THEORETICAL AND PRACTICAL MEANS OF PROVIDING THE DESIRED CUTTING ANGLE OF THE SOIL

N. I. Naumkin, V. F. Kupryashkin, A. S. Kniazkov, E. N. Panyushkina

National research Mordovian state University named N. P. Ogarev
Saransk, e-mail: naumn@yandex.ru

In modern agriculture, construction and mining cuttertools are widely used, which are called machines with rotating work items. Milling cutters are used for soil intensive crumbling, weeds controlling, plant residues grinding, soil layers mixing, fertilizers applying and leveling the surface being treated, soil excavation and other purposes. Energy consumption for processing in sucha way significantly exceeds its consumption in processing with other machines. Therefore, it is advisable to mill heavy soils only, which require intense grinding of ground monoliths and compact soils. One of the disadvantages of suchmilling cutters is the complexity of their design and increased energy consumption for processing. Compared with traditional passive working devices, the use of rotarycutting tools is appropriate only under conditions where conventional machines have poor quality of soil tillage and low productivity.

When milling such machines, each milling cutter blade, moving in soil, cuts a segmental soil layer (shavings) and moves it in a limited space of closed furrow (Fig. 1).As a result, the layer crumbles into small particles, which sizes depend on the mode of milling and soil properties. Soil crumbling intensity increases with layer thickness decreasing and vice versa.

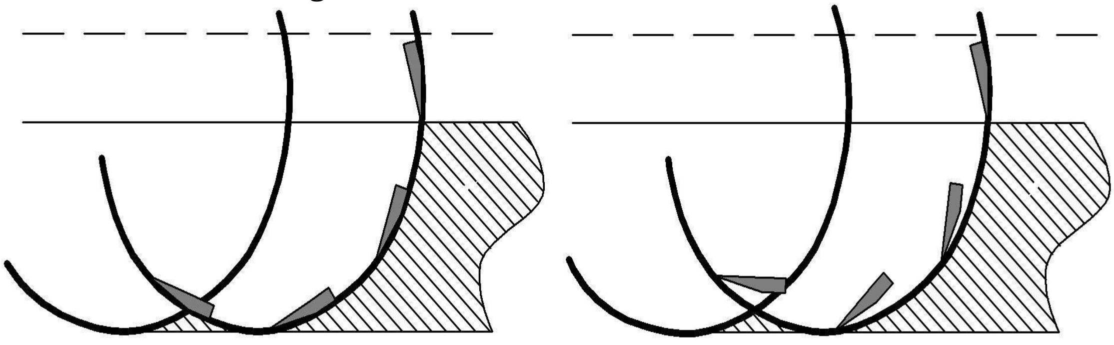

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Fig. 1. Blade movement

Summari zedscientific researches on the issue of tillage active working tools, V.F. Kupryashkin [1, 2] was able to highlight the working area of cutting corners changes in propelled small tillers (PST) within velocity range of cutter progressive motion from 1 to 4 km/h, whereby there is no soil crushing with blade back part. Thus, he suggested one of the ways to reduce the energy intensity of milling. There existsthe nomogram that has been presented by M. F. Senin [3] to determine the angles of working toolsin milling reel, depending on the depth of cutting, reel diameter, sharpening angle, width of blade and kinematic parameters. However, these methods are passive and do not provide optimal energy parameters of tillage, as each new cutter position requires its own cutting angle and it is not always optimal. In this regard, there is need to regulate the cutting angles for the whole working cycle of soil processing. Let consider the methods and devices, which help to combine the possibilities of mode regulating and cutting angles.

G. F. Popov's [4] researches show that during shavings cutting process with conventional milling reel, the power consumed for milling significantly increases compared to upgraded tool, which blades have a constant cutting angle.

In this reel operation (Fig. 1a), each blade, during the cutting process, passes through the trochoid path, with a minimum angle of deviation there from. Thus, there is a minimum soil resistance on blade. Blade movement in a conventional reel (Fig. 1b) involves a cutting angle change that leads to additional cutting resistance. Thus, additional soil crushing and movement it into the free furrow occurs that increases power consumption.

