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СНИЖЕНИЕ ПРИЛИПАНИЯ ГРУНТА НА РАБОЧИЕ ОРГАНЫ ЗЕМЛЕРОЙНЫХ МАШИН ПРИ ИСПОЛЬЗОВАНИИ ЖИДКОСТНОГО ПРОМЕЖУТОЧНОГО СЛОЯ

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Ключевые слова: прилипание, промежуточный слой, грунт, напряжение сдвига.

Аннотация. В данной статье рассмотрено влияния жидкостного промежуточного слоя на прилипание грунта с металлической поверхностью землеройных машин. К качестве профилактических жидкостей использовались противообледенительные жидкости "MAXFLIGHT 04" и "OCTAFLO EG". Получены зависимости напряжения сдвига грунта от влияющих факторов при воздействии профилактических жидкостей. Подтверждена целесообразность применения данного способа для снижения адгезии грунта.

DECREASED ADHESION OF SOIL TO THE WORKING BODIES OF EARTH-MOVING MACHINES WHEN USING A LIQUID INTERMEDIATE LAYER

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Keywords: adhesion, intermediate layer, soil, shear stress.

Abstract. This article discusses the effect of a liquid intermediate layer on the adhesion of soil to the metal surface of earth-moving machines. Anti-icing fluids "MAXFLIGHT 04" and "OCTAFLO EG" were used as prophylactic fluids. The dependences of the soil shear stress on the influencing factors under the influence of preventive fluids have been obtained. The expediency of using this method to reduce the adhesion of the soil has been confirmed.

Introduction. The main reason for the decrease in the productivity of earthmoving machines is the increase in adhesion and friction during the development of moist cohesive soils in conditions of negative temperatures. Adhesion phenomena cause a sharp increase in frictional forces, which amount to 30-60% of the tractive effort [1-6].

The existing methods for reducing friction and adhesion can be divided into four groups. The first method involves the creation of an intermediate layer at the contact boundary, which can serve as a protective shield for the molecular interaction of phases and must have an adhesive interaction [1,2]. The second group includes methods that contribute to the weakening of adhesive bonds due to external influences [4,6]. The third method is based on constructive, technological and mechanical methods [1]. The fourth group is a combination of two or more methods to reduce adhesion [3].

The most used and promising prophylactic method for combating adhesion is the creation of an intermediate layer at the contact boundary of the "working surface - soil" system. This layer plays the role of a screen for the forces of intermolecular interaction, i.e. provides freedom of relative movement of phase surfaces and can be liquid, solid and gaseous. The thickness of the layer must be certain for its anti-adhesive properties to manifest.

Formulation of the problem and method of solution. Consider the use of anti-icing fluids - "MAXFLIGHT 04" and "OCTAFLO EG" as a liquid intermediate layer. They are propylene glycol based de-icing fluids and are intended for ground de-icing of aircraft. They have very good anti-icing performance when used at temperatures up to + 70°C without any operating restrictions. The holding time of the FL on the wing (Holdvertime) from 3 minutes to 12 hours [1].

Experiments on the shear resistance of a wet cohesive soil relative to a metal surface were carried out using MAXFLIGHT 04 and OCTAFLO EG anti-icing fluids at air temperatures ranging from -35 ºC to +5 ºC. The experiments were carried out on a special shear stand [5].

For the experiments, the soil was used - loam. The experiment was carried out at humidity values from 7.5 to 17.5%; with a duration of contact between soil and metal from 3 to 7 minutes, which corresponds to the parameters in which earth-moving machines operate. The plan and results of the experiments are shown in table 1.

Tabl. 1.Experiment design and results

Experiment plan in natural values			Results of measurements of shear force, N		
Ambient temperature Tcp,ºC	Soil moisture W,%	Contact time of the soil-metal system t, min	No impact	With "MAXFLIGHT 04"	With "OCTAFLO EG"
1	2	3	4	5	6
-35	7.5	3	92.73	30.4	32.1
	7.5	7	174.2	62.74	65.3
	12.5	5	186.54	78.91	80.76
	17.5	3	218.54	134.2	136.9
	17.5	7	400	159.89	162.43
-15	7.5	5	63.74	38.25	40.3
	12.5	3	78.45	50.01	51.9
	12.5	5	144.2	56.88	58.12
	12.5	7	240.3	58.84	61.4
	17.5	5	228.5	94.14	96.6
+5	7.5	3	11.6	4.2	5.8
	7.5	7	15.2	5.1	6.57
	12.5	5	17.9	8.3	9.64
	17.5	3	24.3	14.8	16.1
	17.5	7	31.7	17.4	18.97

Mathematical processing of the results obtained was carried out using the MODEL program for multivariate dependences using the least squares method. As a result of processing the experimental data, regression equations were obtained without the effect of a lubricant and using the "MAXFLIGHT 04" and "OCTAFLO EG".

