STUDIES REGARDING THE WORKING PROCESS EXECUTED ON PLOUGHSHARE OF PLANTING MACHINES

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Abstract. The planting machines are agricultural machines destined for rhizome, bulbs, tree seedling, and seedling planting on terrains more or less processed. One of the working organs most used on these machines is represented by the ploughshares. In this article we analyze the interaction between the ploughshares and soil to determine the forces that act on it according to the type (shoe, anchor, etc.) and according to soil.

Keywords: planting machines, ploughshare, soil.

Introduction

Planting machines are machines destined for a wide palette of crops (planting bulbs, seedlings, rhizomes, etc.) and thus they can be classified after the type of the crops that will be processed. From the working process point of view these machines are similar, this (working process) holding the following stages: channel opening, planting material distribution, covering and compaction, ridging (in the case of tuber planted in low humidity conditions), wetting (in the case of seedling planting), fertilization - when it is necessary [1].

The ploughshares of planting machines have the role to open the furrow at a depth of 10-20cm in which the reproductive material will be introduced. These ploughshares can be of different types: feather type, shoe, with one disc, with two discs, butting plough (used for tuber plantation) or of a prism form. Because we are especially interested in planting rhizomes, in this paper we will talk about the prism ploughshare used on these machines [2].

Materials and methods

For realization of a plantation paper of a good quality we must execute the preparation work of the germinal bed. The prism ploughshare (that equips the rhizome planting machines) has the role to open a furrow due to its moving forward in the soil, driving and ensuring the rhizomes on the bottom of the furrow and covering them with soil after compaction is done [3]. This compaction creates the necessary capillarity for water in order for the rhizomes to germinate. The soil layer that covers the rhizomes stops water evaporation [1].

During driving the ploughshare into the soil, in front and the sides loose ground will gather, as a result of pushing the soil by the ploughshare in front and to the sides. The ploughshare breaks these lumps in such a way that at the beginning of the process the sides of the furrow formed outline the surface of the field, falling behind the ploughshare, partially covering the rhizomes, the full covering being made with special devices mounted behind the ploughshare. In Figure 1 a prism ploughshare with sharp point is presented.

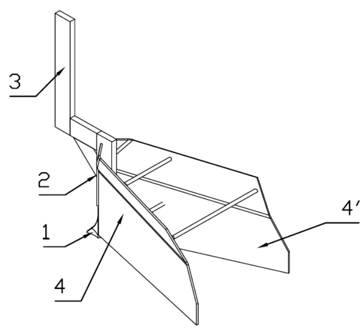


Fig. 1. **Prism ploughshare with sharp point:**
1 – ploughshare tip; 2 careen; 3 – stilt; 4, 4’ – side walls

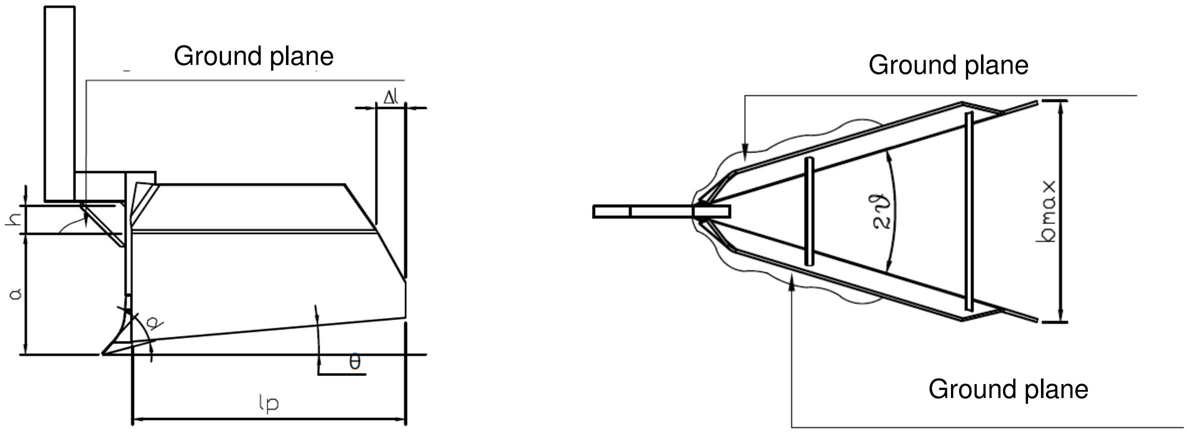


Fig. 2. **The working process executed by the prism ploughshare**

The working process executed by the prism ploughshare is presented in Figure 2.

In Figure 2 we noted:

a – working depth
h – ground wave height in front of the ploughshare
l_p – length of the ploughshare walls at the middle zone
Δl – difference of wall length, resulted by their inclination at the back side
$b_{\max}$ – maximum opening of ploughshare walls
θ – angle of wall inclination at the back side
2ϑ – angle between the careen walls
α – angle of soil penetration of the ploughshare.

The working process is presented in Figure 3.

