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Substantiation of Working Parameters for Winter Service Vehicle with a Snow Compactor Executive Device

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Abstract: The problem of winter urban road maintenance becomes more significant with an increasing number of vehicles on the roads and sizes of cities. The problem of winter urban road maintenance becomes significant due to a rapid urban growth and sharp increase of motor vehicle number. Value of snow removal work increases from year to year. Demands to roadbed quality of highways increases, so, time that was allowed to spend on snow removing decreases, a large number of cars makes work difficult for winter service vehicles, especially in downtown and historic districts of cities. According to the researches transportation costs is 83% of total cost of snow removal work. Distances increase to snow disposal sites and snow melters all the time by the reason of environmental requirements and their location moves far from inhabited localities. Snow compaction during loading is one of the most rational methods to cut the costs on winter road maintenance. It sharply helps to reduce expenses through more rational use of dump trucks and as a consequence reduce their number. Mathematical processing of experimental data has allowed to establish that the suggested as a working hypothesis, mathematical model of loading influence on final density variance during snow briquetting in confined space for different sizes stamps has height adequacy level.

Key words: Maintenance, vehicles, hypothesis, adequacy level, environmental requirements, disposal sites

INTRODUCTION

The problem of winter urban road maintenance becomes more significant with an increasing number of vehicles on the roads and sizes of cities.

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Value of snow removal work increases from year to year. Demands to roadbed quality of highways increases, so, time that was allowed to spend on snow removing decreases, a large number of cars makes work difficult for winter service vehicles, especially in downtown and historic districts of cities. According to the researches transportation costs is 83% of total cost of snow removal work. Distances increase to snow disposal sites and snow melters all the time by the reason of environmental requirements and their location moves far from inhabited localities.

Snow compaction during loading is one of the most rational methods to cut the costs on winter road maintenance. It sharply helps to reduce expenses through more rational use of dump trucks and as a consequence reduce their number (Egorov *et al*., 2016).

This line of research is poorly known and is of strong interest. There is a need in development of such machines, performing calculations and selecting options. The purpose of researches is a reduction of expenses on winter road maintenance through reduction costs for snow transportation from city roadways with develop of all-in-one winter service vehicle that will include snow compactor as a executive device and substantiation of the operating parameters (Leonidovich and Magomedkerimovich, 2016).

The subject of research is a processing of a snow compaction during loading into transport. The target of research is a snow compaction in the snow compactor device placed on winter service vehicle (Tikhomirov, 1974).

During the analysis the condition of a question is studied. Thus, a review of existing methods and technologies of winter road maintenance was made and problems of this branch of the science were also identified. Snow removal equipment for winter road maintenance and ways for further, export of removed snow from road surface were reviewed. Most common

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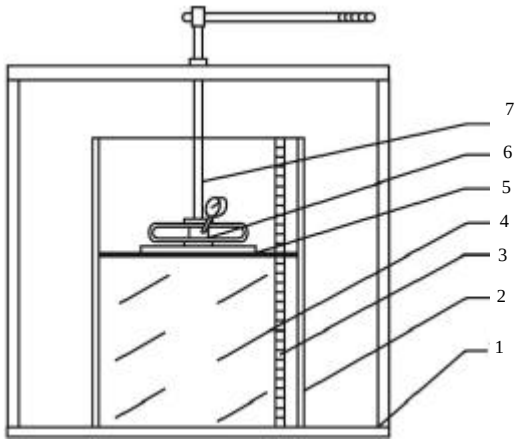

Fig. 1: Experimental rig: 1) Body with screw guides; 2) Dismountable transparent box; 3) Measuring scale; 4) Compacting matter; 5) Stamp; 6) Dynamometer and 7) Screw

snow disposal sites and their requirements were considered. Classification was developed for winter service vehicles which compacting snow during loading (Merdanov *et al*., 2016). The main goals were formulated on a base of the complete analysis.

Develop mathematical model of the snow compacting process (briquetting) in the compactor executive device. Relations should be found on a base of represented mathematical model which help to define parameters such pressure for formation bricks of required density and forces for different parts of executive device. Develop designs of winter service vehicle with a snow compactor which works during loading.

