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DETERMINATION OF THE SOIL FRICTION COEFFICIENT AND SPECIFIC ADHESION

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Summary. A method is worked out to determine the soil friction coefficient and specific adhesion. To determine the coefficient of friction and the specific adhesion, the soil slipping resistance should be assessed at several different values of the specific pressure between the slipping surfaces. Alteration of soil slipping coefficient has an alternative hyperbolic regress. On the basis of this opinion, by the method of least squares, one can determine the coefficients of soil friction and specific adhesion force.

Key words: soil slipping resistance, soil friction coefficient, specific adhesion, studying methods

INTRODUCTION

In most cases the movement of soil during its tillage proceeds along the surfaces of the operating parts of tilling tools and machines. Slipping resistance of soil significantly affects the draft resistance of these tools. For instance, the slipping friction between steel and soil may exceed 35-50% of the total draft resistance in ploughing [Vilde and Rucins 2004]. Therefore the problems of reducing the slipping resistance of soil along the operating parts of the tillage tools always attracts great attention both in designing new structures and the use of the existing machines.

In order to tackle these problems, one should know well the relationships, which determine the value of the slipping resistance of soil along steel.

Investigations by a number of authors show that the soil slipping resistance depends on many factors: its type, its mechanical composition, moisture, structure, adhesion, the humus content, specific pressure of soil upon the surface, physical and chemical properties of the rubbing materials, the state of the surface, duration of the contact, the friction velocity, the value of the internal friction of soil, and others. The mathematical relationships between them are not yet clarified to a sufficient degree. Most of the existing investigations discuss the influence upon slipping resistance of one, two, or seldom three and more factors. Variations in the slipping resistance as dependent on these factors are usually presented in a graphical way without any mathematical approximation.

General evolution of science in the field of slipping friction during the previous decades had a great impact upon the theory of soil slipping along steel and other materials, too. So, in contrast to the previous investigations of the soil slipping resistance using the mechanical theories of friction (the Amonton Law), the recent studies find increasing application of molecular and molecular-mechanical theories of friction allowing for a better explanation of the phenomena proceeding when soil is slipping along the operating parts of the tools [Vilde 2001]. But in spite of all this, up to the present time there are no generalised mathematical relationships that would allow considering the impact of various factors and the use of the above-mentioned theories in particular draft resistance calculations of tools and optimum designs of their operating parts depending on operating conditions.

The purpose of investigations. On the basis of the research of our own data as well as those provided by various other authors, the aim of the present study is to find out the mathematical regularities existing between the resistance of soil slipping along steel, and its physical and mechanical properties.

APROACH

It is accepted to evaluate the frictional properties of materials, including soil, by the slipping resistance coefficient. The latter depends on the friction coefficient and soil adhesion, and it varies with specific pressure between the slipping surfaces [Vilde 2001].

The review of the literature devoted to soil properties showed that investigations carried out only by few authors more or less meet the requirements put forward in the previous section. Among them are Ya.Ya. Nagla, P.U. Bakhtin, N.V. Shchuchkin, A.T. Yakovenko, M.I. Bredun, M.L. Nichols and H.G. Riek [Vilde 2001]. The weak point of the studies conducted by most other researchers is that they lack data concerning any of the basic factors, particularly the composition of soil. Therefore they can serve only as individual examples for testing the usefulness of the deduced general relationships.

As a rule, all the sources provide slipping resistance coefficients of soil. On the basis of these data, by the method of least squares, we have determined the coefficients of friction and specific adhesion force, after these dependencies were deduced, between them, the mechanical composition and the moisture of soil.

RESULTS

On the bases of the previous investigations a method has been worked out how to determine the soil friction coefficient and its specific adhesion using B.V. Derjagin's modified two-part formula:

$$f = f_0\,(1 + p_a\, p^{-1}), \tag{1}$$

where:

f – the resistance coefficient of soil slipping along a surface;
f_0 – the friction coefficient of soil along a surface;
p – the specific pressure of the layer (soil) upon the surface;
p_a – the specific soil adhesion force to the surface.

In order to determine the coefficient of friction and the specific adhesion, the soil slipping resistance is assessed at several different values of the specific pressure between the slipping surfaces.

For example, data are given further (Table 1) which show the changing values in diagram (Fig. 1) of the soil slipping resistance coefficient along a steel surface at different specific pressures along the surfaces.

