THEORETICAL AND EXPERIMENTAL STUDY ON SOIL VIBRATORS USED FOR THE GERMINAL LAYER PREPARATION

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The cultivators are tools included by the complex agricultural sets for preparing the germinal layer having minimal tillage character [8]. From structural and functional point of view these are of various types, both in what concerns the tool frame and the active parts mounted on it [2, 4, 6, 7]. The cultivators frame may be a square bar on which working sections with active parts are fixed. Also, the frame may be trapezoidal with several transverse bars, to which the active parts are connected. They are distributed according to a certain diagram in order to process the soil along the whole working size of the assembly.

The active parts may be fixed on the frame or on the working sections, by help of rigid, elastic or vibrating supports. This kind of fixing will influence the working assembly dynamics, and in view of land use, the quality parameters of the germinal layer preparation. That is why it is necessary to carry out a theoretical and experimental study concerning the active parts of the cultivator as their interaction with soil. The paper approaches the active parts and soil interaction aspects, especially with respect to the active parts on elastic supports.

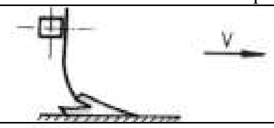
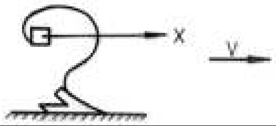
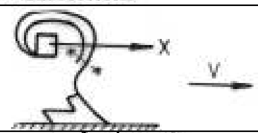
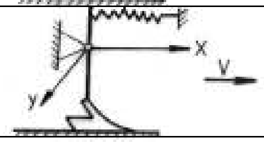
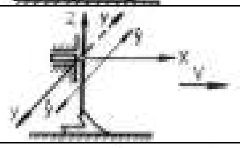
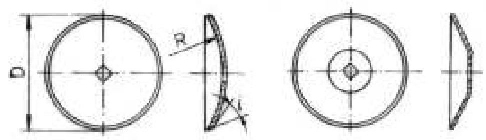
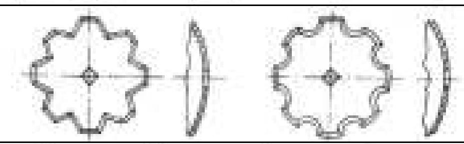
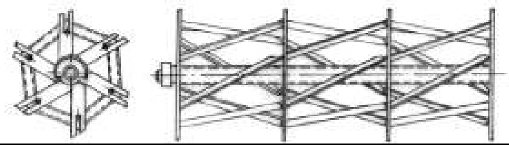
SOME ASPECTS CONCERNING THE ACTIVE PARTS AND SOIL INTERACTION

The complex agricultural assemblies for germinal layers preparation consist of cultivators, soil vibrators and various construction harrows. The typical active parts types on these assemblies are presented in Table 1.

On one hand the germinal layer preparation requires a great energy output from the agricultural machines involved, on the other hand the assemblies' efficiency is low. An increase of their efficiency is possible by using bigger working sizes and velocities, which also require increased tractor power without decreasing the specific energy consumption.

An increase of the working velocity can also be obtained by improving the soil working machines active parts, which contribute by their kinematics and operational dynamics to the decreasing of the traction resistance force and to the improvement of the energy basis traction qualities.

Table 1. The typical active parts of the implements used for the germinal layer preparation

Active part type	Simplified representation
Active part with rigid support (AP1)	
Active part with simple elastic support (AP2)	
Active part with double elastic support (AP3)	
Active part with oscillating one-dimensional support (AP4)	
Active part with oscillating longitudinal-transversal support (AP5)	
Rotational disk active part with con-tinuous cutting edge (AP6)	
Rotational disk active part with saw cutting edge (AP7)	
Rotational active part with helical bars (AP8)	

The main cause determining an increase of the traction resistance force is the frictional force between the active parts surface and the soil. Because of this, the investigation area in this field became the subject of many researches concerning the frictional force decrease. From among the investigated methods we mention: the polishing of the surfaces which make contact with soil, using a cushioning cylinder between the surfaces and the soil, using of an ointment film, using the concatenation of the working parts, covering the surfaces with antifrictional materials, rotating working parts, using a potential difference to bring about the water circulation towards the contact point with the soil, which performs a relative motion with respect to the active part and using active parts on elastic supports to fit the soil vibrators included by the agricultural assemblies for the germinal layer preparation.

THEORETICAL ASPECTS ON THE ACTIVE PARTS WITH ELASTIC SUPPORTS

In Figure 1, there is a simplified representation of a soil working active part, which is mounted on elastic supports. Due to the assembly velocity, the non-uniformity of the soil and the microdislevelments, the resistance force acting on the working active part is given by a random function because the assembly velocity is a time function, sometimes discontinuous, the soil non-uniformity depends on the pedological structure (soft ground, middle ground, compact ground), the microdislevelments depend on the ploughing type and the clime conditions during winter.

