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STATIC DEPENDENCES IN THE SOIL CUTTING PROCESS WITH SOIL-CULTIVATING WORK ORGANS

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ABSTRACT:
Cutting of the land, as an anti-erosive operation, although not very energy-consuming in its character, still requires great efforts, especially when a cut with a comparative large width is to be made, as it is in the process of vertical mulching. The impact on the soil, and the corresponding reactions, are considerable. For the research of this process, as well as for the measuring of the specific work organ, some theoretical analyses have been done in this article.
KEY WORDS:
cutting of the land, statics, acting forces

1. EXPOSITION

Unlike other materials whose characteristics allow them to be processed and used for the needs of different constructions, the soil possesses only the property of strength [1]. The character of the soil and the way of defining its strength reveal the destruction resistance quotient in the cultivation process [2]. Therefore, the quality of strength is essential in calculating the resistance quotient of the soil cutting process [4]. This means that in this rather complicated operation [3, 5], in order to analyze the corresponding reaction we have to calculate the forces acting perpendicularly on the work surfaces, that is to specify the amount of pressure exercised on the soil and the respective friction caused by the movement of the soil along these surfaces.

For making the process easier we accept that the work surfaces are flat, with no changing slant and the strength of the soil remains the same with the change of depth. The acting forces of the work organs, as well as the corresponding reactions, will be analyzed.

The resultant force of the acting forces on one side of the work organ is directed perpendicularly on the work surface which is situated at an angle $\frac{\alpha}{2}$ towards the direction of movement and at an angle β towards the horizon. Consequently, in order to define the constituent forces a special analysis of them will be needed, as shown on fig.1

The coordinating system $O_{x,y,z}$ on which the resultant force F is situated has its starting point 0 at the centre of the work surface and a vertical position towards the work surface O_{xz} ; a horizontal position towards the direction of the movement O_{xy} ; and a vertical position towards the cross-sectional direction of the movement O_{yz} , where V is the speed of the work organ.

The power of the friction will be analyzed at a later stage when some research into the kinematics of the process for determining the direction of the soil movement along the work surfaces will be done.

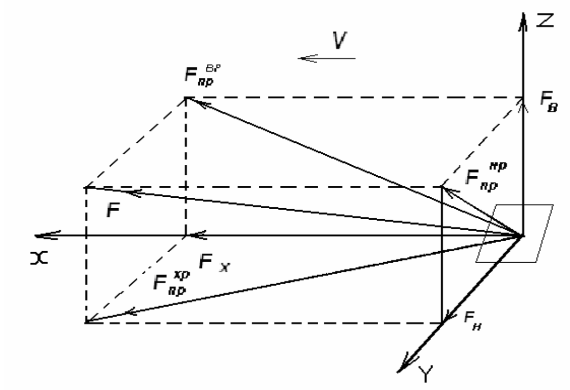


Fig.1. Acting on the soil forces on the one side of the work organ

By projecting the resultant force F on these surfaces $\left(F_{\text{пр}}^{\text{хр}}, F_{\text{пр}}^{\text{bр}} \text{ и } F_{\text{пр}}^{\text{нр}}\right)$, the forces it is constituted from $\left(F_x, F_b \text{ и } F_{\text{н}}\right)$ are defined as a projection on the axes. Taking into account the fact that the value of the resultant force F is in proportion to the value of the work surface area S and the value of the soil hardness, a conclusion can be drawn that its constituent forces $F_x, F_b \text{ и } F_{\text{н}}$ are proportional to the areas of the respective projections of the real work surface (fig. 2), that is

$$F_x - \text{на}\, S_{\text{нр}},\ F_b - \text{на}\, S_{\text{хр}} \text{ и } F_{\text{н}} - \text{на}\, S_{\text{bр}}.$$

The areas of the projections $S_{\text{нр}}, S_{\text{хр}} \text{ и } S_{\text{bр}}$ are in direct relation with the real work surface, while the corresponding angles with the direction of movement α and the position of the horizon β.