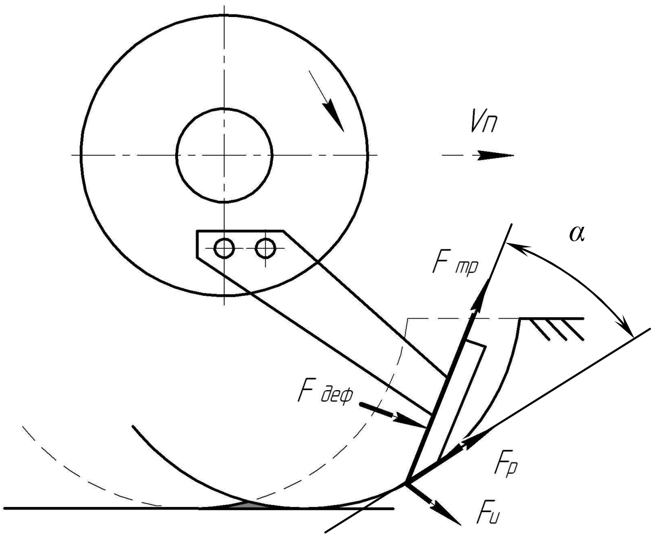


Fig. 2. Forces acting on blade

Analyzing a system of forces acting on the blade (Fig. 2) you can select the ones that have a significant impact on milling energy consumption.

Cutting force F_c, soil frictional force on blade $F_{fr,}$ force to deform cutting layer F_{def}, inertial force to drop the soil F_i (Fig. 2)

The magnitude of these enumerated powers varies greatly because of cutting angle α. Reducing the cutting angle, it is possible to reduce the cutting power of soil. There are three phases when cutter blade interacts with soil.

During the first phase, a blade, cutting into soil almost vertically, separates the most volume of cutting ground, which crumbles and falls into the furrow formed. During the second phase, a blade, while continuing to cut the remainder ground, interacts with soil, which fills a furrow milled. There can be two processes there, which are substantially different from each other. If blade angle is large, the soil accumulates before the blade, thereby increasing the cutter rotational resistance. If small angles are installed, the blade as direct sharp wedge moves through loosened soil, which spills over its upper bound. Deformation of soil in this case is insignificant; therefore, there is little resistance to cutter blade movement. The third phase is characterized by blade output of loosened soil. Blades with large and small angle positions interact with soil in different ways. Blade with large angle of installation throws the soil out of the furrow, therefore, it can be assumed that blade with a small installed angle, exiting loosened layer, will not take soil out.

Table 1 shows the specific design of milling machines both are using in today practice and perspective.

Cutter with constant cutting angle is in the first line, which is mass-produced and proved useful in limited soil areas tillage.

To ensure constant cutting angle G. F. Popov [4] designed an apparatus (Table 1) with cam reel cutters rotating. Blade rack, designed as a rocker, moves as eccentric by means of roller mounted thereon.

This changes the angle of cutting blade mounted on the other end of the rocker arm. Running around cam with roller, rocker arm is rotated, changing the angle of cutting blade. However, the design of such cutting reels proved to be much more complex than ordinary ones, which hinders their practical use.

We offer tillage cutter with variable angle of attack blade (Table 1) based on a synthesis of planetary mechanism. It runs using techniques adapted by L. T. Dvornikova and A. E. Sadieva [5, 6] to identify single linkage mechanism of any complexity together with gear train, which has been later modified by V.V. Dmitriev [6] into conversion method.