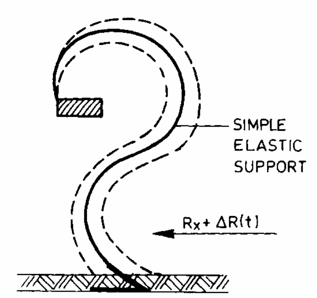


Fig. 1. Working active part mounted on an elastic support

Under these conditions, the working active part on the elastic support has a sustained vibration. The sustained vibrations are due to the mechanical energy accumulated by the elastic support subjected to a high resistance force, which is released when the resistance force has the minimum value. If we consider the active part on elastic support and the soil as a single system, then the active parts vibration is a self-sustained vibration. If they are considered as two different material systems, the vibration is a forced one. We may estimate that an agricultural assembly for germinal layer preparation with a soil vibrator having active parts on elastic supports is subjected to a lower resistance force than the one with active parts on rigid supports. As a consequence, the traction force decreases so that the efficiency of the assembly consisting of a tractor and combine will increase. The combine means a set of various tools like tooth harrows, rotational harrows and soil vibrators.

The interaction between the active parts on elastic supports and the soil is expressed by a system subjected to the following forces: the elastic force in the elastic support of the active part ($-kx$), the damping force ($-c\dot{x}$) and the frictional force $mg\mu_{(v)} = mg\mu(u - \dot{x})$. The motion differential equation is:

$$m\ddot{x} + c\dot{x} + kx = mg\mu\left(u - \dot{x}\right) \tag{1}$$

where u is the assembly velocity. This equation is non-linear because it contains the function $\mu(u - \dot{x})$, where μ, the friction coefficient, depends on the velocity.

Assuming that $\dot{x} > u$, the function μ, meaning the friction coefficient, can be developed as a Taylor series as follows:

$$\mu(u - \dot{x}) \approx \mu(u) - \mu'\dot{x} + \frac{1}{2!}\mu''\dot{x}^2 - \frac{1}{3!}\mu'''\dot{x}^3 + \ldots, \tag{2}$$

where the derivatives $\mu' = \frac{du}{dv}$, $\mu'' = \frac{d^2u}{dv^2}$, $\mu''' = \frac{d^3u}{dv^3}$ are calculated for $\dot{x} = 0$.

The differential motion equation becomes:

$$m\ddot{x} + \left[c + (\mu' - \frac{1}{2!}\mu''\dot{x} + \frac{1}{3!}\mu'''\dot{x}^2 - \ldots)mg\right]\dot{x} + kx = mg\mu(v) \tag{3}$$

Using the change of function: $y = x - \frac{mg\mu(v)}{k}$, so the differential motion equation has the expression:

$$m\ddot{y} + \left[c + (\mu' - \frac{1}{2!}\mu''\dot{y} + \frac{1}{3!}\mu'''\dot{y}^2 - \ldots)mg\right]\dot{y} + ky = 0 \tag{4}$$

For $x = \frac{mg\mu(v)}{k}$ we get $y = 0$, which represents the equilibrium position. We neglect the terms that include $\dot{y}$ raised at a greater power than one and the equation (4) gives:

$$m\ddot{y} + \left[c + mg\mu'\right]\dot{y} + ky = 0 \tag{5}$$

Denominating $2h = \frac{c}{m}$; $\frac{k}{m} = p^2$ and considering equation (5) results:

$$\ddot{y} + [2h + g\mu']\dot{y} + p^2 y = 0 \tag{6}$$

During the working process of the soil vibrators, we are interested in the instability state, because the stability state corresponds to active parts on rigid supports.

According to the motion differential equation (6), we find that the dynamical instability (self-sustained vibrations or sustained vibrations) occurs when the $\dot{y}$ coefficient sign is negative, meaning

$$2h + g\mu' < 0 \tag{7}$$

Because $2h > 0$, the instability necessary and sufficient condition is $\mu' < 0$. From the analysis of Figure 2 we see that the self-sustained vibration occurs for relatively small velocities, because in this case $d\mu / dv$ is a decreasing function.

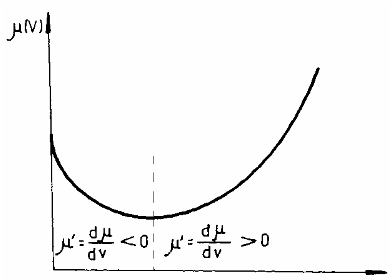


Fig. 2. Variation of the friction coefficient with the speed

So the velocity of an assembly with active parts fixed on elastic supports can not be increased very much. The necessary and sufficient conditions that allow self-sustained vibrations are $\mu' < 0$ and $2h < \mu' g$.

