Dynamics of utility machines with brush-working equipment

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Abstract. The article is devoted to the actual problem of improving the quality of roadway cleaning. In order to achieve the maximum effect from the cleaning of the roadway, it is necessary to ensure the required communal machine movement speed at which the brush working equipment pressing force to the roadway will be optimal.

Research methods. The study results of the influence of the linear movement speed on the value of the force pressing the brush working equipment to the surface being cleaned are presented. A mathematical model of the communal machine workflow is obtained. The simulation was carried out using the software MATLAB the Simulink extension. Parameters of the mathematical model were fixed, only the value of the linear velocity of the communal machine was changed.

Results. As a result of the simulation, graphs of the brush working equipment pressing force to the road way surface of the utility machine were calculated. The approximation of the theoretical dependence of the brush working equipment pressing force to the surface to be cleaned on the linear velocity of the utility machine is carried out, a regression equation is obtained.

Findings. As a result of the work performed, was determined the range of the optimal speed of movement of the utility machine at which the pressing force of the brush working equipment to the roadway would be close to the required value.

Keywords: communal machine, working process, brush working equipment,
linear speed, pressing force

1. Introduction

For the pavement cleaning from dirt, dust, small debris utility machines are used. Territory cleaning is being done according to route cards [9, 13]. These cards are compiled taking into account the requirements of the frequency of technological operations. Sidewalks that are more than 3.5 m wide are recommended to be cleaned by machines intended for the carriageway of highways [16]. On the first class sidewalks mechanized cleaning at higher operating speeds (7-8 km / h) is allowed provided that safe movement of pedestrians is observed [7,10].

To improve the efficiency of the workflow of a communal machine, it is necessary to ensure the optimum speed of its movement, at which the pressing force of the brush working equipment to the roadway will be close to the specified value.

Before proceeding to this study, the works of foreign and domestic scientists published in scientific journals were studied [14]. Studies on a similar topic were conducted by Libardo V., Vanegas-Useche, Magd M., Abdel-Wahab, Graham A., Parker, the results were published in the scientific journal Waste Management in the article "Effectiveness of oscillatory gutter brushes in street sweeping waste", In the article authors determine the values of parameters such as the speed of a communal machine, the angular velocity of rotation of the WEDD, the angle of the drum sector, the pile deformation [15, 17]. An analysis of this work, as well as works with similar subjects, allows us to conclude that the researchers do not consider the dependence of the speed and pressing force of the brush working equipment, which does not allow changing the size of the contact patch at the required intervals.

In view of the foregoing, it is necessary to conduct studies of the dependence of force on speed, in order to solve the problems posed.

To improve the efficiency of the workflow of a communal machine, it is necessary to ensure the optimum speed of its movement, at which the pressing force of the brush working equipment to the roadway will be close to the specified value.

The purpose of this article is to determine the relationship between the pressing force of the brush working equipment to the surface being cleaned and the linear speed of movement of the utility machine.

Objectives of the study are:

1. To determine the optimal modes of workflow of the communal machine on the basis of a mathematical model this will allow carrying out theoretical studies.

2. To build dependence graphs of the standard deviation of the brush working equipment pressing force to the surface being cleaned from the utility machine movement velocity.

3. To carry out an approximation and obtain a recurrent equation.

4. To determine the optimal speed of movement of the communal machine, at which the force pressing the brush working equipment to the roadway will be close to the desired value.

2. Theory

The analysis of the influence of the linear speed of movement on the value of the pressing force of the brush working equipment to the surface being cleaned was carried out on a mathematical model of a complex dynamic system of the communal machine workflow (Fig. 1) [3,4].
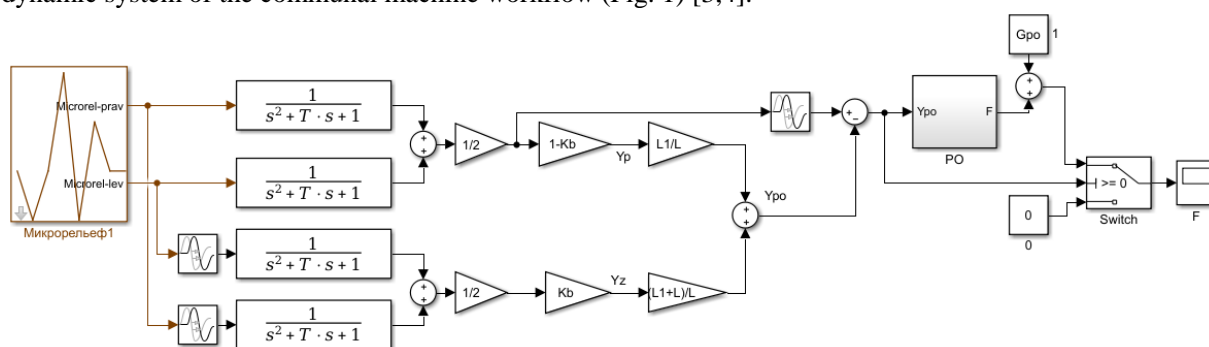

