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The Optimal Parameters of Installation of the Snow Removing Blade

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Abstract

Based on the results of research on the theory of cutting of soil, ice and compacted snow, it is established that the cutting process of compacted snow formations does not significantly differ from cutting of a frozen soil. The article presents the theoretical description of process of interaction of the cutting edge snow plow blade with snow indurated formations, the experimentally obtained dependence of the components of cutting forces (horizontal, lateral and vertical) from the parameters of the cut (cutting angle from 15 – 90 °, cutting depth 10 – 40 mm, when the angle setting of snow plow blade 45°).

The article defines optimal geometric conditions of installation of the snow blade that can be used in the development of new energy-efficient designs for snow working bodies, the improvement of existing technologies and snow removal. The application of optimal parameters in practice will allow to improve the quality of the road surfaces, the performance and efficiency of the snow machines without increasing its capacity, reduction of time, energy, and therefore, financial costs.

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Keywords: energy efficiency; performance; compacted snow; snow plow; the destruction; snow removal equipment; road surfacing.

1. Introduction

Modern industry all over the world focused on optimization, cost reduction, acceleration and improvement of various technological processes. One of the most rapidly developing areas in Russian Federation and abroad, is the development of new designs of snow working equipment and improving the technology of removal snow through the use of optimal parameters of the installation of snow removal equipment, ensuring a higher quality of

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maintenance of road surfacing, performance and efficiency of the snow machines without increasing its capacity, reduction of time, energy, and therefore financial costs.

Growth of volumes of works on removal of snow from pavements of roads due to the rapid increase in their length, the requirements of shortening removal snow and complex physico-mechanical properties of snow formations, depending on the intensity of snowfall, temperature and humidity, the number and speed of passing vehicles, determine the need for a scientific, modern approach to the clarification of optimal parameters of the angles of cutting and installing snow dumps [1].

The basis for the creation of the theory of cutting of compacted snow formations were the advances in the development of soils. Therefore, to create a coherent picture of the joint have been considered achievements in both fields of knowledge. A great contribution to the theory of the destruction and cutting of soils, ice and snow formations as well as in the determination of basic directions of increase of efficiency of winter road maintenance was made by famous scientists [2 – 23], etc. Literary analysis showed that the available data are insufficient to establish regularities of the formation of the cutting forces on the snow plow blade taking into account the geometric parameters of the cut (mounting angle, angle, and depth of cut) and physical and mechanical properties of snow formations, and thus to determine the optimal parameters.

The objective of the study is to evaluate the influence of geometrical parameters of the cut and physico-mechanical properties of snow formations on the energy intensity of the cutting process compacted snow array and substantiation of optimal parameters of the cut.

The cutting process compacted snow formations do not differ qualitatively from cutting frozen soil, investigated by K. A. Artemiev [2], V. I. Balovnev [24], A. N. Zelenin [25]. The nature of the fracture of compacted snow formations blade is determined not only by changing the parameters of the angles of cutting and the installation of the snow blade, but also the physico-mechanical properties of the developed array. The workflow of the cutting blade fig. 1 accompanied by the introduction of the cutting edge of the blade, set the angle α into an array of compacted snow formations.

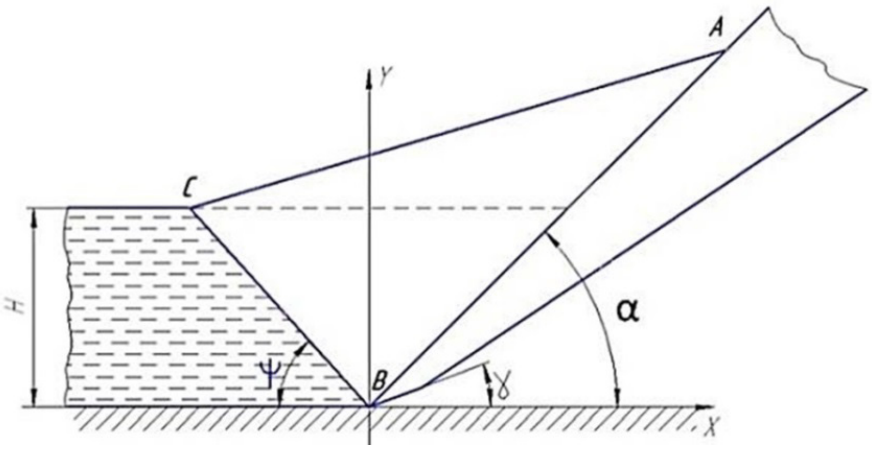

Fig. 1. Scheme of the cutting process of the array compacted snow plow blade.