Develop the methodology of calculations and defining parameters of winter service vehicle. This requires to find out most suitable snow brick geometry for transportation, identify the pattern of change of energy consumption for the production of blocks of different sizes, find out most suitable snow brick density for transportation.

Methodology of research was suggested based on the aims and objectives shown above. It includes realization of analytical and experimental researches.

The problem was considered about snow density determination before loading and direct in the body of dump truck. The density definition methodology was developed, special device was made and multiple measurements were done. The average embankment snow density under these conditions is 0.305 t/m^3 but average snow density of removed snow is 0.299 t/m^3. It's concluded that snow density changes slightly during loading by the common front-end loader. The rational use

Fig. 2: Snow bricks

of dump trucks carrying capacity was defined during snow transportation. Calculations confirmed that an useful factor of carrying capacity during snow transportation from roads is low. Especially with stock dump trucks. The experiment procedure was described that includes the goals and objectives of the experiment, choice of varying factor, description of the experiment procedure, substantiation of wayes of data processing and experiment results analysis, measurements accuracy during test operations Fig. 1. Picture of bricks made during briquetting by the stamp 200×200 mm are shown on Fig. 2.

MATERIALS AND METHODS

Mathematical processing of experimental data has allowed to establish that the suggested as a working hypothesis, mathematical model of loading influence on final density variance during snow briquetting in confined space for different sizes stamps has height adequacy level. This relation shown pictorially in Fig. 3.

It easy to find necessary effort with use the surface of this correlation in executive device to create compact snow bricks of required density and size.

With increasing brick size truck cargo bed fill factor is decreasing in volume but data spread increases toward mean value analysis showed. It says when brick size increases at the most negative ratio of sum for bricks length and cargo bed length, larger gaps appear which gives a sharp drop in the fill factor when all three sides match together. Compacted snow bricks from the compactor device goes directly into the dump truck body during loading. Thereby, bricks fall from some high and hit each other or bottom of the truck cargo bed. Some bricks can be broken after falling that unacceptable as snow density of total volume decreasing (Egorov *et al*., 2016).

During the work process research has determined the optimal snow bricks density based on necessary bricks durability and plunger effort in the snow compacting section.

Several constructions of snow removal vehicle were designed for practical use of the research results.

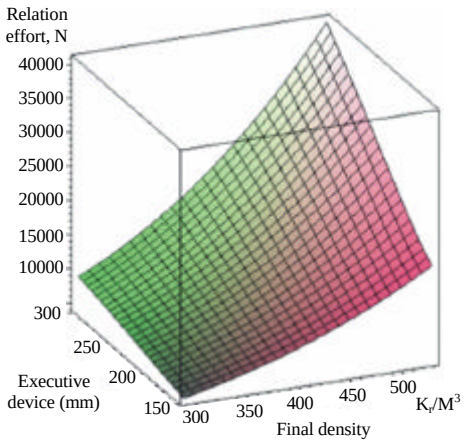

Fig. 3: Relation effort in executive device from snow brick size and final density

Following design constructions (Fig. 4 and 5) are protected by patent of the Russian Federation. This vehicle allows to produce compacted snow bricks during loading.

Calculation methodology and work options selecting of winter service vehicle has been developed based on the researches. The main principles for calculation methodology and work options selecting for snow removal machine with snow compaction executive device:

- Snow bricks size selecting according to fill factor in volume for truck cargo bed
- Snow bricks size selecting according to reduction in energy consumption
- Determination of a necessary snow bricks density
- Calculation of geometrical parameters of a snow compactor device
- Synchronization works of a snow compacting device with base vehicle units

