Investigation of return movement process of vibrocleaver blade

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Abstract. The lack of the necessary amount of equipment for winter maintenance, significant precipitation leads to a decrease in the efficiency of roads. Inside, courtyards and sidewalks are also covered with a layer of compacted snow due to untimely snow removal. The mechanical method of breaking compacted snow is currently insufficiently studied and so far there is no effective equipment to combat snow and ice formations. A peculiarity of the process of compacted snow destruction in the mode of “vibration cutting” is intermittent contact of the blade with the destroyed medium. Condition of steady mode of vibration cutting is criterion of vibration scraper blade release from contact with medium to be destroyed. The purpose of the study is to establish the time at which the contact of the blade with compacted snow is interrupted. Obtained results of calculations make it possible to set values at which vibration cutting mode is possible and to select parameters of hydraulic accumulator, which provides movement of the vibrocleaver blade of compacted snow.

1. Introduction
The role of roads in the Far East is especially great. Highways - in most regions are the only mode of transport. The lack of the necessary amount of equipment for winter maintenance [1-7], significant precipitation leads to a decrease in the efficiency of roads.

The fallen snow forms a layer of compacted snow, which has reduced coupling qualities, at which the transport speed decreases, the number of accidents and injuries of traffic participants increases.

Inside, courtyards and sidewalks are also covered with a layer of compacted snow due to untimely snow removal.

The main method of breaking a layer of compacted snow is chemical using salts that negatively affect the environment [5, 6]. The mechanical method of breaking compacted snow is currently insufficiently studied and so far there is no effective equipment to combat snow and ice formations.

Finding ways to improve the efficiency and performance of snow removers remains an urgent task. In order to solve this problem, experts of many countries on the winter road maintenance and transport facilities have conducted significant studies [8, 9].

2. Materials and methods
Pacific State University has developed several prototypes of equipment for the destruction of compacted snow on roads and sidewalks using the vibration pulse effect of a blade on a layer of snow and ice [8, 9].

The working process of a compacted snow vibrocleaver, designed to destroy snow-ice formations on sidewalks in a mechanized way, is distinguished by a pulse loading mode. The cutting force
depends on the parameters of the layer of snow to be cut: density, depth and width of the cut, angle of
cutting, as well as air temperature. In addition, the cutting force is characterized at the beginning of the
process of interaction of the blade of the blade with snow by an increase in its value, and then, with
chips of snow particles, a sharp decrease in the maximum values characteristic of the destruction of
solid brittle media.

The impulse method of interaction of working bodies with the medium finds increasing application.
There is a problem of creating simple and reliable vibration exciters. A new type of pump hydropulser
is proposed in Russian Patent No. 2162030 (fig. 1).

![Figure 1. Gear type hydraulic pulser design diagram](image)

Peculiarity of gear-type hydropulser is cutout in contacting teeth of windows 1 in order to preserve
kinematic connections between gears 2, 3. During rotation of gears with full teeth, working fluid is
sucked in and pumped into working cavity of hydraulic propeller 4. Pressure at output of hydraulic
pump-pulsator grows under action of elastic force of spring 5. At the moment of interaction of teeth
with openings, pressure chamber 6 of hydraulic propeller 4 communicates with suction chamber 7 of
hydraulic pump and under action of compressed spring 5 rod of hydraulic propeller 4 moves to initial
position, displacing working fluid into suction line. The process of overflow of the working fluid from
the delivery line to the suction line is stopped during the period when the conventional teeth begin to
interact, and the working fluid again begins to be pumped into the working line of the hydraulic
propeller.

Filling of suction line and makeup of possible leaks in hydraulic pusher 4 is performed through
check valve 8 under pressure $p_0 = 0.3 - 0.5$ MPa. Such pressure provides better suction conditions for
the working fluid by the pulsator pump. Hydraulic pneumatic accumulator 9 serves as a reservoir and
is filled with volume of working fluid supplied from drain line of the main hydraulic system.

