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MODELLING OF THE SOIL-TWO DIMENSIONAL SHEARING TINE INTERACTION

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Abtract

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Tillage operation is one of the most power consuming processes in agriculture. In order to minimize the power requirements for the tillage process, it is necessary to know the specific features of the soil-tillage tool interaction system. Hence, this research is aimed to the modelling of the two dimensional shearing tine functioning at different angles of inclination to the travel direction. In this paper the results of the modelling of the soil-two dimensional shearing tine interaction are presented. Experiments were carried out in the soil bin. As the model of the two dimensional shearing tine was used a flat rectangular shaped tool, which short edge was oriented perpendicular to the furrow bottom. The angle between the long edge of the tine and the travel direction ranged from 30º to 90º at an increment 5º. There were revealed three modes of the tine functioning, namely the fixed soil body formation, its moving out of the tine interface and steady soil sliding along the tine interface. Decrease in the soil body mass from 100% to 0% and draught resistance of the tine by 17% during the transition from third to the first mode of functioning were revealed.

Key words: two dimensional shearing tine; fixed soil body; draught resistance; soil sliding

Introduction

Design of the tillage tools of the agricultural implements represents a two dimensional cutting and shearing tines (Goryachkin, 1965; Blednykh and Svechnikov, 2013). In the first case the tine interface is set at an acute angle to the horizontal plane, in the second case – to the travel direction (Klenin and Sakun,1994). In the case when there is no tendency to move of the soil over the cutting tine, on its interface the fixed soil body is formed (Godwin and Spoor, 1977; Aluko and Seig, 2000; Putrin, 2003).The experimental studies revealed that when the fixed soil body on the tine interface is built up, its draught resistance is increased by 50% (Zelenin, 1959; Aluko and Seig, 2000). Thus, the soil body on the interface of the cutting tine, defining the soil movement in the longitudinal plane, increases the draught resistance of the tine.

However, variety of studies was not focused on the soil body formation phenomenon on the two dimensional shearing tine interface. There has been studied the interaction with the soil of the two dimensional shearing tine oriented at the right angle to the travel direction only (Krause, 1975; Koolen and Kuipers, 1983; Sharifat, 1999; Gaifullin and Kurach, 2003).

Hence, this research is aimed to the modelling of the two dimensional shearing tine functioning at different angles of inclination to the travel direction in order to minimize the power requirements for the tillage process.

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Materials and Methods

Two dimensional shearing tine *C'A'O* (Figure 1) is positioned perpendicular to the plane *XOY*. It characterizes the soil translation (*v*) in the horizontal plane to the side from travel direction (*V*). Under the action of the interface *A'C'* the soil layer is displaced to the side and distorted in a horizontal plane at the same time.

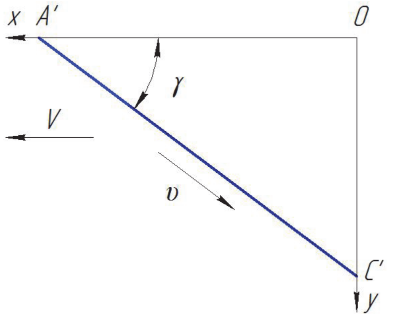


Fig. 1. Scheme of the two dimensional shearing tine

The shearing tine acts on the soil layer being handled in the horizontal plane as the cutting tine in the vertical plane. It loosens up the soil, but its main function is to move the soil layer sideways to the open furrow. The larger the angle γ, the greater is the degree of the soil pulverization and shearing to the side. At the high values of γ there can be no travel along the tine interface of the disturbed soil. The soil particles move with the speed (*v*) along the tine interface *A'C'* in the case of the following criterion:

$\gamma < 90^\circ - \varphi_1$,

where φ_1 – angle of the soil-tine interface friction.

The experimental studies were conducted with the model of the two dimensional tine, as which was used the flat rectangular shaped tool with a size of 26×240×8 cm, which short edge was oriented at the right angle to the furrow bottom, i.e. $\alpha = 90^o$ (Figure 2).

The flat rectangular tine 1 is rigidly fixed to the carrier 2, which is connected with the disc 3, and it could be rotated around its axis 4. There is circumferentially drilled the number of holes 5 on the disc. The angle between the long edge of the tine and the travel direction (*V*) represents the angle γ. Its value is altered by turning the carrier 2 around the axis 4. The holes 5 provide tine carrier rotation through 5º. Carrier is fixed to the disc by means of the bolt connection. During the experiments the angle γ was ranged from 30º to 90º. The experimental researches were carried out under controlled indoor soil bin conditions on the loam soil. The soil moisture content at the layer of 0-15 cm was 26%, the cone index – 1.1 MPa. Working depth was 8 cm, forward speed was 1 m/s. Each test run was replicated four times. In doing so, the draught resistance of the investigated tine was measured.