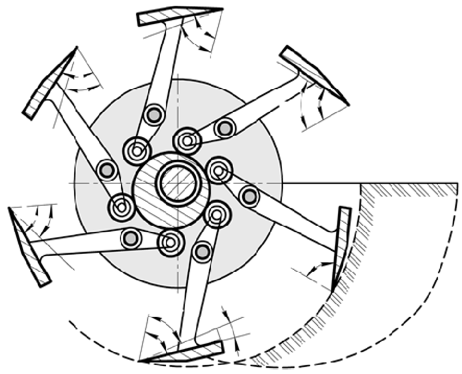
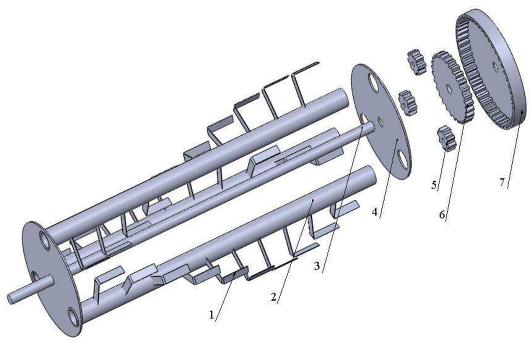
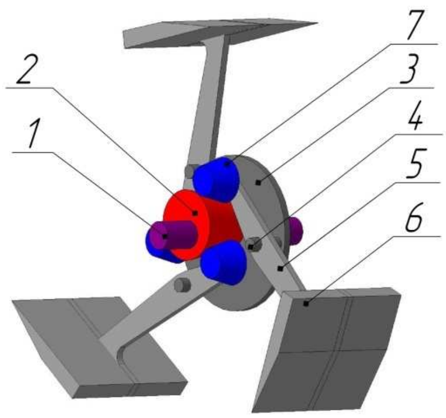
In such design a blade has path-trochoid way in soil layer. This effect is achieved by installing some milling cutters on cutter reel. It, using planetary gears, is rotated around the main cutter shaft. That is, while passing through the soil a blade is rotated around the major axis and reel cutter ones. Selecting gear diameters and angular velocity of cutter reeldepending on cutter forward speed, blade trochoid-movement with the optimal settingsin a certain location can be achieved. If a blade passes throughthe soil with optimal cutting angle, there is no soil friction and its increased buckling. That may be happened if the soil is milled with firmly mounted blade.

Such tillage cutters consists of three cuttingreels, which is fitted up with blades on a screw line with an equal pitch. Each blade has an individual length and edge angle. To simplify the design spiral cutter may be used. The disadvantage of this cutter is the complexity of the design, large metal content, manufacturing complexity and as a consequence it has light endurance. Moreover, it has advantages within the only operation mode.

To overcome these lacks we propose a variable-angle cutter under different operating conditions (Table 1). It retains a constant cutting angle regardless of tillage cutters translational velocity. To do this, their design contains, in contrast to the G.F. Popov’s cutter, additional conical roller. If modes are changed, conical eccentric moves downward or decreasing the diameter of the eccentric, thereby providing the desired cutting angle. For experimental study, a prototype of such a device was designed and built (Fig. 3).

Fig. 3. Multimode cutter

Table 1 – Patterns of tillage cutters

#	Name	Cutter design	Note
1	Cutters with rigidly mounted blade		Advantages: - Simplicity of design; - Reliability; - Low cost Disadvantages: - High energy consumption
2	GF Popov's cutter [4] with a constant cutting angle		Advantages: - low power consumption; Disadvantages: - design complexity, - Has an advantage for the only one cutting mode
3	Planetary cutter [5, 6] with changeable angle of attackof blade		Advantages: - High degree of soil crumbling; low power consumption. Disadvantages: - design complexity, - Single-mode operation
4	Multimode cutter with a constant angle cutting Mordovia NP Ogarev State University		Advantages: -possibility of use a predetermined cutting angle for different modes; -low power consumption.; Disadvantages: - design complexity

The main advantages of such design using are: 1) milling soil power consumption decreasing by reducing soil friction on blade; 2) increase in productivity due to increase in forward speed of cutter and lack of friction on the back of blade (is used for mounted cutters); 3) improving cutter stability by reducing the urging force; 4) reducing the height of the ridge; 5) maintaining a constant cutting angle regardless of cutter translational velocity.

Its disadvantages are design complexity and reducing of soil crumbling.

The use of tillage tools with constant cutting angle will reduce energy consumption for soil milling, also provides the necessary quality of soil loosening, including heavy and wet ones, while providing a translation of tillage machine.

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