The so defined constituent forces acting in the three reciprocally perpendicular directions of the space and their resulting reactions can be considered not only for measuring the work organ, but also for working out a desirable process since the relation among the respective pressure forces can be calculated by defining the relation among the real work surface projections and vice versa. The possible relations are the following:

$$\frac{F_x}{F} = \frac{S_{\text{нр}}}{S};\ \frac{F_b}{F} = \frac{S_{\text{хр}}}{S};\ \frac{F_{\text{н}}}{F} = \frac{S_{\text{вр}}}{S} \text{ и } \frac{F_x}{F_b} = \frac{S_{\text{нр}}}{S_{\text{хр}}};\ \frac{F_x}{F_{\text{н}}} = \frac{S_{\text{нр}}}{S_{\text{в}}};\ \frac{F_b}{F_{\text{н}}} = \frac{S_{\text{хр}}}{S_{\text{вр}}}.$$

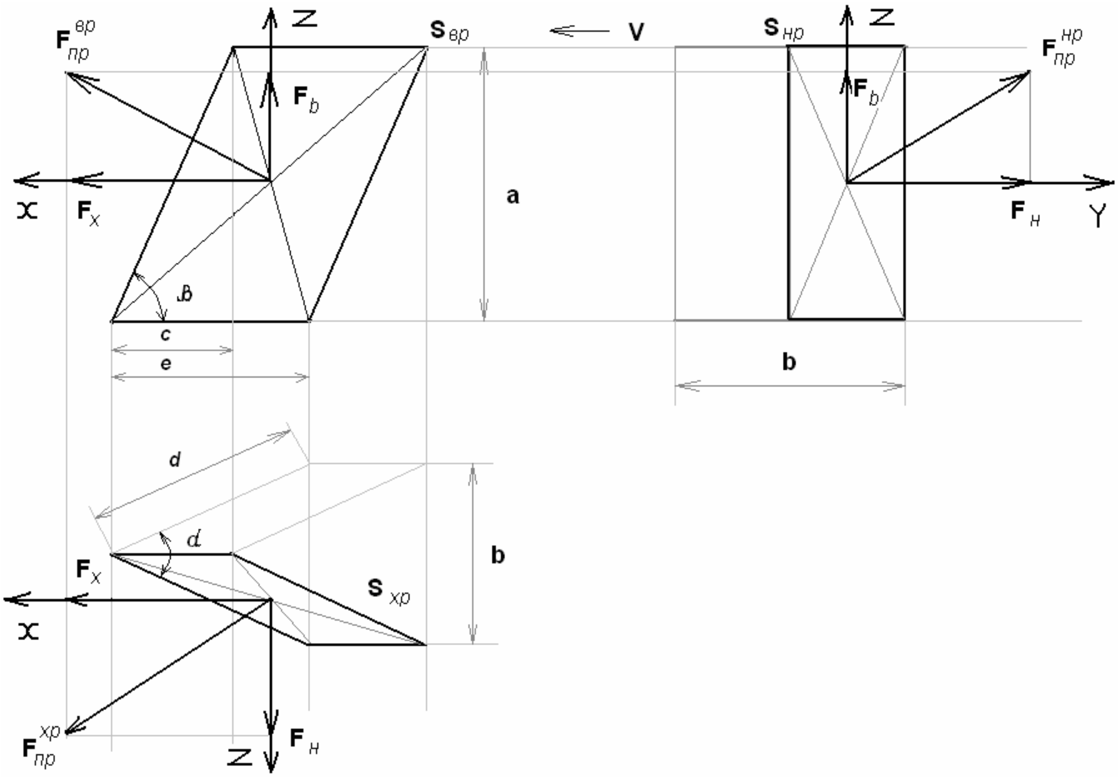


Fig.2. Projections of the cutting work organ surface
1- at the side ; 2 – at the front ; 3 – at the top