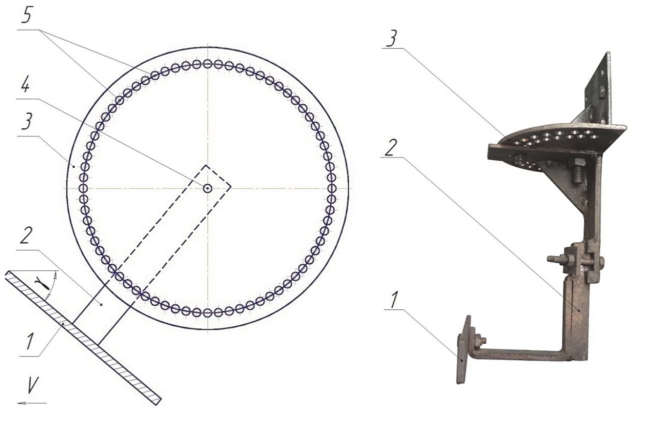


Fig. 2. The model of the two dimensional shearing tine
1 – the flat rectangular tine; *2* – tine carrier; *3* – disc; *4* – disc axle; *5* – the bolt holes on the disc

The tine displaced the soil sideways to the open furrow which was to the left of the travel direction (*V*) (Figure 3).

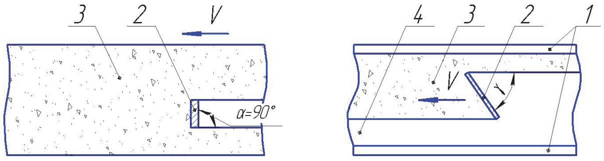
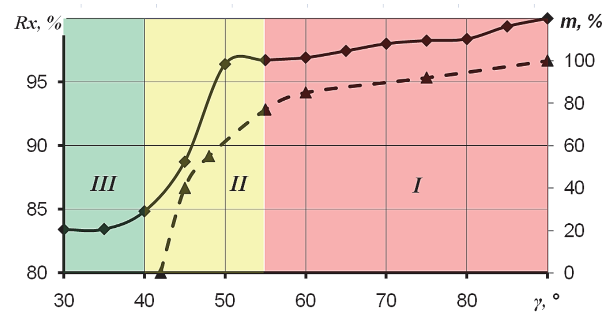


Fig. 3. Scheme of the movement of the tine in the soil
a – side view; *b* – top view
1 – the wall of soil bin; *2* – shearing tine; *3* – soil; *4* – open furrow

Results and Discussion

During the interaction with the soil of the tool modelling the two dimensionals hearing tine functioning, three modes are clearly identified (Figure 4).

The first mode, which is lasted during the change of γ from 90º to 55º, is characterized by the process of the soil volume accumulation in front of the tine interface followed by the fixed soil body formation thereon (Figure 5, a, d). In cross section it has the shape of a wedge. The mass of the fixed soil body and draught resistance depend on the angle γ. The highest values obtained during the experiment are taken as 100%.With a decrease in the angle γ from 90º to 55º the mass of the accumulated soil decreases from 100 to 80%. In this case its draught resistance is almost leveled out. Its decrease was only 3%.