Without impact:

$$Y_{wi} = 134.3 + 1.026 \cdot T_{cp} - 4.3 \cdot W - 46.08 \cdot t - 0.1 \cdot T_{cp}{}^{2} + 0.1074 \cdot W^{2} + 3.985 \cdot t^{2} - \\ - 0.4 \cdot T_{cp} \cdot W - 0.8 \cdot T_{cp} \cdot t + 1.3 \cdot W \cdot t. \quad (1)$$

With "MAXFLIGHT 04":

$$Y_{maxaxflig} = 41.22 + 0.66 \cdot T_{cp} - 8.14 \cdot W + 4.4 \cdot t - 0.33 \cdot T_{cp}{}^{2} + 0.43 \cdot W^{2} - 0.27 \cdot t^{2} - \\ - 0.22 \cdot T_{cp} \cdot W - 0.17 \cdot T_{cp} \cdot t - 0.062 \cdot W \cdot t. \quad (2)$$

With "OCTAFLO EG":

$$Y_{octafloEG} = 45.03 + 0.64 \cdot T_{cp} - 8.4 \cdot W + 3.93 \cdot t - 0.03 \cdot T_{cp}{}^{2} + 0.44 \cdot W^{2} - 0.21 \cdot t^{2} - \\ - 0.224 \cdot T_{cp} \cdot W - 0.172 \cdot T_{cp} \cdot t - 0.07 \cdot W \cdot t. \quad (3)$$

Since the equations are multifactorial (which cannot be displayed on a conventional planar graph), it is necessary to build quasi-one-factor dependencies on their basis with fixed values of two of the three factors.

Results and discussion. The graphs of the dependence of the shear stress on the ambient temperature are presented in figure 1. The analysis of these dependencies in the investigated range of change of factors shows that with a decrease in the ambient temperature, the shear stress increases both with the action of the anti-icing fluid and without it. With the use of the MAXFLIGHT 04 anti-icing fluid, the shear stress decreases: at soil moisture W = 17.5% and contact time t= 7 min, the shear stress decreases by 55%; at soil moisture W = 12.5% and contact time t = 5 min, the shear stress decreases by 59%; with soil moisture W = 7.5% and contact time t = 3 min, the shear stress decreases by 51%. With the use of anti-icing fluid "OCTAFLO EG", the shear stress decreases: at soil moisture W = 17.5% and contact time t = 7 min, the shear stress decreases by 53%; at soil moisture W=12.5% and contact time t = 5 min, the shear stress decreases by 57%; at soil moisture W = 7.5% and contact time t = 3 min, the shear stress decreases by 49%.

The graphs of the dependence of the shear stress on soil moisture are presented in figure 2. Analysis of these dependencies shows that with a change in soil pressure, shear increases. With the use of the MAXFLIGHT 04 anti-icing fluid, the shear stress decreases: at ambient temperature Tcp = 5°C and contact time t=7min, the shear stress decreases by 43%; at ambient temperature Tcp = -15°C and time t = 5 min, the shear stress decreases by 48%; at ambient temperature Tcp=-35°C and time t = 3 min, the shear stress decreases by 45%.

With the use of anti-icing fluid "OCTAFLO EG", the shear stress decreases: at ambient temperature Tcp = 5°C and contact time t = 7 min, the shear stress decreases by 41%; at ambient temperature Tcp = -15°C and time t = 5 min, the shear stress decreases by 46%; at ambient temperature Tcp = -35°C and time t = 3 min, the shear stress decreases by 43%.