The corresponding surface areas can be calculated in the following equations:

$$S = a.b.a = \frac{a.b}{2\sin\frac{\alpha}{2}};\ S_{bp} = e.a = \frac{1}{2}a.b.\cot g\frac{\alpha}{2};\ S_{HP} = \frac{a.b}{2};\ S_{xp} = c\frac{b}{2} = \frac{a.b}{2}\cot g\beta$$

Where :

a - is depth of the cutting process

b - is width of the cut

From this follows that:

$$\frac{F_x}{F} = \sin\frac{\alpha}{2};\ \frac{F_b}{F} = \sin\frac{\alpha}{2}.\cot g\beta;\ \frac{F_H}{F} = \sin\frac{\alpha}{2}\cot g\frac{\alpha}{2};\ \frac{F_x}{F_b} = tg\beta;\ \frac{F_b}{F_H} = \frac{\cot g\beta}{\cot g\frac{\alpha}{2}} = \sin\frac{\alpha}{2}.\cot g\beta.$$

The result shows that the relative change of the constituent forces depends neither on the width or depth of the cutting process, nor on their relation, but only on the angle of the work surface position towards the direction of movement along the OX axis and the angle of position β. These relations are shown on fig. 3.

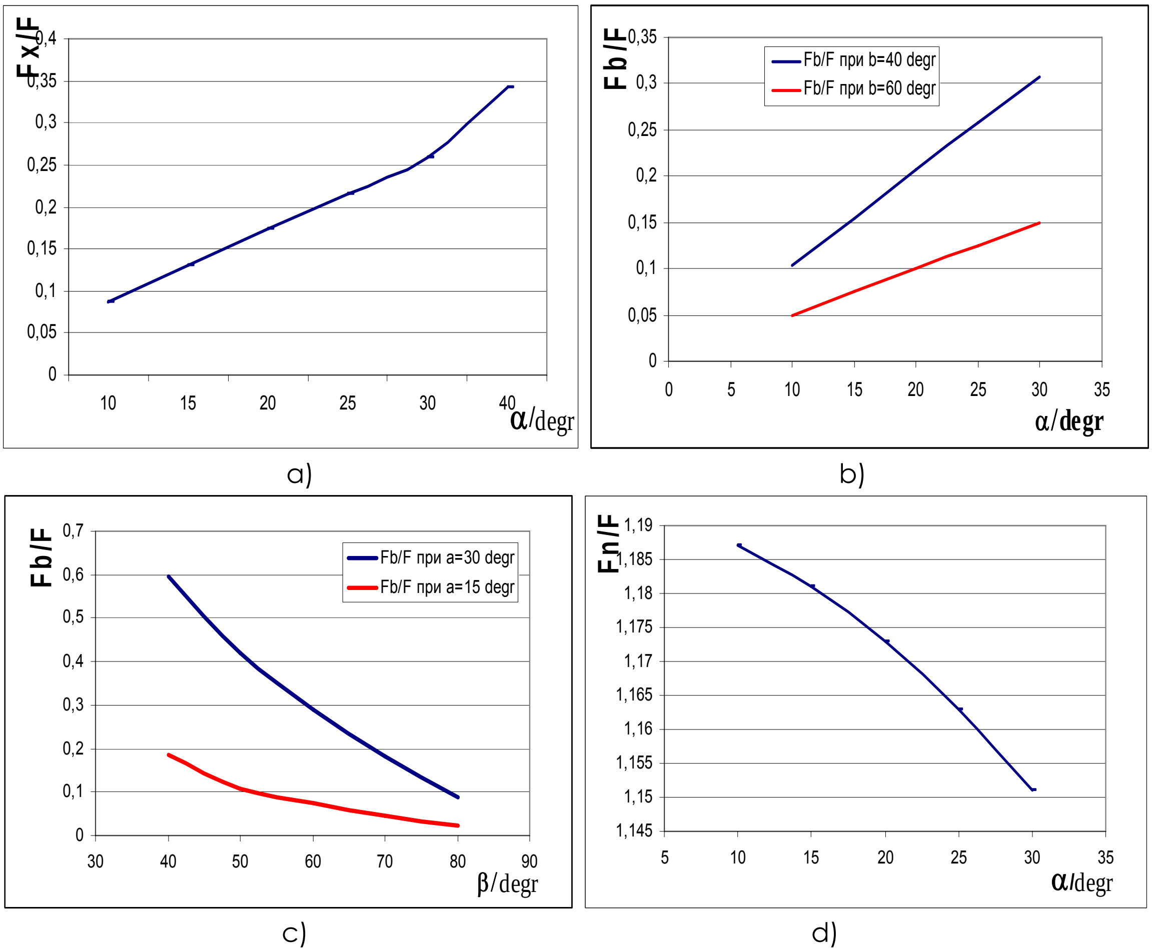


Fig.3. Relative change of the constituent forces which is dependent on the angles a and β:

a) relative change of the horizontal constituent force F_X, in relation to angle α ;

b) relative change of the vertical constituent force F_b in relation to angle α , at a constant angle β= 40° and β= 60°;

c) relative change of the vertical constituent force F_b in relation to angle β , at a constant angle α = 30° and α = 15°;

d) relative change of the cross-sectional constituent force F_H in relation to angle α .