Figure 1. Block diagram of a complex dynamic workflow system of a communal machine in the notation Matlab Simulink.

The input effects of the mathematical model are disturbing effects from the micro relief of the roadway (Microrel-prav, Microrel-lev) on the running equipment of a communal machine [1, 2]. Namely these effects which lead to an uncontrollable change in the pressing force (F) of the brush working equipment to the surface being cleaned, which is the output parameter of the model [5, 6].

In the course of a machine experiment, all the parameters of the mathematical model were fixed, only the linear velocity (V) of the displacement of the utility machine was changed from 1 to 12 km / h [8, 12].

3. Experimental results

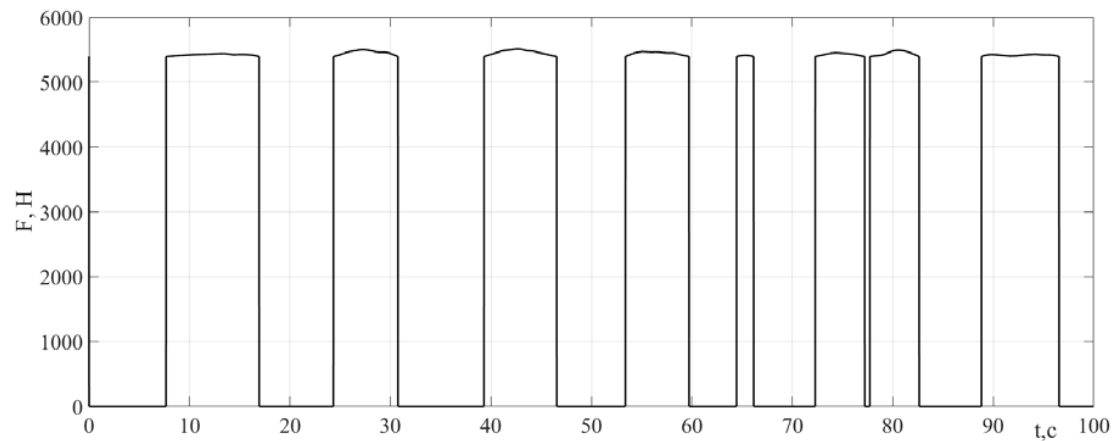The simulation results are shown in Figures 2-6.

Figure 2. The change in the pressing force of the brush working equipment to the surface being cleaned in time for V = 1 km / h.
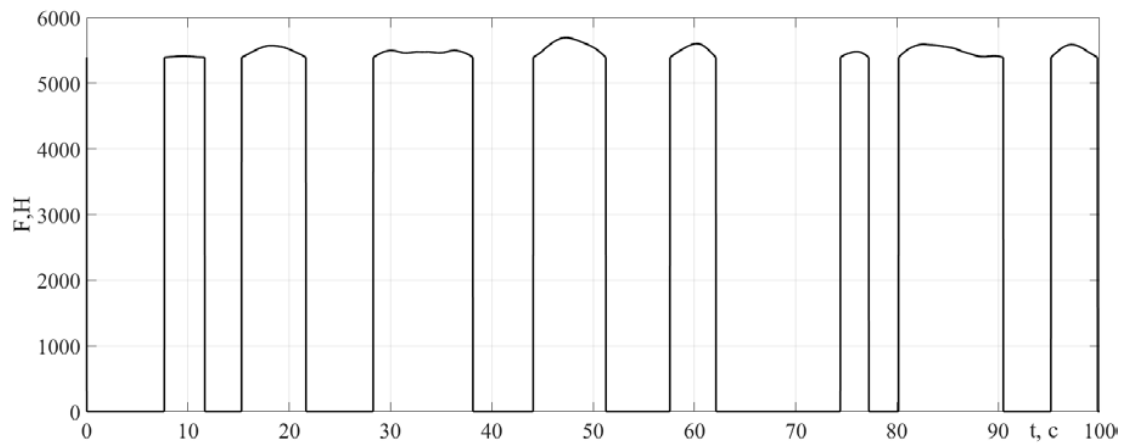