The process of spalling of particles of snow begins in the moment in the contact zone of the cutting edge of the blade array with the stresses of compression, tension and shear reaches the limiting values. The voltage arising at the border of the cutting edge – compacted snow when moving the working body is transferred from the blade to develop the pattern. When the maximum stress state is spalling particles of compacted snow on the ground slip BC, which is at an angle ψ (the angle of the splice) to the surface of the cut. With continued movement of the blade, the process is repeated. On the line of contact of the cutting edges with the array are formed of core concentration of force lines of the stress. Part of the power lines, causing cracking of the material sample and its cleavage, i.e. the separation of a number of elements of various sizes, are exposed to the surface of the blade, is pushed away from the

working area. In the process of conducting experiments on cutting of compacted snow formations have the following:

- the size and shape of the shearing bodies sliding depend on the parameters of the angle of the blade, the angle and depth of cut;
- fragments puncturing the developed environment is accompanied by a sharp release of energy of adhesion of particles of compacted snow formations by shearing and ejection of bodies from the cutting zone, which indicates that cutting edge before the formation of the leading cracks, which is characteristic for elastic and unstable fracture [12].

The deformation energy accumulated as a result of implementing the cutting edge of the working tool in the array is consumed in the formation of cracks, but it is more than necessary for this, so the remainder of the energy is converted into kinetic energy release of the fragment of the deleted environment.

2. Main Part

Pilot studies using actual equipment, it is technically difficult and economically costly, therefore the decision was made to bench test using model blade auto grader GS 10.06 (width 250 mm), manufactured in 1:10 scale, under the following conditions [6]

$$l_{\mathrm{m}} = \frac{1}{10} l_{\mathrm{p}} \qquad (1)$$

where l_m – length of the model blade, mm;

l_{p} – length of the blade, mm;

The experiments were carried out on samples cut from snow Nakata (density 400 – 450 and 450 – 500 kg/m^3), located on the surface of the road. Ambient temperatures ranged from – 5 to – 8 ^{o}C.

Load parameters arising from the interaction model of the blade with an array of compacted snow formations were recorded using a special tensometric head [26], the design of which has three horizontal thrust (to ensure the exclusion of the mutual influence of components on each other) [1] mounted with a single strain gage resistance of FKPA 20 – 200 according to the schemes proposed in [27, 28].

When conducting experimental studies angles the model of the blade was varied from 90 – 15^{o} increments of 15°, angles of cut from 15 – 90° with the same step, when the chip thickness of snow 10, 20, 30, 40 mm.

