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Soil chip thickness of a spading machine with different operating modes

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Soil chip thickness of a spading machine with different operating modes

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Abstract. The article uses the SAM software product to synthesize the kinematic model of a spading machine in different operating modes. Dimensions of the kinematic units are set according to the dimensions of the units of real machines. The trajectory of motion of the working body upon which the size and shape of the soil chips depend is analyzed. The soil chip thickness depends on the operating modes of a spading machine. The different operating modes definite different parameters of cross-section area of a soil chip.

1. Introduction

In our country primary soil tillage is done mainly by turning the surface layer at a depth of about 30 cm and is practically used in growing all filed crops requiring such tillage. For this purpose, mainly ploughshares are used and the operation is carried out after harvesting the previous crop, that is, during the summer-autumn season. Surface treatments preceding sowing are carried out during the spring season [2].

In growing vegetable crops outdoors or in greenhouses intensive methods are used and the time between primary tillage and sowing or transplanting is minimal. In these cases it is preferable to carry out the primary tillage with machines with active working organs to provide a grain-size soil composition suitable for the subsequent operations. The primary tillage with them can be done at elevated soil moisture without distorting the microrelief, which is important if watering is by gravitation. According to Coleman [1], primary tillage machines with active working organs are suitable for organic farming and according to their working principle, they are: with rotary working organs (rotary ploughs) and with reciprocating movement (spading machines). Spading machines virtually imitate manual turning of the soil by using a soil with a spade.

According to some authors [3], the advantages of the spading, i.e. the better residues incorporation and the absence of the soil compacted layer, cannot be easily evaluated, because in this case the crop yield and quality should be checked for a significant time period.

The time needed for cutting the soil chip is determined depending on the constructive parameters and the operating mode of the performing unit [4].

According to some authors, the spading machine [5] with active drive ensure maximum improvement of soil structure by intensive crushing, aeration of the cultivated soil layer and its separation in fractions. In coarse soil aggregates and residues from grown vegetables remain on the surface, preventing soil from claying, drying, wind and water erosion. Provides excellent levelling of the soil surface, a prerequisite for precise execution of subsequent technological operations.

The objective of the present paper is to study the soil chip thickness of a spading machine by kinematic model created by a specialized engineering software.

2. Material and methods

The synthesis of kinematic models of the spading machine and determination of the soil chip thickness has been done by the software product SAM [7]. The software product allows drawing of a mechanism, setting operating parameters of that mechanism, and outputting velocity and acceleration graphs relative to the path of selected points of the mechanism.

The following unit dimensions were used to draw the mechanism of the spading machine (Figure 1):

- knee length 1 (crankshaft rotation radius) – 0,15 m;
- arm length for mounting the working body 19+20+23 – 0,37 m;
- length of working body 22 (spade) – 0,3 m;
- distances between the crankshaft axis and the hinge for mounting the timing bar on the frame 3+10 – 0,4 m;
- length of the timing bar 7 – 0,26 m.