Figure 3. Change in the pressing force of the brush working equipment to the surface being cleaned in time for V = 4 km / h.
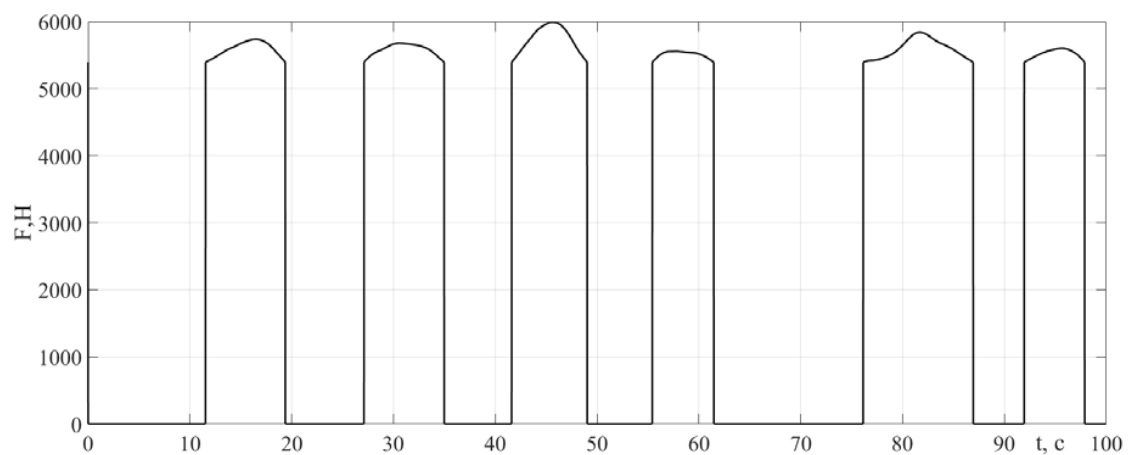

Figure 4. The change in the pressing force of the brush working equipment to the surface being cleaned in time for V = 8 km / h.
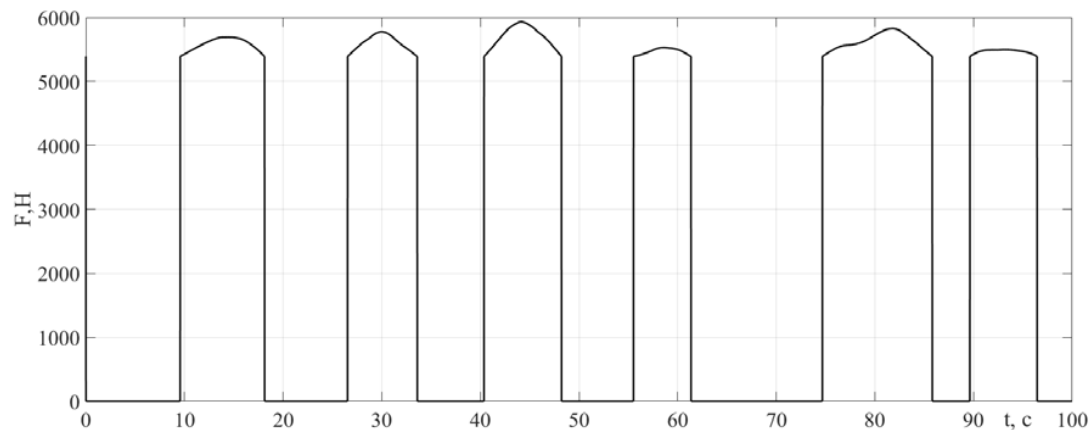
Figure 5. The change in the pressing force of the brush working equipment to the surface being cleaned in time for V = 10 km / h.