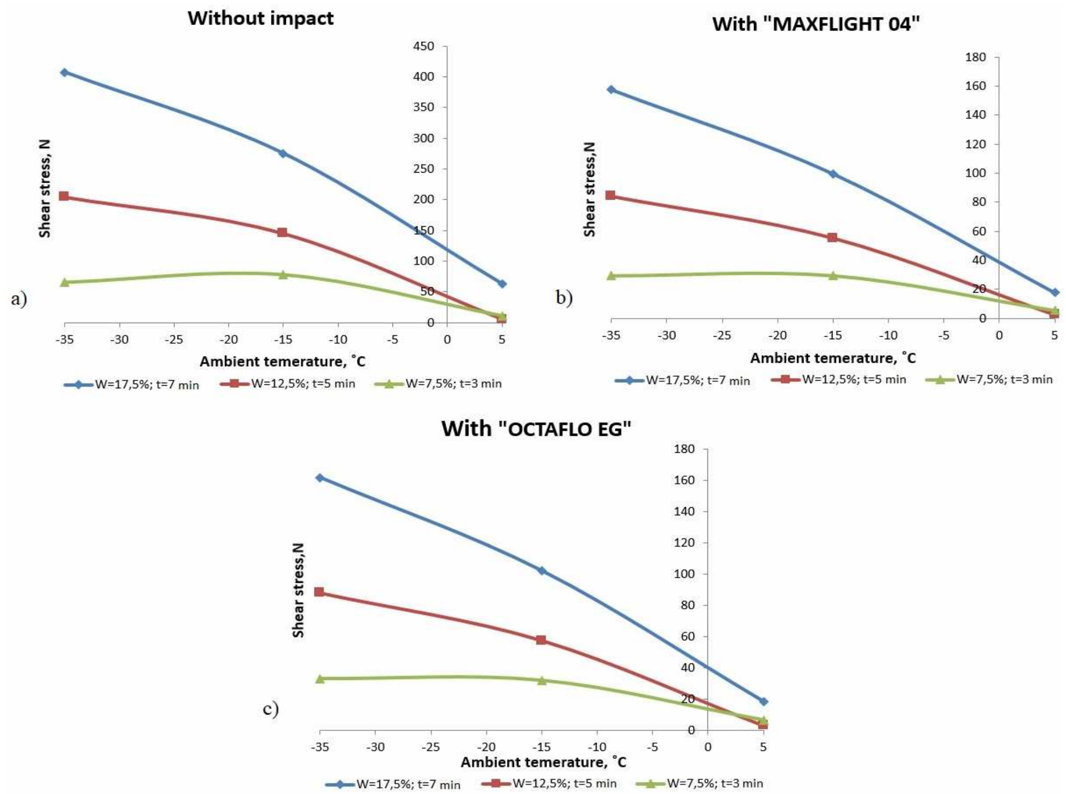

Fig. 1. Dependences of the shear stress on the ambient temperature in natural values: a) without affecting the contact area; b) using "MAXFLIGHT 04"; c) using OCTAFLO EG

The graphs of dependences of shear stress on soil contact time are shown in figure 3. Analysis of these dependences shows that with an increase in the time of contact of the soil with a metal surface, the shear stress increases. With the use of the MAXFLIGHT 04 anti-icing fluid, the shear stress is reduced: at ambient temperature Tcp = 5 ° C and soil moisture W = 17.5%, the shear stress decreases by 28%; at ambient temperature Tcp = -15 ° C and soil moisture W = 12.5%, the shear stress decreases by 36%; at ambient temperature Tcp = -35 ° C and soil moisture W = 7.5%, the shear stress decreases by 32%. With the use of anti-icing fluid "OCTAFLO EG" the shear stress is reduced: at ambient temperature Tcp = 5 °C and soil moisture W = 17.5%, the shear stress is reduced by 26%; at ambient temperature Tcp = -15 °C and soil moisture W = 12.5%, the shear stress decreases by 34%; at ambient temperature Tcp = -35 °C and soil moisture W = 7.5%, the shear stress decreases by 30%.