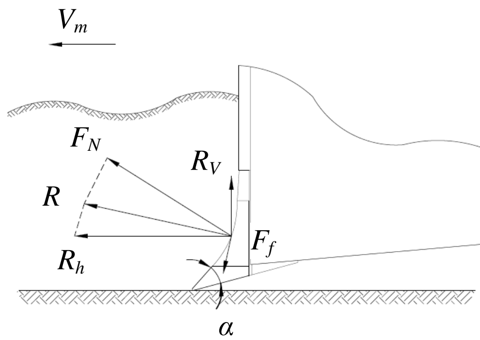


Fig. 3. **The working process executed by the ploughshare**

The ploughshare angle of soil penetration is $\alpha = 35 \div 70$ °. Entering the soil, the ploughshare achieves lateral movement of soil particles and also on the plough direction.

On a soil particle, subjected to ploughshare action, the following forces act $\overline{F}_H$ – normal force and $\overline{F}_f$ – friction force. The results of the two forces tend to move the particle and lift it.

$$\overline{R} = \overline{F}_N + \overline{F}_f \quad (1)$$

$$\overline{R} = \overline{R}_h + \overline{R}_V \quad (2)$$

Adding to that, through the ploughshare movement inside the soil, a lateral movement of dislocated soil takes place. As a result in the contact area between the soil and the ploughshare lateral walls a friction process occurs. For matching this force it is necessary to apply the action force F.

The working process executed on the wall of the ploughshare can be assimilated with the executed one by an arrow at a ϑ angle to which we apply the action force F (Fig. 4).

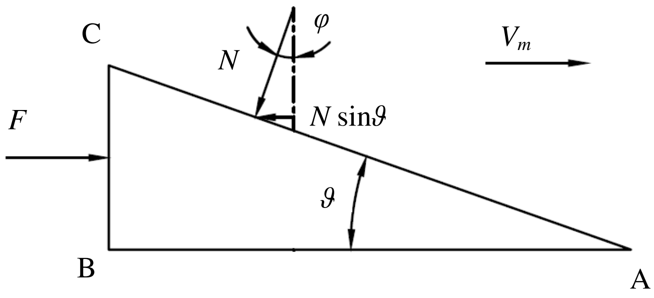


Fig. 4. **Determining the *F* force of action for the *ϑ* arrow**

In this case the action force is

$$F = N \cdot \sin \vartheta$$

In reality, due to a soil arrow travel the phenomenon of friction appears that opposes the friction force travel $F_f = \mu \cdot N$ which takes place on the AC surface. In this case we obtain:

$$N' = \sqrt{N^2 + \mu^2 \cdot N^2} = \sqrt{N^2 + F_f^2} \tag{4}$$

where μ – is the friction coefficient (μ = tgφ).

Following the resulting N' will deviate from the normal to the AC arrow surface with a ϕ that will lead to the figure (Fig. 4. b):

$$N' = \sqrt{N^2 + F_f^2} = \sqrt{1 + \mathrm{tg}^2\, \varphi} \tag{5}$$

As a result, the value of the F force necessary for arrow drive ends with the expression:

$$F = N' \cdot \cos\left[\frac{\pi}{2} - (\vartheta + \varphi)\right] = N' \cdot \sin(\vartheta + \varphi) = \frac{N}{\cos(\varphi)} \cdot \sin(\vartheta + \varphi) \tag{6}$$

In reality the machine ploughshare for rhizome planting is prismatic following the working process executed by this can be similar to that of a top angle 2ϑ (Fig. 5).

