Increasing the life of the brush working equipment of a utility vehicle by using a device to control its position

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Abstract. The article is devoted to the urgent problem of the resource increasing of the brush working equipment of a communal machine. To increase the resource of the brush working body, it is necessary to provide the recommended area of the contact spot of the brush bristles with the surface to be cleaned. This can be done by using a brush position control device. The results of the study of the effect of bristles deformation on the area of contact between the brush working equipment and the surface being cleaned are presented. A variant of the position controlling device of the brush working equipment of a communal machine providing the recommended area of the contact spot between the bristles and the surface being cleaned is proposed. A design diagram of the deformation of the brush working body is presented. As a result of the interaction process analysis between the brush working equipment and the surface being cleaned a relationship is obtained connecting the area of the contact spot with the deformation of the pile. A graph of this dependence is constructed. As a result of the work performed, a relationship is determined that allowing to determine the value of the contact area of the brush working equipment with the surface being cleaned for various values of the bristles deformation taking into account their wear.

Keywords: anthropogenic sources, oil refining and petrochemical enterprises, hydro-pneumatic accumulator, brush working equipment, contact spot area, bristles deformation.

1. Introduction
In Russia, a municipal machine equipped with a cylindrical brush is used as the main machine for cleaning roads and adjoining territories. In order to investigate the working process of this machine, it is necessary to consider its complex dynamic system. Track rollers allowing the brush working equipment to copy the irregularities of the surface being cleaned are the link that transfers dynamic loads to the machine [1,6]. They significantly affect the change in the vertical coordinate of the BWE (brush working equipment) due to the change in the vertical coordinates of the irregularities of the surface being cleaned and, as a result, the pressing force of the brush bristles [8]. This leads to increased wear of the pile and a decrease in the resource Brush Working Equipment [3].

The use of a control device for the position of the switchgear in the vertical plane eliminates track rollers from the design and thereby reduces the negative dynamic effect on the elements of the switchgear. To implement the proposed control device, it is necessary to establish a relationship between the area of the contact patch of the pile and its deformation between the area of the contact spot of the brush bristles and their deformation.

The purpose of this article is to determine the relationship between the area of the contact spot of the brush working element with the surface being cleaned and the deformation of its brush.

2. Formulation of the problem
Research objectives are:
1. To determine a possible way of the controlling position of the brush working equipment allowing to take into account the change in the length of the brush bristles during its operational wear.
2. To conduct the analysis of the process of interaction of the brush working equipment with the surface being cleaned.
3. To obtain the dependence connecting the area of the contact area of the brush working equipment with the surface being cleaned, the parameters of the brush working equipment, and the deformation of the brush bristles.
4. Implementation the subsystem for calculating of the contact area of the brush working equipment with the surface being cleaned, and obtain the area values at various values of the brush bristles deformation.
5. Using the obtained values, construct a graph of the dependence of the area of the contact spot on the deformation of the brush bristles, carry out its approximation and obtain a recurrence equation.

3. Theory
The results of previous studies [1,8] indicate that the required area of the contact spot ($S_c$) of the brush working equipment with the surface being cleaned depends, in particular, on the length of the bristles which change due to the wear. It is possible to provide the required area of the contact spot during the operation of the communal machine (CM) using the control device (CD) by the position of the brush working equipment. One of the options for implementing this CU is shown in figure 1. In this option, it is proposed to use a hydro-pneumatic accumulator (HPA), which provides the pressure in the rod cavity of the hydraulic cylinder for controlling the position of the brush working equipment needed to maintain the necessary contact spot.

![Figure 1](image)

Figure 1. Changes in the position of the brush working equipment due to the control device while reducing the length of the bristles due to wear

Thus, with a change in the length of the brush working equipment brush bristles ($d_{b1}$, $d_{b2}$), its rigidity will change and therefore the necessary value of the pressing force at which the contact spot area will correspond to the required values [5]. Hydro – pneumatic accumulator (HPA) will allow you to maintain a certain force of pressing the brush working equipment (BWE) to the surface being cleaned, regardless of the wear of the brush bristles.
The proposed BWE position controlling method (figure 1) allows you to abandon the use of support wheels mounted on the brush working equipment which limit the area of use of the communal machine (CM), for example, when stripping instrument space (figure 2b).

In the cleaning process the instrument space, the design of the brush working equipment deforms (figure 2a) as it often comes into contact with the curb. In addition, it is not possible to provide the required value of the pressing force of the BWE to the surface to be cleaned, which leads to uneven wear of the brush bristles (figure 2b) and resource decrease of the BWE brush bristles (figure 2b).