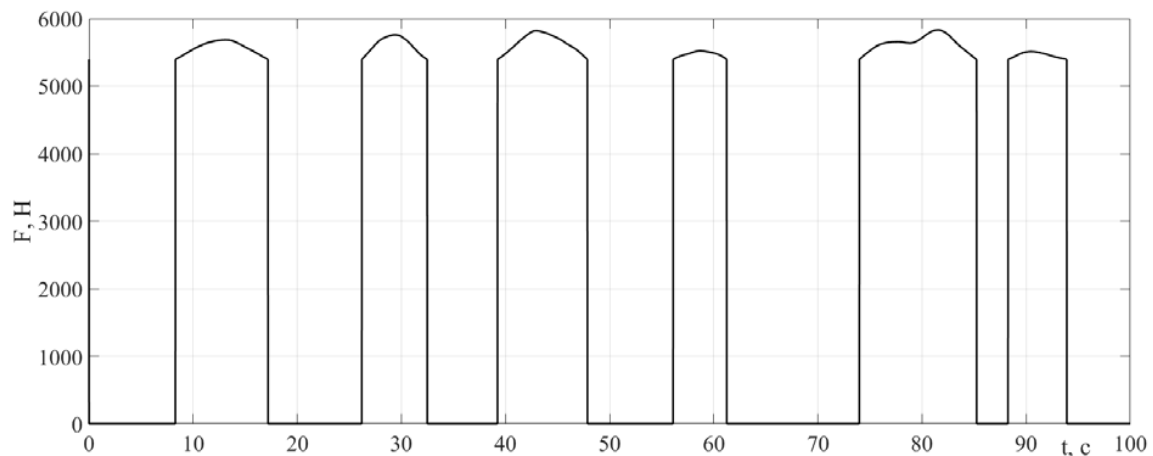**Figure 6.** The change in the pressing force of the brush working equipment to the surface being cleaned in time for V = 12 km / h.

4. The discussion of the results

The analysis of the obtained graphs showed that the linear speed of movement of the communal machine influences the number and length of sections on which the brush working equipment contacts the roadway.

In order to determine whether the force of pressing the brush working equipment to the roadway corresponds to the required values, it is necessary to determine the standard deviation of these values relative to each other (Fig. 7). The calculations were carried out for a communal machine equipped with a cylindrical brush, the characteristics of the pile of which are such that the required value of its pressing force is 5.4 kN.
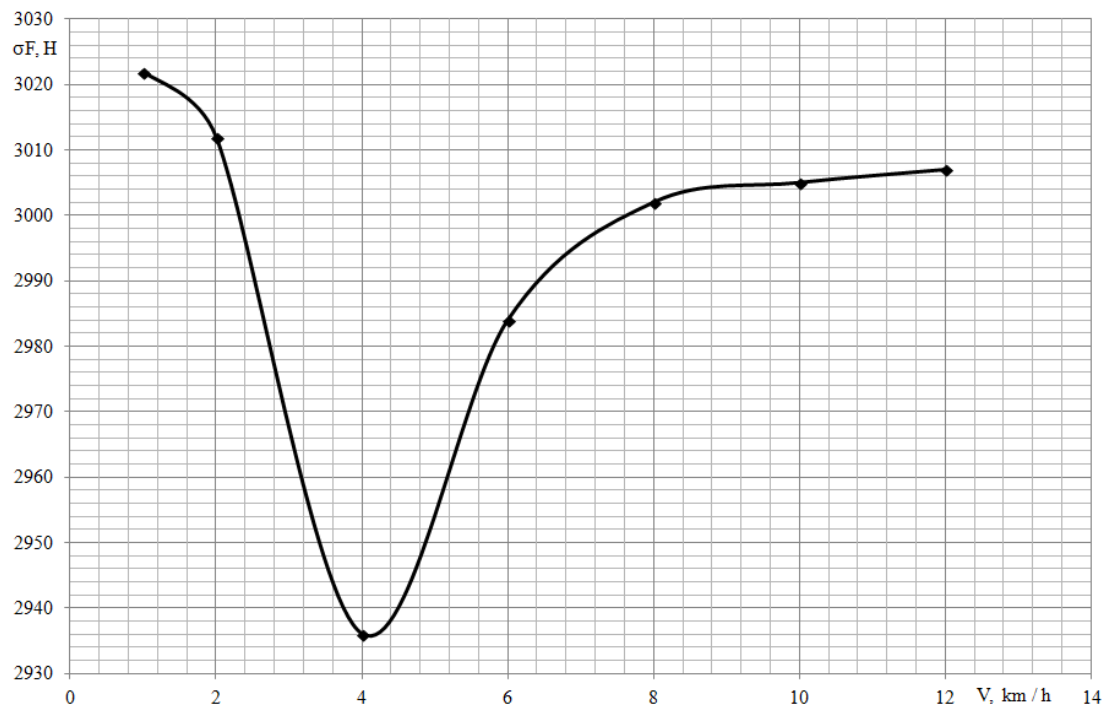
Figure 7. Dependence of the standard deviation of the pressing force of the brush working equipment to the surface being cleaned from the linear speed of movement of the communal machine.

