

Figure 4. Dependence of the coefficient of friction f_s of straw/hay on the fingers of the haystack truck on the speed V (mps)

The analysis of the obtained data shows a decrease in the coefficient of friction with an increase in pressure on the fingers. With an increase in the load from 0.24 to 1.2 kN, the coefficient of friction decreases by 20 – 25 %. An increase in the speed from 0.1 to 0.5 mps leads to an increase in the friction force by 10 to 15 %.

The highest value of the coefficient of friction of sliding straw/hay on the fingers of the haystack was obtained on buckwheat straw and hay of awnless brome (Figure 4). The greatest difference at a speed of 0.5 mps in the friction coefficients of oat straw and buckwheat straw was 22 %.

Loading and unloading operations are carried out on various surfaces: ground surface, sod, asphalt, straw, gravel [1]. Research has been carried out to determine the friction coefficients of barley straw for various backgrounds (Figure 5).

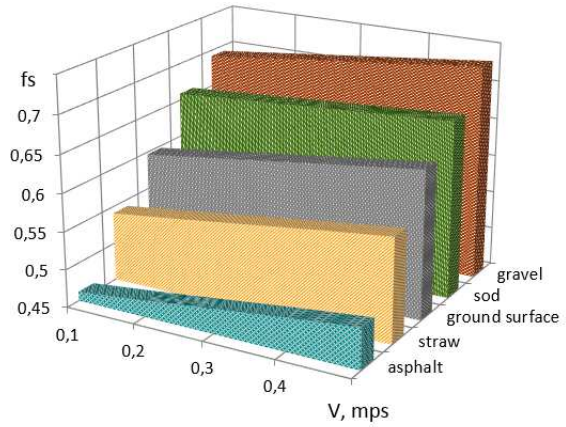

Figure 5. Dependence of the coefficient of friction f_s of barley straw on the background of the velocity V (mps)

Strain resistance is a significant characteristic of straw and hay, which determines the parameters of the finger tips of the haystack platform. The influence of the angle of the finger-tip cone β and the density of straw/hay p on the resistance to the introduction of the fingers of the haystack is studied (Figure 6). Tips with different cone angles have different deforming effects on straw/hay. To reduce the resistance when loading the haystack, by eliminating the formation of an outgrowth of compacted straw or hay in front of the tip, the platform fingers should be used with a cone angle of β≤ 20°.

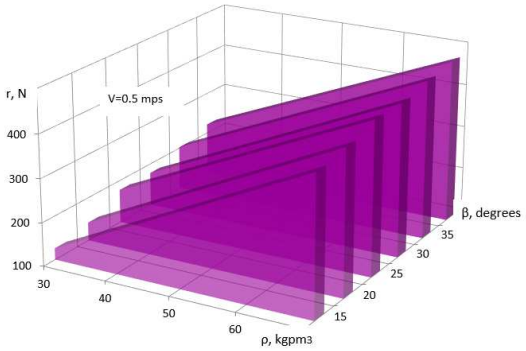

Figure 6. Dependence of the penetration resistance r (N) of the finger tip into the straw on the density of the material ρ (kgpm^3)

Based on the conducted experimental studies to determine the coefficients of friction and resistance to the introduction of the fingers of the haystack into the straw/hay, the loading resistance of the haystack was determined depending on the angle of inclination of the $\alpha_П$ platform (Figure 7).

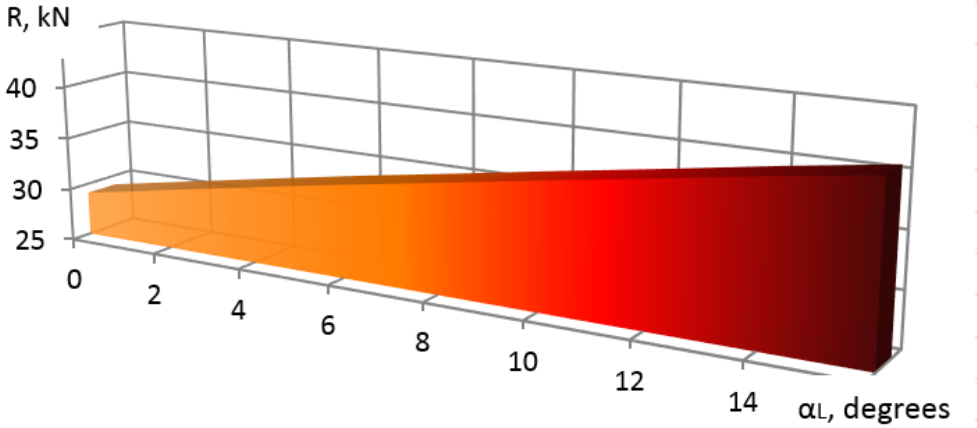

Figure 7. Dependence of the load resistance of the haystack truck R (kN) on the angle of inclination of the α_L platform

4. Conclusion

The use of a haystack truck will increase the productivity of transporting straw or hay from the stacks to the places of consumption due to less time spent on loading and unloading operations and reduce energy consumption.

1. For aggregating a haystack truck with tractors with a nominal tractive effort of 30 kN, the angle of inclination of the platform during loading should be provided with $\alpha_L \leq 10°$.

2. In order to ensure a stable position of the cargo during its transportation (taking into account starting from the place, acceleration, overcoming the lifting by the transport unit), the condition α>-2.9 ° is obtained, which should be provided by the mechanism for lowering and lifting the front part of the haystack platform or / and the rear attachment device of the tractor.

3. When unloading a haystack truck, the friction force that occurs between the load and the platform must be overcome by lifting the front part of the platform and by the action of the friction force that occurs between the part of the load and the surface of the unloading platform. Taking into account the coefficients of friction of straw/hay on the fingers of the haystack platform and on the surface of the unloading platform, the unloading condition is set - $\alpha_U > 20°$ (for a connected load). Without taking into account the friction forces from the contact of a part of

the stack at the back of the platform with the surface of the platform (for bulk-in rolls or bales), the required angle of inclination of the platform is $\alpha_U > 27°$.

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