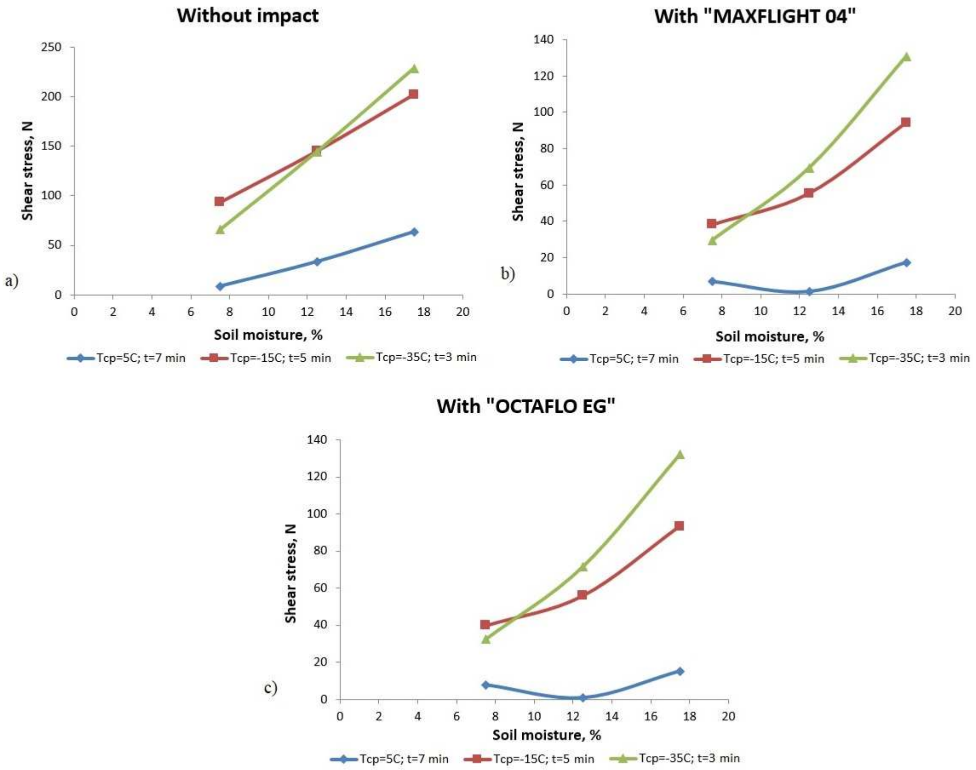

Fig. 2. Dependences of shear stress on soil moisture in natural values: a) without affecting the contact area; b) using "MAXFLIGHT 04"; c) using "OCTAFLO EG"

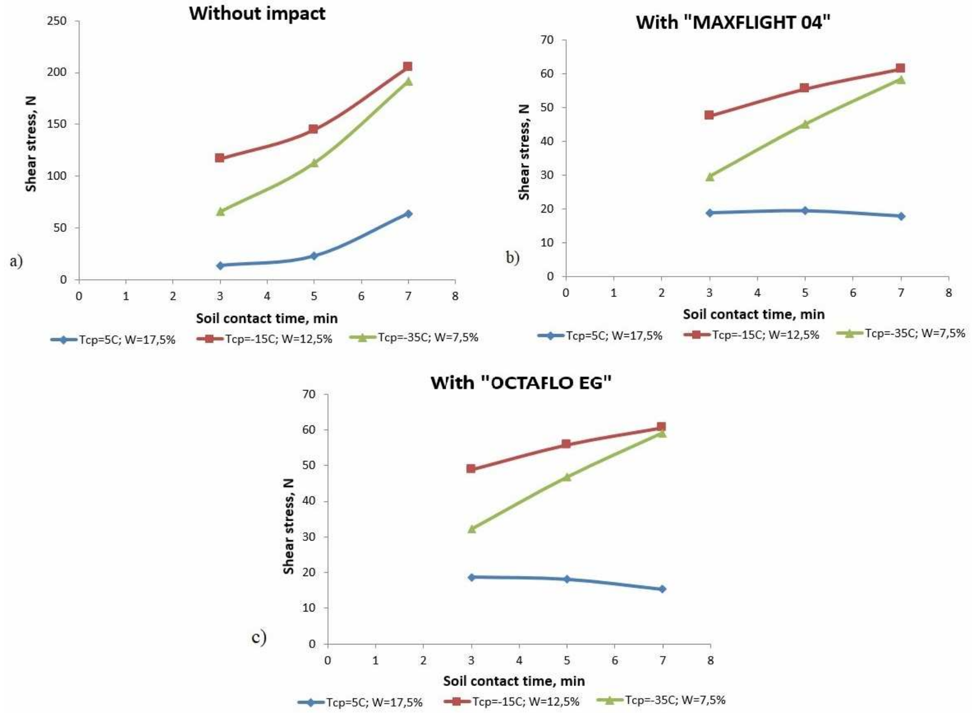

Fig. 3. Dependences of shear stress on soil contact time in natural values: a) without affecting the contact area; b) using "MAXFLIGHT 04"; c) using "OCTAFLO EG"

Conclusion. An experiment was carried out on the use of anti-icing fluid as a preventive method for creating an intermediate layer at the contact boundary to reduce the adhesion of soil to the metal surfaces of the working bodies of earth-moving machines. Mathematical processing of multivariate dependencies was carried out according to the results of experimental data to obtain regression equations. Quasi-one-factor dependencies were constructed. The implementation of the identified methods and design solutions makes it possible to improve the efficiency of earth-moving machines that develop wet soil in conditions of negative temperatures.

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