—■— –the draught resistance Rx; –▲– – the mass of the soil body m

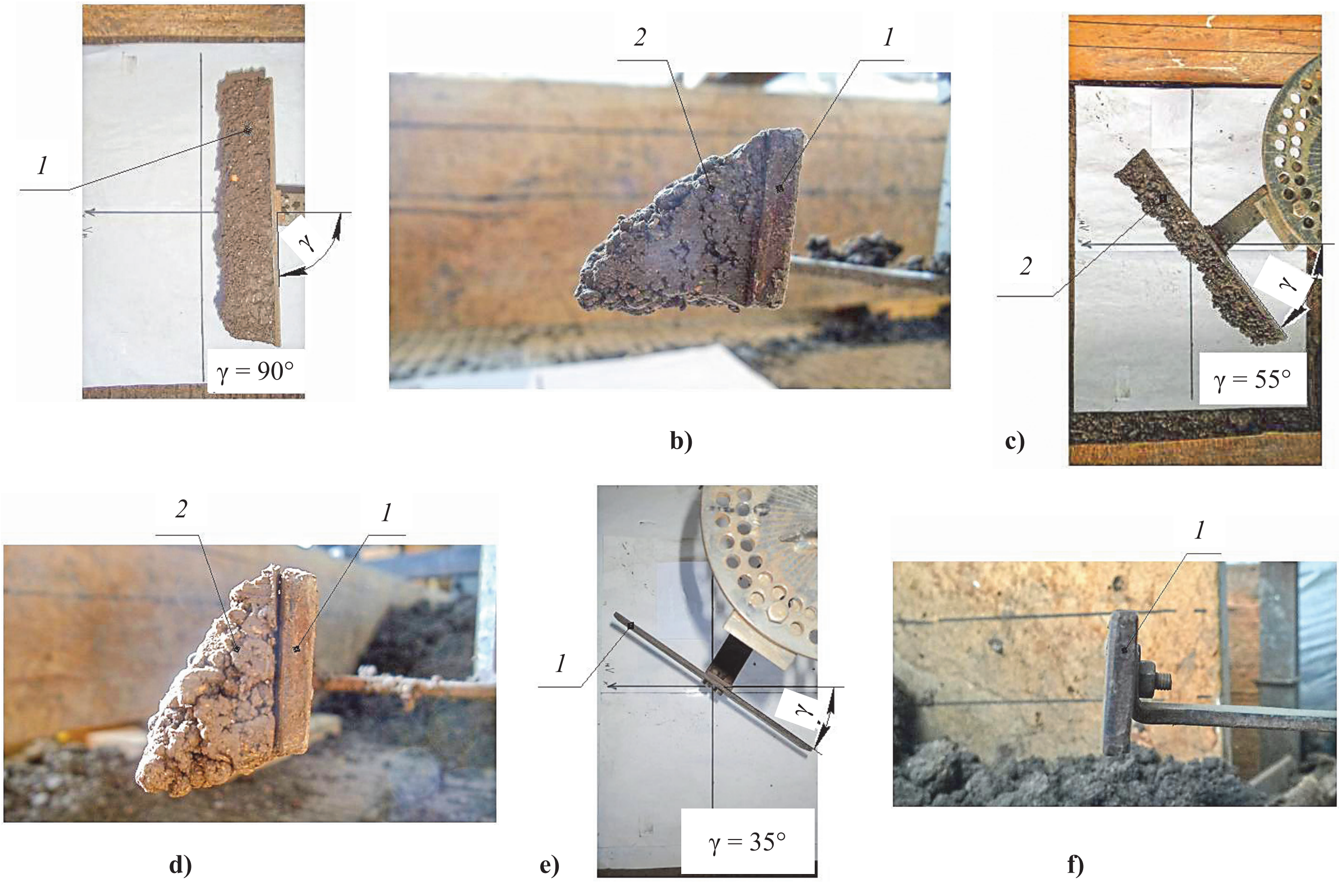
Fig. 4. Effect of the angle γ on the draught resistance (in %) of the tine and the mass of the soil body (in %) fixed on its interface

The second mode is associated with the moving out of the tine interface. This process occurs when the γ is varied from 55º to 40º. In doing so, the soil mass decreases from 80% to 0% and draught resistance of the tine decreases by 12%. This transitional period is presented in Figure 5, b, e.

The third mode is characterized by a complete vanishing of the accumulated soil mass from the tine interface (Figure 5, c, f). The soil particles begin to steadily slide up along its interface. This process occurs when the angle γ is changed from 40º to 30º. The draught resistance of the tine during this and the first phases differs by 17%.

Conclusion

Modeling of the soil-two dimensional shearing tine interaction revealed three operation modes, namely the soil



b) c) d) e) f)

Fig. 5. Top and side views to the tine in the I (a, d), II (b, e) and III (c, f) modes of interaction with the soil

1 – shearing tine; *2* – fixed soil body volume accumulation and fixed soil body formation, its moving out of the tine interface and steady soil sliding along the tine interface. These modes occur when γ is equaled to 90-55º, 55-40º and 40-30º respectively. The mass of the fixed soil body is reduced from 100-80%, 80-0% and to 0%. The draught resistance of the tine is reduced by 3, 12 and 2% respectively. The total decrease in the draught resistance of the tine in the latter mode in comparison with the first one is 17%.

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