Use of repair-recovery compositions for reducing the adhesion of soils to working bodies of machines

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Abstract. This article discusses the impact of repair-recovery compositions on the process of buildup of the soil working bodies of earthmoving machines. Adhesive forces can be reduced by creating an intermediate layer at the interface between the phases of the system "surface of the working member - the medium to be treated. This layer serves as a screen for intermolecular interaction forces of phases, has a small adhesion and cohesive interaction and has a "lubricating" effect, i.e. provides the possibility of relative displacement of phase working surfaces. Experimental work is conducted in accordance with the mathematical theory of planning of experiments (plan Box 3). After handling of an experiment graphical dependences of effort of shift from a surface without repair and recovery structures and with use of repair and recovery structures were received. The experiments carried out showed that when the RVS is applied, the adhesion of the soil to the metal surface of the digger's working member is reduced by an average of 18%.

1. Introduction

Soil adhesion is a phenomenon of bond formation due to intermolecular interaction. It manifests itself both in the form of freezing forces at minus temperature and in the species of adhesion forces at plus temperature.

Adhesive forces can be reduced by creating an intermediate layer at the phase boundary of the system "surface of the working body - the medium being processed". This layer acts as a screen for the forces of intermolecular interaction of phases, has a small adhesive and cohesive interaction, and has a “lubricating” effect, that is provides the possibility of relative movement of the phase working surfaces [1-9].

One of the effective techniques for performing the function of a phase separator is creating intermediate layer from repair-recovery composition (RVS) [3].

2. Formulation of the problem

Consider RVS as a prophylactic method for the formation of an intermediate layer at the interface between the metal surface of the working body of the digging machine and the soil being developed in order to reduce soil adhesion.
3. Method for solving the problem

RVS is a multicomponent finely dispersed mixture of minerals and special additives. In a wide variety of technological properties of minerals, their tribotechnical characteristics are the least studied. Therefore, their use for solving problems in the field of lubricating capabilities is currently limited.

RVS geo-activators are used to increase physical and mechanical abilities of the friction units during various combinations of materials of interacting surfaces. Due to its uniqueness, PBC geo-activators have the ability to significantly reduce the influence of leading factors affecting the wear of mechanisms.

The mechanism of occurrence of the antifriction protective layer can be characterized by the following sequence of steps: superfinishing operation, cleaning of the micro relief, tight auto-frettage of RVS particles in the recesses of the micro relief, the operation of forming a ceramic-metal layer. Having studied the above process and the structure of the layer, it should be assumed that this material (RVS) can be used to reduce the adhesion of the soil to the working bodies of earth-moving machinery. This decrease will reduce labor costs and time for work. To determine the adequacy of this hypothesis, comparative experiments were carried out with and without a deposited layer and with varying different conditions: ground pressure, outdoor temperature.

The test model for the experiments was a simulator of the front wall of the excavator bucket, which is a metal box with devices installed on it that interact with the ground. The simulator is mounted on a trolley that has the ability to move with an electric motor through a system of blocks [8].

When conducting experiments, the mathematical theory of experimental design was used. As factors of variation (table 1), the factors most affecting the freezing strength of the soil with the working body were selected: the outdoor temperature - X1 (°C) and the load on the ground - X2 (kg).

The experiment was carried out in accordance with the Box-3 mathematical plan (table 2). The experimental responses were: shear stress from the surface without RVS, shear stress from the surface with RVS. The averaged data of the experimental results are presented in table 3.