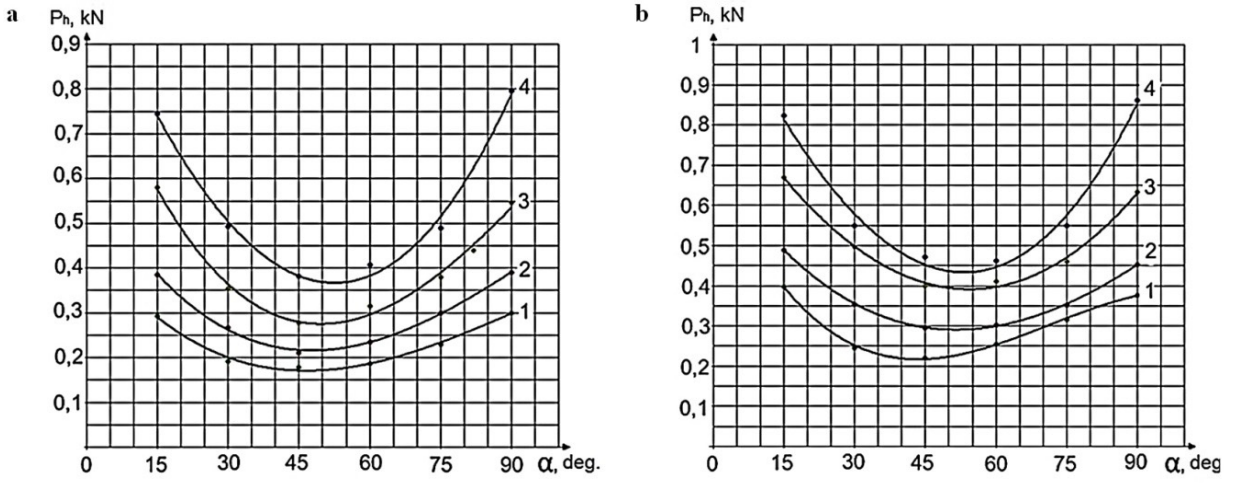

Fig. 2. Dependence of the horizontal component of the effort of cutting compacted snow formations on the angle (α) and depth (h) cutting at the angle setting of the blade 45°: (a) snow-formation density 400 – 450 kg/m^3; (b) snow education a density of 450 – 500 kg/m^3: depth of cut 1, 2, 3, 4 – respectively 10, 20, 30, 40 mm.

The analysis of statistically processed data of experimental researches it is established that the optimal values of the components of force of cutting of compacted snow formations are provided at the angle setting of the blade 45°. Graphs of the dependences of the components of cutting force (horizontal, lateral, vertical) from the angle and depth of cut are presented in fig. 2 – 4.

From obtained graphical dependences it is seen that the horizontal component of the cutting force is characterized by the size of the developing stress-deformed state when introducing the cutting edge of the blade into an array of compacted snow formations. The magnitude of the horizontal component with increasing the cutting angle varies according to a polynomial dependence.

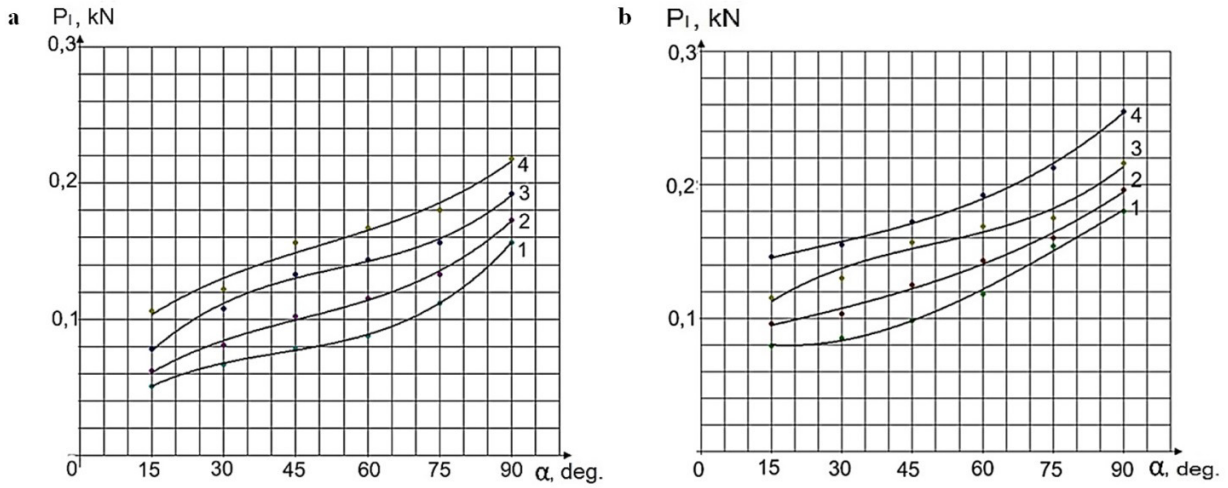

Fig. 3. Dependence of the lateral component of the effort of cutting compacted snow formations on the angle (α) and depth (h) cutting at the angle setting of the blade 45° (the symbol see Fig. 2)