The stability and instability cases of the active parts should be studied also from the working condition point of view meaning: the soil type (soft, middle, compact), the soil humidity and the working depth. For soft and middle soils we need elastic supports with a relative small factor of rigidity, as for the compact grounds the factor of rigidity should be greater.

For great working depths (10-20 cm) the active parts with elastic supports will work on self-sustained vibrations, unlike the active parts working at smaller depths (4-10 cm). This way we may explain the variety of combines and working active parts for germinal layer preparation.

According to the conditions above, the vibrations (self-sustained vibrations) are maintained due to the mechanical energy accumulated by the elastic support during the working process.

EXPERIMENTAL RESEARCHES AND CONCLUSIONS

In order to establish the influence of the working active parts with elastic support on the traction force some experiments were made in the following conditions [2]: soft, middle and compact soils; the soil vibrators were provided with four types of supports (see Tab. 1): *a* – rigid support (*AP*1); *b* – simple elastic support (*AP*2); *c* – double elastic support (*AP*3); *d* – double elastic support (*AP*4).

Table 2. Experimental results of the testing of different working parts

Soil type	Work depth [cm]	Work velocity [km/h]	Specific traction resistance [N/m]							
			Type of supports							
			a		b		c		d	
			N/m	%	N/m	%	N/m	%	N/m	%
soft	6-7	5	2240	100	1800	80.3	1900	84.8	2100	93.7
		7	2240	100	1800	80.3	1860	83.0	2000	89.2
		9	2300	100	1750	76.0	1900	82.6	1940	84.3
	8-12	5	2790	100	1250	80.6	2280	81.7	2350	84.2
		7	2800	100	2200	78.5	2250	80.3	2300	82.1
		9	2850	100	2150	75.4	2190	76.8	2230	78.2
	12-18	5	3000	100	-	-	2900	96.6	2500	93.3
		7	3000	100	-	-	2900	96.6	2800	93.3
		9	3110	100	-	-	2850	91.6	2750	88.4
middle	6-7	5	2300	100	2090	90.4	2120	90.8	2300	100.0
		7	2310	100	2100	90.0	2100	90.9	2310	100.0
		9	2430	100	2070	88.4	2070	88.4	2270	97.0
	8-12	5	2500	100	2450	98.0	2260	90.4	2450	98.0
		7	2640	100	2400	82.2	2260	77.3	2450	83.9
		9	2700	100	2400	88.8	2230	82.6	2590	88.5
	12-18	5	3280	100	-	-	3250	99.0	3050	93.0
		7	3300	100	-	-	3200	96.9	3000	90.9
		9	3340	100	-	-	3300	98.9	2900	86.8
compact	6-7	5	2340	100	2210	94.4	2200	94.0	2340	100.0
		7	2370	100	2200	92.8	2240	94.5	2300	97.0
		9	2400	100	2180	90.8	2300	95.8	2370	98.7
	8-12	5	2550	100	2300	90.2	2350	92.1	2400	94.1
		7	2510	100	2290	91.2	2340	93.2	2400	95.6
		9	2640	100	2240	84.8	2300	87.1	2370	89.7
	12-18	5	3500	100	-	-	-	-	3400	97.1
		7	3530	100	-	-	-	-	3400	96.3
		9	3600	100	-	-	-	-	3200	88.8

The experiments have been made for various working depths of the active part (6-7; 8-12; 12-18 cm) with different working velocities (5; 7; 9 km/h) [2]. The results are shown in Table 2. From the analysis of the experimental results, the following conclusions can be drawn:

– the traction force is greater for the rigid supports device in comparison to the elastic supports devices, so: the case (b) decreases it with 13.7%; case (c) with 10.6%; case (d) with 8.1%;

– the active parts on simple elastic supports (b*) do not work as an active vibrating part for depths greater than 12 cm, because the vibration amplitude cancels;

– assuming the same soil type and the same working depth for the active parts, the traction force depends on the support type of construction. Thus, for a 6-7 cm depth the traction force is greater for the high elasticity constant supports because in these conditions the vibrating character is less present, but the performance is close for the rigid supports. On the contrary for greater depths the active parts on high elasticity constant supports work with stronger vibrations while the ones on lower elasticity constant supports, in the same working conditions, tend to behave like a part on a rigid support.

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SUMMARY

The completed studies aimed at the creation of the theoretical and experimental bases for the elastic active elements of the soil vibrators. Experiments were carried out with elastic supports on various soils, working depths and velocities.