| Table 1. Factor Levels and Intervals. |
|---------------------------------------|
| Levels varies | Coded value | Temperature, °C | Load, kg, |
| X1 | X2 |
| A lot of(Ximin) | -1 | 0 | 1 |
| medium (X10) | 0 | -5 | 2 |
| higher(Ximax) | +1 | -10 | 3 |
| intervals | - | 5 | 1 |

| Table 2. Plan of the experiment in coded and natural values. |
|-------------------------------------------------------------|
| # test | Coded value | Natural value |
| X1 | X2 | T, °C | N, kg |
| 1 | 1 | -1 | -10 | 1 |
| 2 | 1 | -1 | -10 | 2 |
| 3 | 1 | +1 | -10 | 3 |
| 4 | 0 | -1 | -5 | 1 |
| 5 | 0 | 0 | -5 | 2 |
| 6 | 0 | +1 | -5 | 3 |
| 7 | -1 | -1 | 0 | 1 |
| 8 | -1 | 0 | 0 | 2 |
| 9 | -1 | +1 | 0 | 3 |
As a result of processing the experimental data, the following regression equations are obtained for the properties of the processed material for the coded values of the variables:

1) Surface shear stress without RVS:

\[ Y_1 = 6.2 + 5 \cdot x_1 + 2.53 \cdot x_2 + 3.6 \cdot x_1^2 - 1.6 \cdot x_2^2 + 2.65 \cdot x_1 \cdot x_2 \]  

2) Surface shear stress with RVS:

\[ Y_2 = 5.2 + 4.567 \cdot x_1 + 2.666 \cdot x_2 + 2.6 \cdot x_1^2 - 0.2 \cdot x_2^2 + 2.45 \cdot x_1 \cdot x_2 \]  

Each of the model equations reflects the influence of variable factors on the response function.

\[ \text{Table 3. Experiment feedback.} \]

| #  | T, °C | N, kg | \( Y_1 \), kPa | \( Y_2 \), kPa |
|----|-------|-------|----------------|----------------|
| 1  | -10   | 1     | 6.3            | 5.8            |
| 2  | -10   | 2     | 16.8           | 13             |
| 3  | -10   | 3     | 18.1           | 17.9           |
| 4  | -5    | 1     | 4.1            | 4.4            |
| 5  | -5    | 2     | 5              | 4.8            |
| 6  | -5    | 3     | 6.37           | 6.0            |
| 7  | 0     | 1     | 3              | 2              |
| 8  | 0     | 2     | 4              | 3              |
| 9  | 0     | 3     | 4.2            | 4.3            |

The sequence of stages of processing the experimental results - testing the hypothesis on the adequacy of the found model. Verification of this hypothesis is carried out according to the Fisher F-criterion. The obtained regression equations were tested for adequacy by comparing two variances at a 5% significance level (that is, at \( \alpha = 0.05 \) and a confidence probability of 95%). The verification results indicate the adequacy of the obtained equations (table 4), because the value of \( F_P < F_m \).

\[ \text{Table 4. Checking the adequacy of regression equations.} \]

| Index                                      | Calculated coefficient Fisher, \( F_P \) | Tabulated coefficient Fisher at \( \alpha = 5\% \), \( F_m \) |
|-------------------------------------------|------------------------------------------|-------------------------------------------------------------|
| Disruption force on the surface without RVS | 0.707                                     | 5.99                                                        |
| Force breakdown on the surface with RVS    | 0.702                                     | 5.99                                                        |

4. Analysis of the results

The experiments showed that when applying RVS, there is a decrease in soil adhesion to the metal surface of the working body of an earth-moving machine by an average of 18%. An analysis of the graphical dependencies (Fig. 1-2) showed that the effect of the pressure of adhesion on the adhesion of the soil to the working body is more significant at negative temperature, and with increasing temperature, the effect of the pressure decreases.
Figure 1. Response surface without affecting the simulator.

Figure 2. Response surface with created RVS layer.
5. Conclusions
The results of experimental studies of using RVS as an intermediate layer on the adhesion of soils to the metal surface of earthmoving machines at low temperatures allow a number of conclusions and practical recommendations to be made: the use of RVS as a preventive method for creating an intermediate layer at the contact boundary to reduce soil adhesion to metal surfaces of working bodies of earth-moving machinery reduces the value of the shear force by an average of 18%. Using this method allows to increase the efficiency of earthmoving machines that develop wet soil in conditions of subzero temperatures.

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