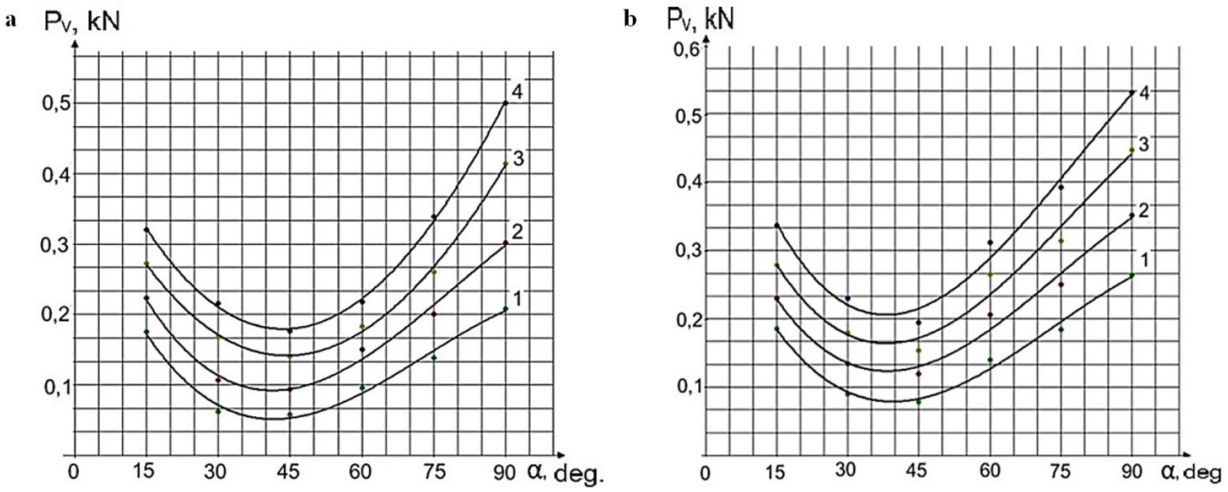

Fig. 4. Dependence of the vertical component of the effort of cutting compacted snow formations on the angle (α) and depth (h) cutting at the angle setting of the blade 45° (the symbol see Fig. 2)

The obtained large values of the horizontal component of the cutting effort due to the fact that when the cutting angles of 15 – 45° the cutting edge of the blade comes to a fairly great depth in developing the array as a result of

the indentation snow in the array before the separation of the particles of snow. The cutting edge of the blade is included in the array until will not have force sufficient to overcome the shear resistance of the particles of snow in front of the knife. When this angle of cutting is the development of large deformation of the chip, which corresponds to the maximum amount of force to cutting. When cutting angles 45 – 50º observed lowest values of the horizontal component is due to the fact that the angles at the introduction of the knife in the array, even at small depth, immediately there is a separation of particles of compacted snow. The increase in the value of the horizontal component of the efforts of cutting corners when cutting 45...50 – 90° due to the fact that at these angles there occurs cleavage of large particles of snow with minimal implementation of a cutting edge of the blade in the array being developed [29 – 31].

With the increase in the values of the cutting angle and cutting depth lateral component increases, this is due to the gradual increase in contact area of the working body with the array, this results in an increase in the specific load per unit area [30 – 31].

The analysis of dependency graphs of the vertical component of the cutting force is established: if you increase the cutting angle from 15 to 45° there is a significant decrease in the values of the vertical component of the cutting force, at angles of 40 – 55° observed minimum values, higher values of cutting angle of from 55 to 90º of the cutting forces increase rapidly.

3. Conclusions

The process of implementing the cutting edge of the working body is characterized by almost linear growth in the components of the cutting force, followed by stabilization (at constant depth).

In the process of experimental researches it is established:

- at an angle of 45 ° to the installation of the blade enables lower cutting forces to 45 – 50% in comparison with angles of 60 – 90º and the optimal combination of components of the cutting force and the width of overlap (0,2 – 0,3 m) gauge of the motor grader;
- the minimum effort of cutting are provided for angle cutting 45 to 50º;
- the size and shape of the shearing bodies sliding depend on the parameters of the slice;
- fragments puncturing the developed environment is accompanied by a sharp release of energy of adhesion of particles of compacted snow shearing and ejection of bodies from the cutting zone.

On the basis of the conducted theoretical and experimental investigations determined the optimal settings of the blade, which can be used to develop new energy efficient designs snow working bodies and the improvement of existing and technologies snow removal. The application of obtained parameters in practice will allow to improve the quality of the road surfaces, the performance and efficiency of the snow machines without increasing its capacity, reduction of time, energy, and therefore financial costs.

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