In order to determine the relationship between the deformation of the brush bristles and the area of the contact spot, it is necessary to consider the interaction of the brush working equipment and the surface being cleaned.

Within this interaction, the brush carries out three processes [2,4]:
- deflects (the brush bends elastically);
- straightens (the brush overcomes the friction force);
- makes free vibrations.

The scheme (figure 3) of the interaction of the BWE with the surface being cleaned allows us to consider four characteristic positions of single bars of the brush [7, 8]:

1) at the beginning of the contact of the next bar of the brush with the surface being cleaned under the influence of centrifugal force;
2) bending the bar and moving the brush along the surface to be cleaned;
3) a sharp transition of the bar from the bent state to the straightened position;
4) the bar takes a radial position.
4. Results of the experiments and discussion

As a result of the analysis of the design scheme (figure 4), the dependence of the width of the contact spot of the CM the surface being cleaned (x_k) on the deformation of the brush bristles (Y_{po}) (dependencies 1-5) was obtained.

\[
\begin{align*}
L &= r - Y_{po} \\
F_{pr} &= \frac{x_k}{2} + L_{BC}^2 \\
L_{BC} &= r - Y_{po} \\
x^2 &= \frac{x_k}{2} + L_{BC}^2
\end{align*}
\]

Where L_{bc} is the height of the location of the drum or brush core above the surface to be cleaned, m; \( r \) is the radius of rotation of the brush, m; \( Y_{po} \) - brush bristles deformation, m; \( F_{pr} \) - pressure force, H.
As a result of the analysis of the design scheme (figure 4), the dependence of the width of the contact spot of the CM the surface being cleaned ($x_k$) on the deformation of the brush bristles ($Y_{ro}$) (dependencies 1-5) was obtained.

\[ r^2 = \left( \frac{x_k}{2} \right)^2 + (r - Y_{po})^2; \tag{2} \]

\[ Y_{po} = r - \sqrt{r^2 - \left( \frac{x_k}{2} \right)^2}. \tag{3} \]

Lepesh G.V. [1] determined the optimal values of the width of the contact spot (70-100 mm), at which the required efficiency of the CM working surface is ensured (Figure 5).

![Figure 5](image)

**Figure 5.** The dependence of the deformation of the brush bristles on the width of the contact spot

1 – brush working equipment; 2 – optimal contact spot; 3 – deformation of the brush bristles; 4 – surface to be cleaned

With the increase in the width of the contact of the brush working equipment with the surface being cleaned the cleaning efficiency increases smoothly.

Taking into account that $S_k = x_k \cdot L_b$, dependence (4) takes the form:

\[ S_k = 2 \cdot L_b \cdot \sqrt{r^2 - (r - Y_{po})^2}. \tag{4} \]

The block diagram of the subsystem for calculating the area of the contact area of the switchboard with the surface depending on the deformation of the pile, implemented in Matlab Simulink, shown in figure 6.

![Figure 6](image)

**Figure 6.** The block diagram of the subsystem for calculating the area of the contact area of the brush working equipment with the surface
The presented block diagram is one of the components of the simulation model of the communal machine working process. This subsystem makes it possible to take into account the influence of the brush bristles deformation and wear on the change in the area of the contact place of the brushing body with the surface being cleaned.

The obtained dependence (formula 4) allows us to determine what kind of the brush deformation is necessary to ensure that the contact spot area takes the required values. This, in turn, will improve the quality of cleaning the roadway and increase the operational life of the BWE. The compiled block diagram of the subsystem of the communal machine working process allows you to determine the value of the contact spot of the brush working equipment taking into account the wear of the brush.

As a result of the simulation, the dependence shown in figure 7 is obtained.

![Figure 7. Dependence of the contact spot area of the brush working equipment with the surface being cleaned on the bristles deformation](image)

As a result of approximating the graph by a third-order polynomial, the dependence is obtained:

$$S_k = 63408 \cdot Y_{po}^3 - 3309 \cdot Y_{po}^2 + 69,022 \cdot Y_{po} + 0,0054.$$  

The determination coefficient in this case is $R^2 = 0,9973$.

5. The discussion of the results
The graphical dependence (figure 7) makes it possible to determine bristles deformation length necessary to ensure that the area of the contact spot of the brush working equipment of a communal machine with the surface to be cleaned takes the necessary value.

6. Resumes and conclusions
The analysis of the interaction process between the brush working equipment of a communal machine and the surface being cleaned made it possible to obtain the relationship connecting the dimensions of the contact spot of the brush working equipment with the surface being cleaned and the deformation of the bristles taking into account their wear. The obtained dependence is used to compile a mathematical model of the working process of a communal machine and confirm its adequacy.

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