A peculiarity of the process of compacted snow destruction in the mode of "vibration cutting" is
intermittent contact of the blade with the destroyed medium.

The working process consists at the initial stage of introducing the blade into the compacted snow
with movement to the position $x_0$, and then when the gear windows are opened, the blade returns to
the initial position and simultaneously moves forward with the speed of the base machine $V_M$. The blade
cutting edge coordinate will be

$$x = x_0 - x + V_M \cdot t$$

(1)

The purpose of the study is to establish the time during which the contact of the blade with
compacted snow is interrupted.

The process of returning the blade is presented in the form

$$m \cdot \ddot{x} + k \cdot \dot{x} + c \cdot x = c \cdot x_0 - p \cdot F$$

(2)
where \( m \) - rod weight; \( k \) - coefficient of viscous friction; \( c \) - spring stiffness; \( F \) - piston area; \( x_0 \) - initial position of rod; \( p \) - pressure in hydraulic pusher cavity.

Pressure in front of hydraulic push-rod decreases sharply from initial position \( p_0 \), and then increases as blade returns to initial position due to overcoming resistance to movement of working fluid [9, 10]

\[
p = p_0 \cdot e^{-\alpha t} + \left( \frac{\lambda}{d} \cdot \frac{l}{d} + \xi \right) \left( \frac{2 \cdot F_r}{f_{TR}} \right)^2 \rho_{hf} \cdot x^2
\]  

(3)

where \( \alpha \) is the coefficient that takes into account the intensity of the initial pressure drop, \( \alpha = 400 \) 1/s; \( \lambda \) - is coefficient of resistance to the movement of the working fluid; \( l \), \( d \) - the length and diameter of the pipelines; \( \xi \) - is the coefficient of local resistance, \( \xi = 10 \); \( F_r = 0.25 \cdot \pi \cdot D^2 \) - the area of the hydraulic pushrod; \( D \) - the diameter of the hydraulic pushrod; \( f_{TR} = 0.25 \cdot \pi \cdot d^2 \) - the area of the pipelines, \( \rho_{hf} \) - the density of working fluid.

3. Results and Discussion

The solution of equations (2, 3) is performed in the MATLAB program with the accepted values of \( m = 0.003 \) kg·s\(^2\)/cm; \( k = 0.2 \)  kg·s/cm; \( F_r = 1.13 \) cm\(^2\); \( f_{TR} = 0.5 \) cm\(^2\); \( V_M = 100 \) cm/s; \( c = 91.8 \)  kg/cm; \( x_0 = 0.6 \) cm... 1.6 cm.

Results of transient processes of vibrocleaver blade movement are obtained. It was established that at the moment of opening of gear teeth windows, the blade reaches a value \( x_0 \), and the pressure drops sharply from the value \( p_0 \) (fig. 2) to values determined by pressure losses on local resistances and along the length of pipelines.

![Figure 2. Pipeline pressure change transients](image)

Under the influence of another force, the blade starts a return movement (fig. 3). The speed of the return motion depends on the value \( x_0 \) and \( p_0 \). At the same time, the vibrocleaver blade continues to move with the base machine at a speed \( V_M \).

The return speed of the blade depends on \( x_0 \) and \( p_0 \) (fig. 4).
Condition of steady mode of vibration cutting is criterion of vibrocleaver blade release from contact with medium to be destroyed.

\[-V_x > V_M\] (4)

It is found that at the speed of the base machine \( V_M = 1.0 \text{ m/s} \) (100 cm/s) only at \( x_0 > 0.8 \text{ cm} \), the speed of return movement can ensure that the blade comes out of contact with the medium to be destroyed.

![Figure 3. Transient processes of vibrocleaver blade return movement](image)

![Figure 4. Transients of vibrocleaver blade return speed](image)

4. Conclusion
The obtained calculation results make it possible to set the values at which the vibration cutting mode is possible and to select the parameters of the hydraulic accumulator, which provides movement of the blade of the vibrocleaver of compacted snow up to the values \( x_0 > 0.8 \text{ cm} \).

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