The analysis of the dependence of the standard deviation of the pressing force of the brush working equipment to the surface being cleaned from the linear speed of movement of the utility machine showed that its minimum extremum is in the range of linear speeds of 2 ... 6 km / h. To determine the optimal value of the linear velocity, it is necessary to establish the form of the dependence σF=f(V). To do this, we will approximate, i.e. build a trend line (Fig. 8) [11,18].

$$\sigma F, H = -0{,}0203V^6 + 0{,}8069V^5 - 12{,}418V^4 + 92{,}105V^3 - 331{,}31V^2 + 501{,}72V + 2771{,}1$$
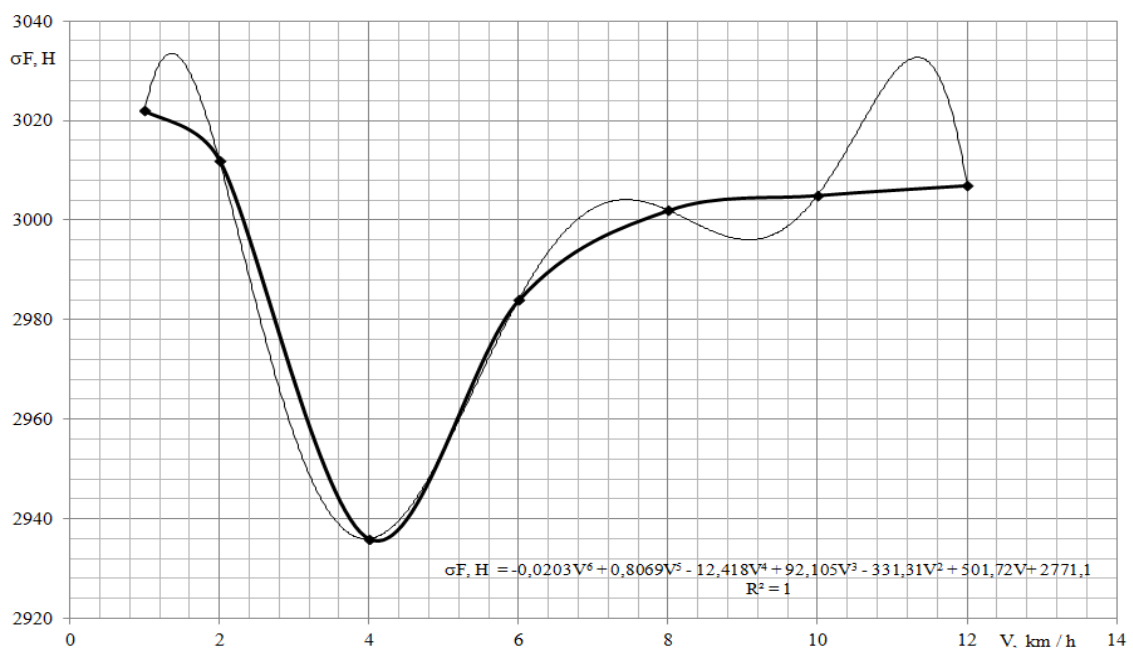$$R^2 = 1$$

Figure 8. Approximation of the dependence of the standard deviation of the pressing force of the brush working equipment to the surface to be cleaned from the linear velocity of the utility machine of the fourth order polynomial.

The result is a dependency:

$$\sigma F(V) = -0.0203 \cdot V^6 + 0.8069 \cdot V^5 - 12.418 \cdot V^4 + 92.105 \cdot V^3 - 331.31 \cdot V^2 + 501.72 \cdot V + 2771.1, \quad (1)$$

wherein $R^2 = 1$.

5. Resumes and conclusions

In the course of the research work, the regression equation $\sigma F = f(V)$ was obtained. This equation can be used in further scientific studies of the working process of a communal machine to determine the rational value of the speed of movement of the machine at which the pressing force of the brush working equipment to the roadway will be close to the desired value. The results of the study indicate that the required value of the speed of movement of a communal machine equipped with a cylindrical brush is in the range of 2 to 6 km / h. The data obtained will be useful to the utility machine operator to select the speed limit.

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