The horizontal constituent force F_X depends only on angle α (fig. 3.a), as the value $\frac{F_X}{F}$ decreases relatively with the decrease of the angle. We can draw a logical conclusion that it depends indirectly on the angle β, since with its decrease the angle α, which is the real work angle, measured in the horizontal surface, also decreases.

The relative change of the vertical constituent force $\frac{F_b}{F}$ depends not only on the angle α, but also on the angle β (fig. 3b and fig.3c). In both cases it changes proportionally, but in the described practical range of change of the angles it is less affected by the change of the angle a. From a practical point of view it is important to notice that with the decrease of the angle β which specifies the position of the work surface toward the horizon, the vertical constituent force relatively increases.

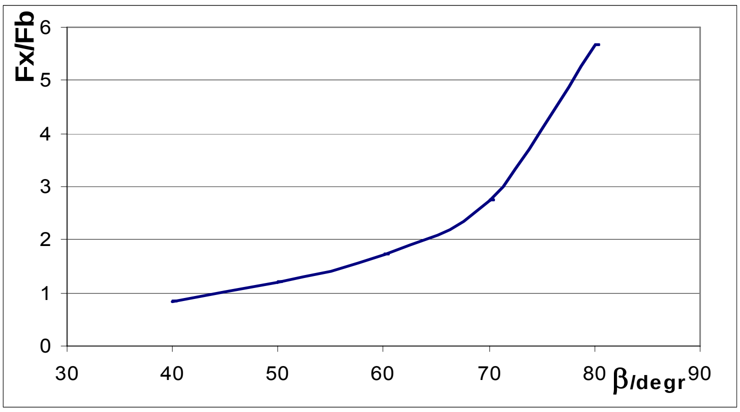
The relative change of the cross-sectional constituent force $F_{H/F}$ (fig.3 d) under these conditions depends only on angle a, because as the angle increases, $F_{H/F}$ decreases insignificantly. Consequently it can be ignored as it balances with the opposite force of the corresponding work surface.

The character of the grooving procedure depends greatly on the interrelation of the constituent forces. To explain it further a relation of the forces depending on the angles which show the position of the work surface a and β, has been illustrated on fig.4.

