The 3rd International Conference on
″Computational Mechanics
and Virtual Engineering″
COMEC 2009
29 – 30 OCTOBER 2009, Brasov, Romania

THEORETICAL ASPECTS CONCERNING THE INTERACTION BETWEEN ACTIVE MACHINE PARTS AND THE SOIL

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Abstract: *The paper addresses theoretical studies concerning the mechanical-mathematical modality of the interaction between the active machine parts that equip the germinative bed preparation aggregate and the soil; the active machine parts are fitted onto the frame of aggregate tools by means of rigid and elastic brackets.*
Keywords*: rigid bracket, elastic bracket, complex aggregate.*

1. INTRODUCTION

Soil-loosening machines are tools that make up the structure of complete aggregates for shallow and deep loosening of the arable soil with a view to preparing the germinative bed for sowing and planting. From a constructive point of view, they differ both as regards the frame and the active parts that are used. The active working parts are fitted onto a frame by means of rigid or elastic brackets or by sections of special structures. The means of fitting active parts influences the dynamics of the germinative bed preparation aggregate; from an agro-technical viewpoint, it influences the quality values of the germinative bed preparation work, as well as power values. In the given context, a theoretical study must be performed on the interaction between the active parts and the soil.

2. A STUDY ON THE ACTIVE PART OF THE KNIFE TYPE FITTED RIGIDLY ONTO THE FRAME

The active part works inside the soil for deep and shallow soil loosening and is analyzed by means of a mechanical model presented in fig.1

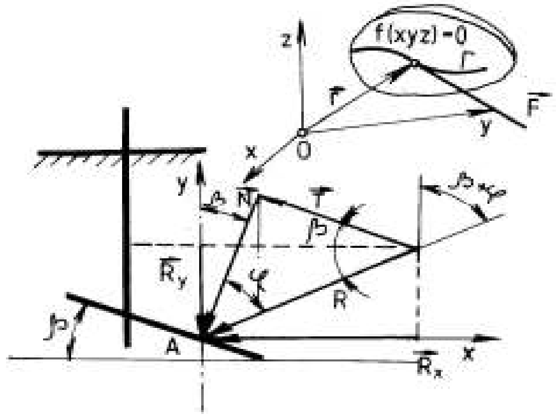

Figure 1

The normal reaction $\vec{N}$ and the friction force between the soil and the knife $\vec{T}$ both act upon the knife, their resultant being $\vec{R} = \vec{N} + \vec{T}$ or, if we refer the resultant $\vec{R}$ to the Oxy guide mark, it has the constituents $\vec{R} = \vec{R}_x + \vec{R}_y$, where R_x represents the force that opposes the active part upon aggregate motion, whereas R_y represents the vertical constituent of the resultant that keeps the active part in the soil.
If one considers the surface of the active part as being a function $f(xyz) = 0$, normal reaction at the surface of the active part has the direction of its gradient, thus $N = \lambda \, grad \, f$, where λ is a constant.
The motion equation of a material point on the said surface is:

$$m\ddot{\vec{r}} = \vec{F} - \lambda \, grad \, f \qquad (1)$$

Relation (1) reported to the Oxyz reference system is represented by means of the equation system

$$\begin{aligned} &m\ddot{x} - F_x - \lambda \, grad \, \partial f / \partial x; \\ &m\ddot{y} - F_y - \lambda \, grad \, \partial f / \partial y; \\ &m\ddot{z} - F_z - \lambda \, grad \, \partial f / \partial z. \end{aligned} \qquad (2)$$

These equations, associated with the surface equation $f(xyz = 0)$ form a system of four equations with four unknown values (λ, x, y, z) that determine the position of the material point at a certain given moment and normal reaction.
It results from fig. (1) that the module of force $R_x$will be determined with the help of the relations:

$$\begin{aligned} &R_x = R \sin(\beta + \varphi); \\ &R_x = N \sin \beta + T \cos \beta; \end{aligned} \qquad (3)$$

Where β is the target angle of the active part, φ the friction angle between the soil particles and the surface of the active part.
Knowing the friction coefficient μ, one can determine the friction force

$$T = \mu N = \mu \lambda \, grad \, f, \qquad (4)$$

in which $grad \, f = \partial f / \partial x \, \vec{i} + \partial f / \partial y \, \vec{j} + \partial f / \partial z \, \vec{k}$.
If one replaces the expression for N and T in relation (3), one will obtain the expression of force R_x, as follows

$$R_x = \lambda |grad \, f| (\sin \beta + \mu \cos \beta) \qquad (5)$$

Taking into account the significance of the terms in relation *(5)*, it results that the force of resistance to traction depends on the shape of the active part and on soil properties. This reasoning has resulted in the hypothesis that travelling speed is constant and the soil is loosened without micro dislevelments.
If one considers the actual working conditions, in which there are micro dislevelments and in which the soil is non-homogeneous, then the force of resistance to traction depends on time and has a random nature, being expressible by means of the relation:

$$R(t) = R_x + \Delta R(t) \qquad (6)$$

The relation $F = f\,G + kab + \varepsilon\, abv^2$ developed by V.P.Goreacikin shows that the resistance of soil working tools depends to a great extent on the travelling speed; thus, traction can be expressed depending on speed by means of the relation:

$$R_{(v)} = R_x + \Delta R_{(v)}.$$

3. A STUDY OF THE ACTIVE PART FITTED ONTO THE FRAME BY MEANS OF AN ELASTIC BRACKET

Figure 2 shows the mechanical model on which the shallow and deep loosening process is studied, with reference to active parts fitted onto elastic or vibratory brackets.