Table 1. The resistance coefficient of wet clay soil slipping along a steel surface

p [kg·cm^{-2}]	0.0165	0.033	0.049	0.068	0.097
f	2.8	2.0	1.6	1.3	1.0

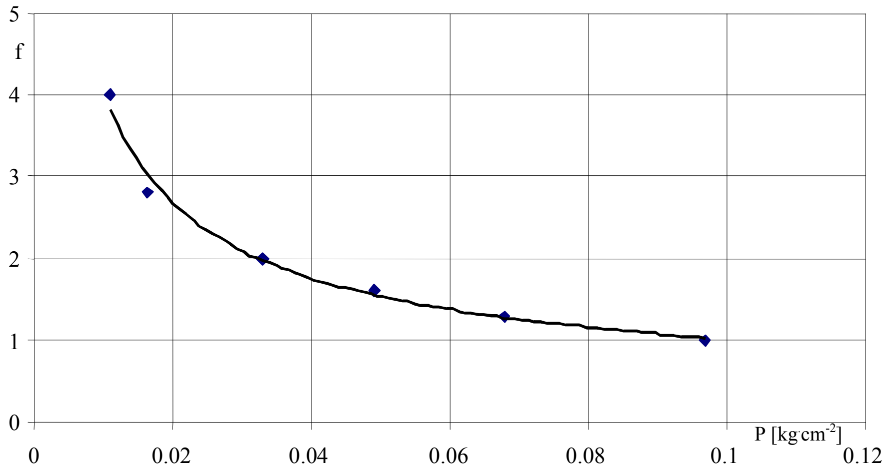

Fig. 1. Alteration of soil sliping resistances coefficient along steel surface depending on the specific pressure on the surfaces

It is evident from Table 1 and the graph that the variation in the soil slipping coefficient has an alternative hyperbolic regress. By means of the method of least squares, one can determine the coefficients of soil friction f_0 and specific adhesion force p_a, using formulas:

$$f_0 = \frac{\sum x^2 \sum y - \sum x \sum xy}{n\sum x^2 - \left(\sum x\right)^2}, \tag{2}$$

$$f_0 p_a = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - \left(\sum x\right)^2}, \tag{3}$$

$$p_a = \frac{f_0 p_a}{f_0}, \tag{4}$$

where: $x = p^{-1}$; $y = f$; n – the number of measurements (at least 5).

Using this method reveals the friction coefficients and specific adhesion for certain soils. For the clay soil, given as an example above: the friction coefficient $f_0 = 0.79$ and the specific adhesion $p_a = 0.043$ kg/cm^2. A computerised laboratory device is developed for the determination of these soil characteristics for several surfaces and ranges of slipping speeds.

The basic factors affecting the frictional properties of soil are its composition and moisture. Individual factors – the coefficient of friction, adhesion, plasticity, internal friction etc. – are more or less dependent on the first ones. Therefore the evaluation of the frictional properties of soil involves, first of all, the assessment of the varying friction coefficient and specific adhesion force of soil depending on its composition and moisture. It is evident that the answer to these questions can be found only in experiments in which the frictional properties of soils are determined taking into account their composition and moisture.

The studies of mathematical correlations between the frictional properties and the other parameters of soils should be complex and all-embracing, covering as many factors as possible; the friction coefficient and soil adhesion should be determined at a different specific pressure, mechanical composition, moisture, chemical composition, density, structure, slipping speed and other parameters. As a rule, all the sources provide slipping resistance coefficients of soil. On the basis of these data, by the method of least squares, we can determine the coefficients of friction and specific adhesion force, after these dependencies were deduced between them and the mechanical composition, and moisture of soil [Vilde 2001], as well as draft resistance of soil tillage machines [Vilde and Rucins 2004, Rucins and Vilde 2004].

CONCLUSIONS

1. On the basis of investigations a method is worked out to determine the soil friction coefficient and specific adhesion.
2. To determine the coefficient of friction and the specific adhesion the soil slipping resistance should be assessed at several different values of the specific pressure between the slipping surfaces.
3. Variations in the soil slipping coefficient have an alternative hyperbolic regress. On the basis of this assumption, using the method of least squares, one can determine the coefficients of soil friction and specific adhesion force.

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