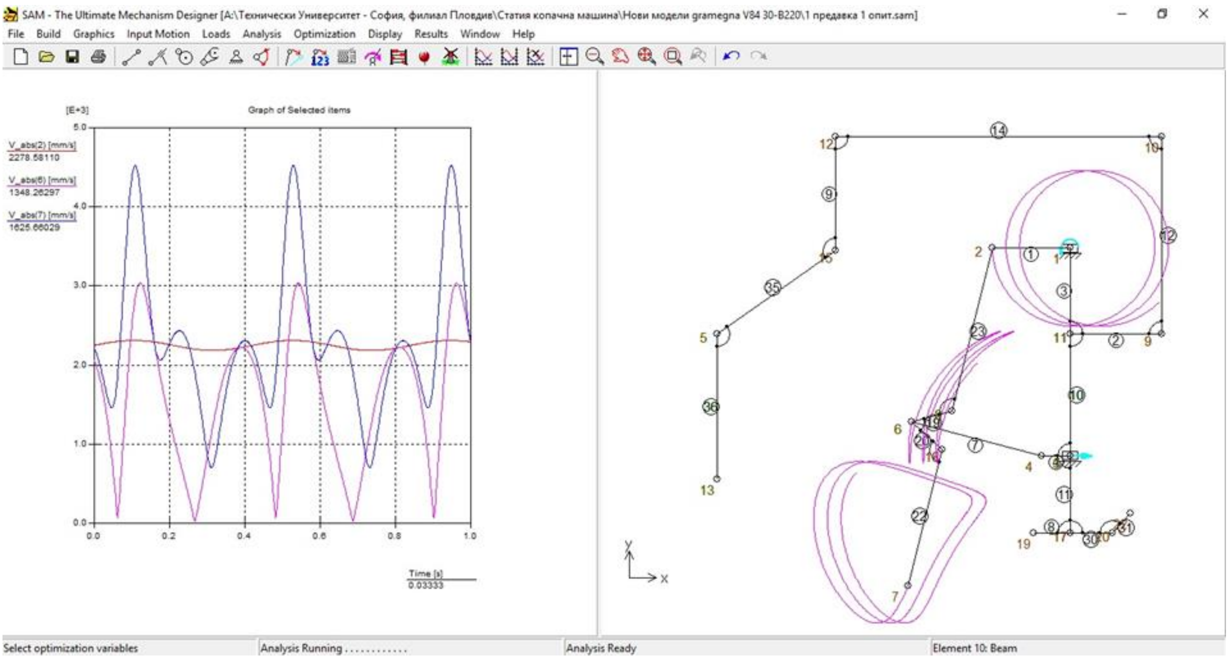

Figure 1. Using the software product SAM for synthesizing a kinematic model of a spading machine

It is assumed that the tractor with which the machine is aggregated moves in one gear and the changing of engine rotations variations the velocity of movement (working velocity *Vw*) which takes the following values 0,063 m/s, 0,147 m/s, 0,231 m/s. Since the velocity of rotation of the independent power take-off shaft (PTOS) of the tractor is proportional to its velocity (within one gear), at the relevant velocities of movement the velocity of rotation of PTOS is 460 min^{-1}, 500 min^{-1} and 540 min^{-1}. The gear ratio of the spading machine reductor is 3,21, therefore the crankshaft velocity of rotation of the machine ranges from 143 min^{-1} to 168 min^{-1}.

The trajectories of movement of selected points in the machine mechanism have been built, the absolute velocity of the working body and the parameters of the soil chips at operation of the spading machine have been determined.

3. Results and discussion

Fig. 2 presents a diagram of a spading machine created by using the software product SAM. The trajectories of point B at the crank of crankshaft 1 of the machine and point M of the working body (spade) 3 of the machine are shown. The trajectory of point B is divided into sections at 45° by the crankshaft rotation angle. The trajectory of point M is also divided into sections that correspond to the given rotation angle of the machine crankshaft. It can be seen that the individual sections of the trajectory of point M, corresponding to the same angle (45°) of rotation of the machine crankshaft, are of different length. Accordingly, the absolute velocity at point M of the working body has different meanings at different rotation angle of the machine crankshaft.

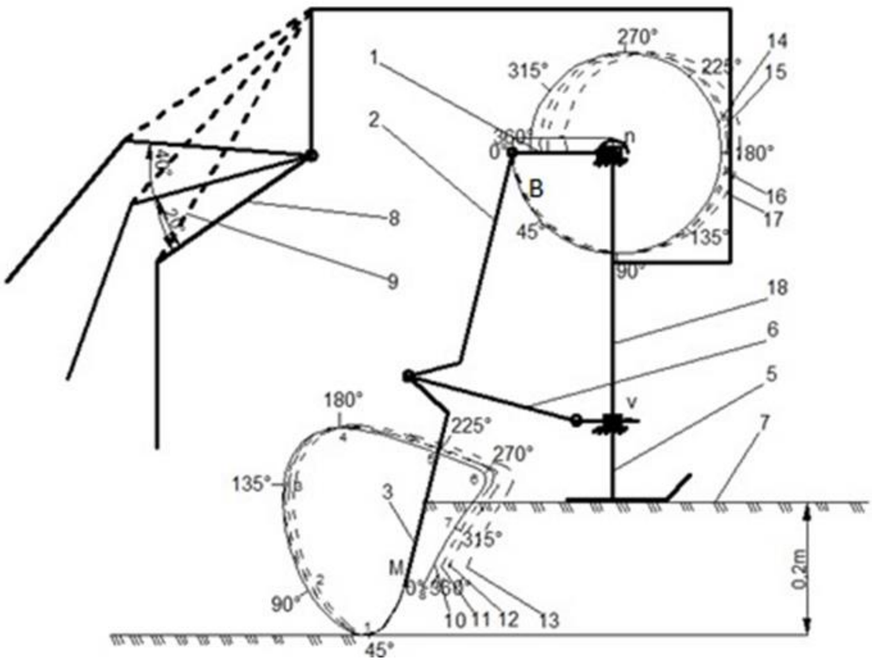

Figure 2. Diagram of a spading machine:
1 – crankshaft; 2 – arm; 3 – working body (shovel); 4 – arm; 5 – sliders; 6 – timing bar; 7 – soil layer; 8 – deflector cap; 9 – chain for cap adjustment chain;10, 11, 12, 13 – trajectory of movement of point M of the working body (the shovel); 14, 15, 16, 17 – trajectory of movement of point B of the crankshaft.