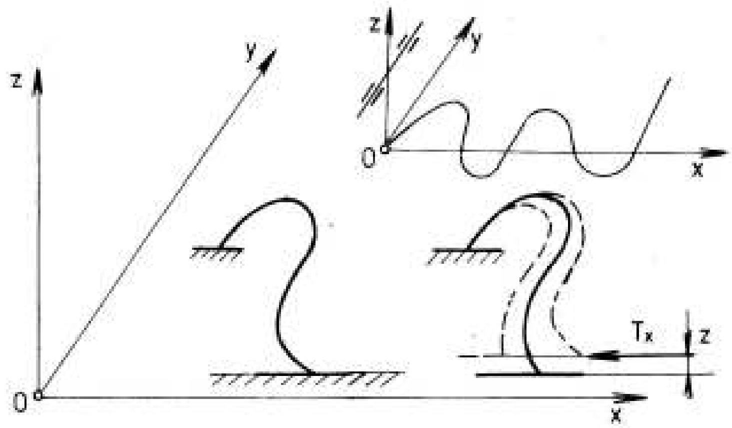

Figure 2

As already mentioned, due to the variation of the travelling speed, to the soil's lack of homogeneousness and to the micro dislevelments, the force of resistance to traction varies, which results in the active part fitted onto the elastic bracket having a maintained vibration motion; in other types of active parts for soil loosening, vibrations are maintained forcedly.
The energy that the elastic bracket accumulates upon contact with dislevelments or portions of soil with variable resistance provides vibration maintenance.
The analysis of the elastic bracket active part motion points to the fact that the greater the energy level accumulated by the elastic bracket, the lower the resistance force opposed to traction.
In figure 2 we consider the Oxyz reference system, in which Ox is the advancing direction, Oy the direction perpendicular on Ox, both of them making up horizontal plane Oxy, in which soil loosening takes place. If the vibration direction is around axis Oy and the advancing direction is Ox, the equation of oscillatory motion is

$$I = A\sin\omega t = A\sin 2\pi\, x/\lambda \qquad (7)$$

where λ is the vibration wavelength.
The friction force T acting upon the active part is tangent to the trajectory of a point belonging to the active part and its slope can be calculated by means of the relation

$$tg\alpha = dy/dx = (2\pi A/\lambda)\cos 2\pi\, x/\lambda \qquad (8)$$

The projection of friction force T on the advancing direction will be determined by means of relation

$$T_x = \frac{\int_0^{\pi/2} T\cos\alpha\, dx}{\pi/2} = \frac{2T}{\pi}\int_0^{\pi/2}\frac{dx}{\sqrt{1+\left[(2\pi A/\lambda)\cos 2\pi\, x/\lambda\right]^2}};$$

$$T_x = \frac{2T}{\pi}\int_0^{\pi/2}\frac{dx}{\sqrt{1+(2\pi A/\lambda)^2-(2\pi A/\lambda)^2\sin^2 2\pi\, x/\lambda}};$$

$$T_x = T\frac{\lambda^2}{\pi^2}\frac{1}{\sqrt{\lambda^2+4\pi^2A^2}}\int_0^{\pi/2}\frac{dx}{\sqrt{1-\frac{(2\pi\, A/\lambda)^2}{1+(2\pi\, A/\lambda)^2}\sin^2 2\pi\, x/\lambda}} \qquad (9)$$

We write $m = 2\pi x/\lambda$, $p = 2\pi A\big/\sqrt{\lambda^2+2\pi^2A^2}$ and the relation becomes:

$$T_x = T\frac{\lambda^2 p}{2\pi^3 A}\int_0^{\pi/2}\frac{dm}{\sqrt{1-\left(4\pi^2\, A^2/\lambda^2+4\pi^2A^2\right)\sin^2 m}}. \qquad (10)$$

After calculating the integral, the value of the projection of the friction force on the Ox advancing direction is

$$T_x = T\frac{\lambda^2 p}{2\pi^3 A}\left\{1+\sum_{i=1}^{n}\left[\frac{(2n-1)!!}{(2n)!!}\right]^2 p^{2n}\right\}. \qquad (11)$$

The analysis of relation *(11)* depending on the travelling speed, frequency and vibration amplitude points to the functional aspects presented in table 1.

Table 1

Parameters		Types of vibrations	

	I	II	III
Speed (v)	constant	constant	growing
Frequency (f)	constant	growing	constant
Amplitude (A)	growing	constant	constant
Projection of force T on Ox axis (T_x)	Reduction of T_x projection decreases	Reduction of T_x projection increases	Reduction of T_x projection decreases

3. **CONCLUSIONS**

The theoretical study performed on active soil loosening parts leads to the conclusions listed below:

- Active parts used in deep and shallow soil loosening with a view to its preparation for sowing and planting are fitted onto rigid or elastic (vibratory) brackets.
- The resistance force opposing aggregate travelling (R_x) for active parts fitted onto rigid props depends on the geometrical shape of the active part materialized through its surface and the friction coefficient between the soil and the active surface of the working part. Due to the discontinuous nature of the phenomenon, quantification of the resistance force is done depending on time and advancing speed.
- In the case of active working parts fitted onto elastic props, the force of resistance to aggregate travelling depends on the projection of the friction force over the travelling direction, which is actually determined by the parameters of vibratory motion, such as: travelling speed, frequency, pulsation and amplitude.
- The study performed shows that elastic props must be structurally conceived in such a way as to match the aggregate destination, the type of soil and loosening that is performed, namely deep and shallow loosening.
- The theoretical study conducted results in the performance of certain types of active soil processing parts that could reduce resistance to traction, while also providing protection of the soil's structure and the quality indices required by the preparation of the germinative bed for sowing and planting.

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