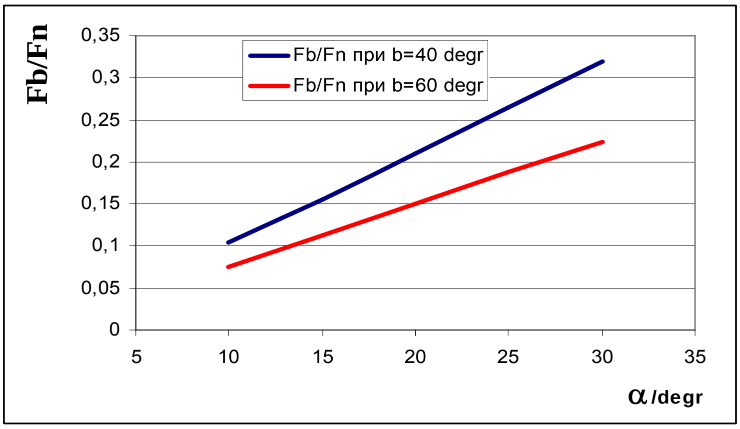
The relation between the horizontal constituent force F_X and the vertical constituent one F_b.(fig.4.a) depends only on the angle of the position of the work force towards the horizon β.

By considering the results of Fig. 4.a, a conclusion can be reached that at a vertical position of the work surface the increase of the angle β causes the horizontal constituent force F_X to increase progressively to infinity, when compared to the vertical constituent F_b. Taking into account the fact that the horizontal constituent force F_X can be overcome by part of the pulling effort of the energy device, while the vertical constituent force F_b is balanced by the motion system of the machine, within the range of the common effort of the two forces it is necessary to transform the horizontal constituent F_X into the vertical one F_b as the friction in rolling of the motion wheels is less than the one in sliding of the work organs. This transformation might be achieved by decreasing the angle β, the results of which are more noticeable when the values of the angle are higher.

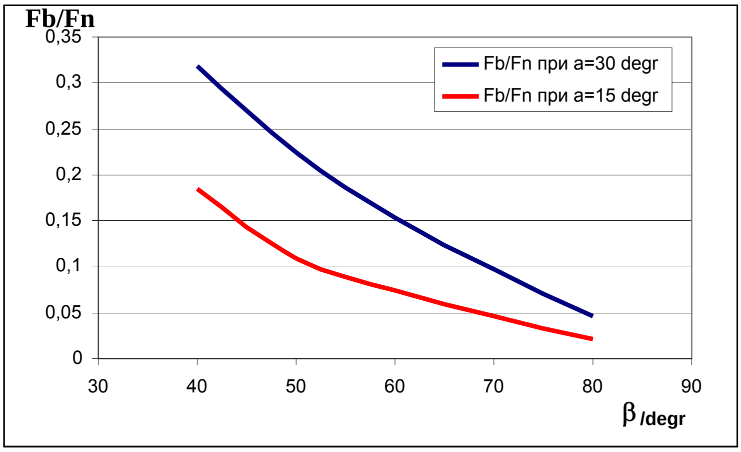
The change of correlation between the vertical constituent force F_b and the cross-sectional one F_H in relation to the angles of the work surface position shown on fig. 4 b and 4.c is different. Concerning angle a. the following change can be observed: the relative part of the vertical constituent force F_b increases, while the relative part of the cross-sectional one F_H decreases to the same extent. With angle β we can outline the reverse tendency which is due to the decrease of the relative share of the vertical constituent force F_b. Within the described range of change of angles a and β, the influence of the latter is stronger, in that case a decrease in the correlation of the constituent forces F_b/F_H.



a)



b)



c)

Fig. 4. Change of the constituent forces relation depending on the angles a and β

a) change of the relation F_X/F_b depending on the angle β ;

b) change of the relation F_b/F_H depending on the angle α ; at a constant angle β = 40° and 60°;

c) change of the relation F_b/F_H depending on the angle β , at a constant angle α = 30° and 15°.

The so analyzed correlations and their graphic realization might be used for other experiments with changes of the angles of the position of the work surface to a certain extent and direction in order to achieve definite results.

2. CONCLUSION

As a result of this theoretical analysis we can make the following conclusion: This theoretical experiment defined the forces acting in the cutting process, their relative change and correlation in relation to the change of the angles of the position of the work surface towards the direction of movement and the horizon, which is essential for the projection of a desired process and the construction of the corresponding work organ.

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