Fig. 3 is a graphical representation of the variation of the absolute velocity of the M (lower end of the working body) relative to the crankshaft rotation angle. It can be seen that within a small interval of rotation of the machine crankshaft the velocity of point M increases significantly. In this interval the soil is overthrown by the working body, and therefore higher velocity, respectively greater kinetic energy of the overthrown layer is needed in order to obtain better fragmentation of the soil.
The values of the trajectory and the absolute velocity of point M of the working body of the machine are shown in table 1. It shows that the total length of the road traversed by point M of the working body of the machine does not change and is about 1 m per revolution of the crankshaft. The absolute velocity of the working body increases with an increase in PTOS rotation frequency from 5,203 m/s at 460 min^{-1} to 6,165 m/s at 540 min^{-1}. The absolute velocity of the working body reaches its maximum in the range between 90º and 135º of the crankshaft rotation.
The trajectory covered by point M on the spade on the vertical plain OXY (Figure 4) can be divided depending on the process carried out by the spade into the following sections:
- A – B – inserting the spade into the soil;
- B – C – overthrowing the soil;
- C – D – moving the spade for the next insertion.

The soil chip is the area surrounded by points AD0B. It can be seen that it has almost Rectangular cross section (Figure 5). The thickness of the chip is equal to the distance between points A and D, which is the step of the working body. In individual sections, the absolute velocity value changes as follows: when the spade penetrates into the soil it is the lowest; when the soil aggregates are dropped off the spade, the speed reaches its maximum; when shifting the spade for subsequent penetration into the soil, the speed is slightly higher than that at insertion.

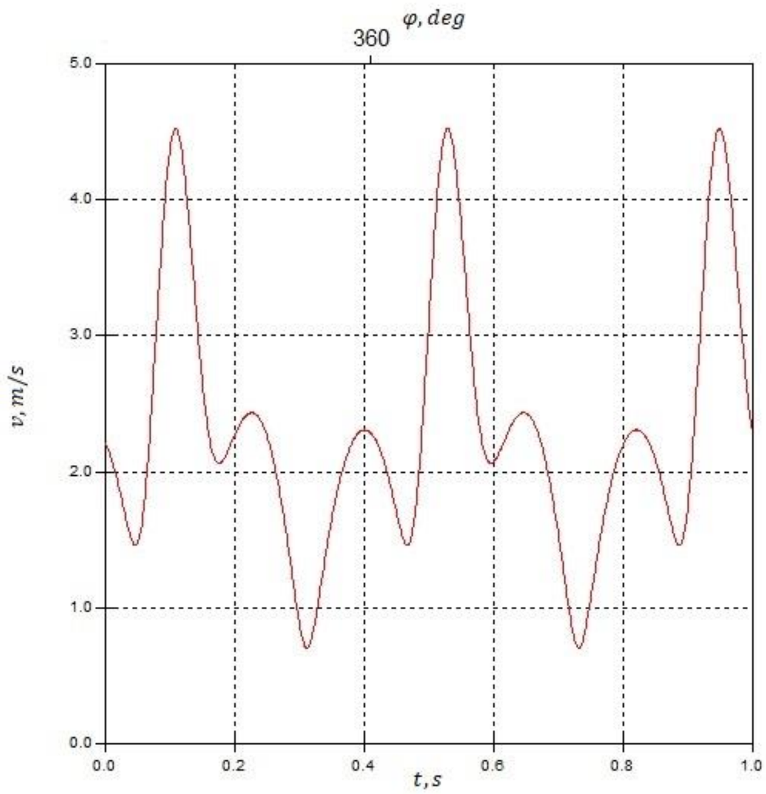

Figure 3. Diagrams for absolute velocity V at point M in the mechanism of the spading machine according to the angle φ of rotation of the machine crankshaft

Figure 4 shows the step of the working body of the spading machine - the distance between two identical points of two consecutive trajectories. At the accepted operating parameters it is 0.088 m. The step of the machine is determined analytically by the expression

$$\boldsymbol{X = \frac{60.V_w.i}{n}, m,} \tag{1}$$

where *Vw* is the progressive speed of the machine, *m/s*;
i – the transmission ratio of the reductor of the spading machine;
n - rotation speed of the tractor power take-off shaft, min^{-1}
The rotation speed *n* of the tractor PTOS at the same tractor gear changes in pro rata to the crankshaft rotation frequency of the tractor engine, and the speed of movement *Vw* also changes accordingly. For this reason, the machine step remains constant when changing the rotation frequency of the PTOS within the gear used.
From Fig. 4, it can be seen that the bottom of the furrow in operation of the spading machine is uneven, the height of ridge depending on the size of the step of the working body. At a smaller step Fig. 4 the height of ridges along the bottom of the furrow decreases, and a bigger step Fig. 5 the height of ridges along the bottom of the furrow increases. The soil chips are with different thickness because the step X (1) of the working body of a spading machine is different. The soil chip is the area by points ADOB in the figures.