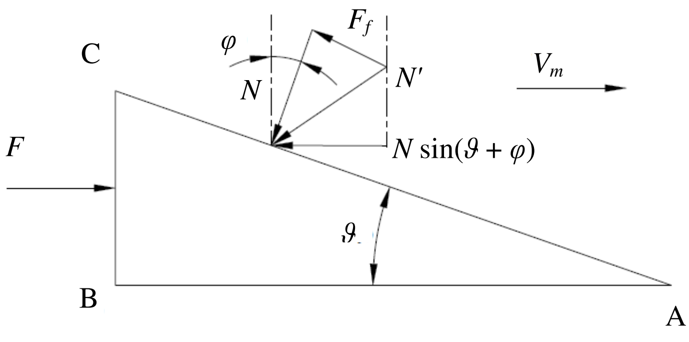


Fig. 5. **Working process of an arrow with top angle**

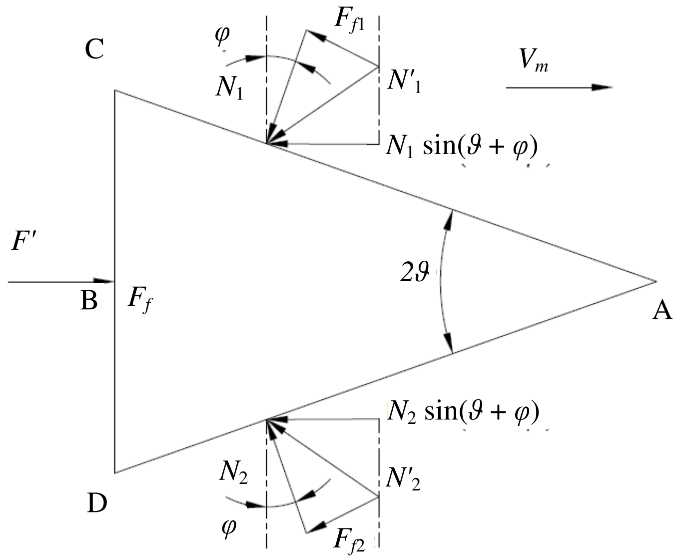


Fig. 6. **Determining the action force of the arrow 2ϑ**

Doing the hypothesis that soil is homogeneous, we can make approximations $N_1 \cong N_2$; $F_{f1} \cong F_{f2}$.

Following that:

$$\begin{aligned} F' &= N_1 \cdot \sin(\vartheta + \varphi) + N_2 \cdot \sin(\vartheta + \varphi) = \\ &= (N_1 + N_2) \cdot \sin(\vartheta + \varphi) = 2 \cdot N' \cdot \cos\left[\frac{\pi}{2} - (\vartheta + \varphi)\right] = \\ &= 2 \cdot N' \cdot \sin(\vartheta + \varphi) = \frac{2N}{\cos(\varphi)} \cdot \sin(\vartheta + \varphi) \end{aligned} \tag{7}$$

The condition for the prism ploughshare to do the working process is that the traction force applied needs to fulfil the condition:

$$F_t > \frac{2N}{\cos(\varphi)} \cdot \sin(\vartheta + \varphi)$$

The friction angle (φ) depends on the friction coefficient between different types of soils and steel from which the ploughshare is made. In Table 1 the friction coefficient values are presented. Values presented in Table 1 have been determined through experiments.

Table 1

Friction coefficient values

Nr.	Soil type	Friction coefficient	Soil moisture	
			Absolute, %	From the water capillary capacity, %
1.	Sandy soil	0.26...0.31	3.0 ÷ 7.7	20 ÷ 30
2.	Argil soil	0.30...0.40	5.0 ÷ 13.0	18 ÷ 48
3.	Cernoziom	0.40	18.0	44
4.	Argil-middle	0.70	22.0	54
5.	Argil	0.45...0.55	20.0 ÷ 24.0	45 ÷ 54
6.	Argil-hard	0.27...0.38	11.0 ÷ 16.0	25 ÷ 35

Results and discussion

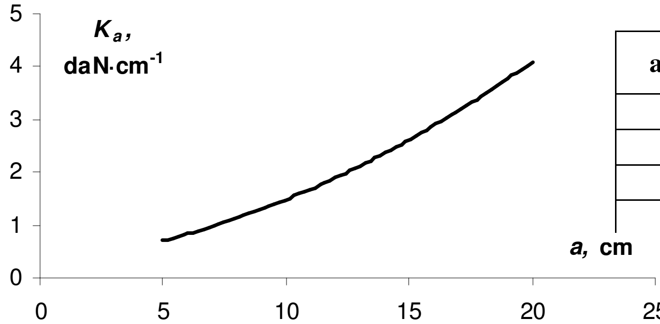
The resistance force at soil entry R_t in the case of prism ploughshare, can be approximated as being the sum of two forces: the cutting force that appears on the ploughshare knife, respectively the resistance force at the drive on the lateral walls of the dislocated soil.

$$\overline{R_t} = \overline{R} + \overline{F'} \qquad (9)$$

The the cutting force can be approximated, according to Bernaki [4] with the relation

$$R = k \cdot a \text{, daN} \qquad (10)$$

in which K_a (daN·cm^{-1}) resistance to soil processing and a represents the working depth of the ploughshare. Figure 6 shows how K_a varies according to the working depth.



a, cm	K_a, daN·cm^{-1}
5	0.8
10	1.2
15	2.9
20	4.0

Fig. 6. **Variation module of the resistance according to the working depth [4]**

F' component can be approximated with the relation

$$F' = k \cdot a \cdot b \qquad (11)$$

in the hypothesis that the terrain in which the plantation is executed is processed and the soil is considered as a homogeneous environment.

In (11) relation the following have been noted:

a – working depth
b – working width (maximum opening of ploughshare walls)
k – specific resistance at processing daN·cm^{-2}, resistance which has values according to soil types:
light soils, $k = (0.8 \div 1.1)\cdot 10^4$ N·m^{-2};
middle soils, $k = (1.1 \div 1.8)\cdot 10^4$ N·m^{-2};
hard soils, $k = (2 \div 2.7)\cdot 10^4$ N·m^{-2};
very hard soils, $k = (2.7 \div 3)\cdot 10^4$ N·m^{-2}.

Conclusions

Having values for resistance at driving the ploughshare we can perform the finite element analysis. The obtained results following this analysis must be verified experimentally for eventual corrections.

Acknowledgements

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