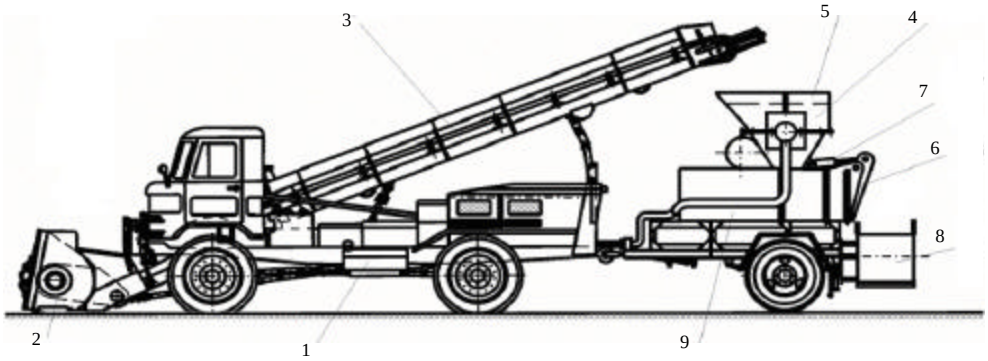

Fig. 4: Snow removal vehicle: 1) Base vehicle; 2) Intake executive device; 3) Conveyor; 4) Receiving hopper; 5) Protecting screen; 6) Compression chamber tailgate; 7) Hydraulic cylinder opener for tailgate; 8) Discharging trap and 9) Press chamber

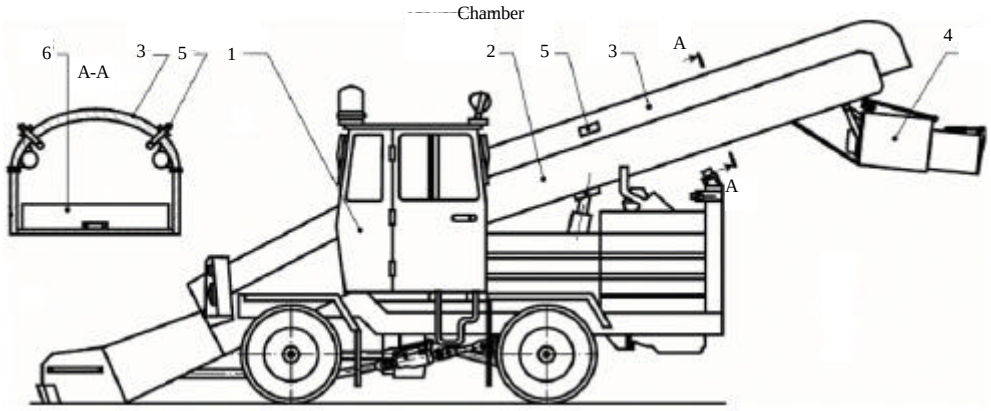

Fig. 5: Snow loader and snow compactor device: 1) Base vehicle; 2) Transporter; 3) Conveyor casing; 4) Press chamber; 5) Thermal equipment and 6) Conveyor track

- Load calculation in executive device for snow bricks production
- Choice of hydraulic cylinder for executive device, hydraulic system calculation, calculation of capacity on compaction of a snow

RESULTS AND DISCUSSION

As a result of the analysis of researches on application of snow compactor vehicles during cleaning and export of a snow from city roads it is established that:

- Snow must be compacted before loading into the transport
- There is no calculation methodology and work options selecting for snow removal machine with snow compacting device during loading and lack of it design
- There is no mathematical relation of snow compaction process in the enclosed volume under heavy loads

Mathematical model of snow briquetting in the executive device was developed. On the basis of this mathematical model new relations were created. It allows to determine such parameters like a pressure for snow breaks creation and operating force for snow compactor executive device parts. Mathematical methodology relations adequacy was confirmed during experimental research.

Following researches were made for development calculation methodology and snow removal machine work options selecting:

- Average embankment snow density on roadway and in the dump truck during transportation after loading by stock front-end loader
- Relation determined for change in dump truck fill factor depending snow bricks size
- Most suitable snow brick geometry for transportation was found
- Revealed a pattern change in the energy consumption for production different sizes and numbers of bricks
- Most suitable snow brick density for transportation was found
- Several constructions of snow removal vehicle with snow compacting during loading were designed and protected by patent of the Russian Federation
- Methodology of calculations and defining parameters for winter service vehicle was developed

CONCLUSION

For carrying out of experimental researches the experimental installation consisting of following elements is developed and designed (Maratovich *et al*., 2016).

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