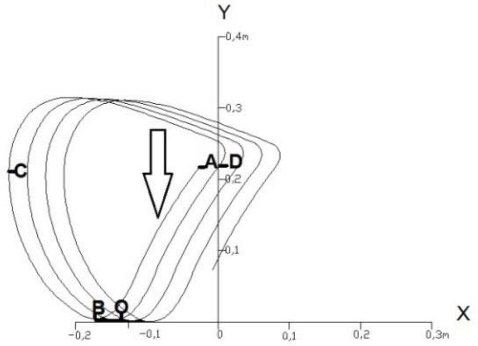

Figure 4. Trajectory of point M on the working body of the spading machine for smaller step.

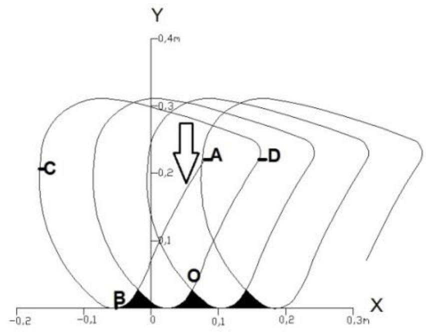

Figure 5. Trajectory of point M on the working body of the spading machine for bigger step.

Table 1. Values of absolute velocities and the distance covered by point M of the spade depending on the crankshaft rotation angle of the machine

Crankshaft rotation angle, °	Distance covered by point M, m	Absolute velocity V, m/s
At rotation frequency of PTOS n = 460 min^{-1}		
45	*0,116*	*2,006*
90	*0,233*	*4,410*
135	*0,350*	*3,968*
180	*0,467*	*2,082*
225	*0,584*	*2,361*
270	*0,700*	*1,608*
315	*0,817*	*2,086*
360	*0,935*	*2,242*
Max		***4,514***
Min		***0,695***
At rotation frequency of PTOS n = 500 min^{-1}		
45	*0,116*	*2,224*
90	*0,233*	*4,762*
135	*0,350*	*4,271*
180	*0,467*	*2,242*
225	*0,584*	*2,584*
270	*0,700*	*1,797*
315	*0,817*	*2,266*
360	*0,935*	*2,433*
Max		***4,961***
Min		***0,753***
At rotation frequency of PTOS n = 540 min^{-1}		
45	*0,116*	*2,324*
90	*0,233*	*5,168*
135	*0,350*	*7,509*
180	*0,467*	*2,435*
225	*0,584*	*2,767*
270	*0,700*	*1,895*
315	*0,817*	*2,470*
360	*0,935*	*2,601*
Max		***5,314***
Min		***0,825***

The study has been conducted at the farm of agricultural producer. The soil aggregates dimensions are determined according the Kachinsky classification [6]. During each experiment from the experiment plan a soil sample is taken to working depth, which is divided by sieves into fractions of different aggregate sizes. Sieves with openings 0,001, 0,01, 0,025, 0,05 and 0,1 m are used, these are weighed to the nearest 1g and the values are averaged. The relative share of fractions in the sample is determined by the dependence [8]. The fraction size is with no difference when the change the operating speed rotation frequency of the PTO. The step X (1) determinate by tree operating speeds is 0,0225m (Fig. 4) 0,0524m 0,0824 m (Fig. 5). Step size 0,0225m including fraction size from 0,001 to 0,01 mm. Aggregates with this sizes up to 0,01 m are the most desired in preparation soil tillage. When using the machine for pre-sowing soil tillage it is preferable the share of that fraction to be until 50 percent of total aggregates. Step size 0,0524 m including fraction sizes from 0,001 to 0,01 m up to 40 percent and fractions sizes from 0,01 to 0,25 and form 0,25 to 0,50 m up to 40 and 25 percent. Step size 0,0824 m including fractions sizes above 0,1 m up to 95 percent of total aggregates. The position of the deflector cover helps to better crushing of the aggregates. When the deflector cover is on 0 degrees crushing increase and decrease with the increase degrees.

4. Conclusion

An analysis of the kinematics and the soil chip thickness of a spading machine has been made by using a specialized engineering software. It has been found out that the speed of the working body varies considerably depending on the rotation angle of the machine crankshaft. The trajectory of the working body and the shape of the soil chip shredded by it is determined. The soil chip thickness increase with the working speed of a spading machine. The soil fractions of certain size have been drawn in relation to operating speed, frequency of rotation of the PTO of the tractor and the position of the deflector cover. The granulometric composition of the soil when cultivated with a spading machine is influenced by the machine operating speed and the position of the cover.

Acknowledgments
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