# The impact of the grinding angle of the soil dredging tool on its performance

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**Abstract.** This investigation explores the optimization of the backhoe blade's entry angle, addressing its crucial role in enhancing energy efficiency and operational effectiveness in subsoil manipulation - a fundamental aspect of agricultural tillage technologies. Utilizing an integrated approach that combines detailed field experiments with robust theoretical simulations, the study methodically quantifies the effects of angular variations on energy demands and mechanical performance during soil dredging. Our results reveal precise angular configurations that offer optimal reductions in energy use while significantly improving the disruption and aeration of the subsoil layer. This optimization contributes directly to the development of advanced, precision-engineered agricultural implements aimed at boosting sustainability and productivity in farming practices. Furthermore, the outcomes of this research provide pivotal insights into soil health management strategies, potentially influencing crop yield through improved root penetration and water absorption. These findings are expected to serve as a benchmark for future innovations in agricultural machinery design, aligning with global trends towards more sustainable agricultural practices and enhanced food security. This study sets a new standard for agricultural tool engineering, paving the way for transformative changes in the sector.

## 1 Introduction

In the world, energy and resource efficiency is the most important issue in creating new agricultural techniques and technologies and improving existing machines. Taking into accountthat "more than 1.8 billion hectares of landarededicatedannually for the cultivation of variousagricultural crops worldwide" [1], one of the importanttasks is the development of high-qualityand productive and energy-resource-efficient tillagemachinesand devices is being counted. In this regard, greatattention is being paid to the development of plugsthat soften the subsoil at the same time as plowing. Some progress has been made in developed foreign countries in this direction, including the USA, Germany, the Netherlands, England, Italy, the RussianFederation, Belarus, Ukraineand other countries.

In the world, scientific research is being carried out for developing new scientific and technical bases of plugs that soften the subsoil at the same time as plowing the fields where

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agricultural crops are grown. In that direction, among other things, the development of soil deepening plugs simultaneously softens the subsoil at the same time,is gaining importancewhich have high work quality and productivity, economical energy resource , improved technological process, while plowing the land freed from agricultural crops.

As a result of fundamental reforms and deep structural changes in the agriculture of our republic, works are being carried out on the introduction of the creation of promising agrotechnologies for obtaining abundant and high-quality harvests from agricultural crops, their modernization, saving manual labor and resources, maintaining soil fertility and improving the efficiency of work.

In the Strategy of Actions on the five priority directions of the development of the Republic of Uzbekistan in 2017-2021, including "further improvement of the reclamation condition of irrigated lands for the modernization and rapid development of agriculture, development of networks of reclamation and irrigation objects, agriculture introduction of intensive methods, firstly, modern agrotechnologies that save water and resources, wide use of agricultural machinery with high productivity" [3] In the implementation of these tasks, it is of great importance to ensure high-quality plowing of land and energy resource efficiency due to the development of plows with improved working process.

This research work is based on the Decree of the President of the Republic of Uzbekistan No. PD-5853 dated October 23, 2019 "On approval of the strategy of agricultural development of the Republic of Uzbekistan for 2020-2030" dated July 31, 2019 -Decision No. 4410 "On measures related to the rapid development of agricultural machinery, state support for the provision of agricultural machinery to the agricultural sector" and other regulations related to this activity serves as a certain extent to the implementation of the tasks specified in the legislative documents [4, 5].

At present, in order to soften the layers under the earth, which contain gypsum, gravel and sand, handmade deep softeners of various constructions are used. This leads to increased consumption of labor, fuel and other operational costs and excessive soil compaction. Also, when processing through the existing working bodies with a deep softener, a secondary dense heel layer is formed in the soil. This, in turn, has a negative effect on the deep development of plant roots and high yield. Conducted literature analysis and research results show that the main soil treatment, i.e plowing, along with the softening of the subsoil in one pass of the aggregate, has been showing its effectiveness in the world experience. However, two-level PD-3-35 plugs equipped with deep softeners in the form of arc claws, designed for this high energy consumption technological process, have a number of technical and technological shortcomings which is not working. Also, our scientists have proven that a secondary dense heel layer is formed in the sub-soil layer when treated with arc-shaped plow softeners.

Currently, subsoil softening is carried out either before plowing or after plowing, together with loosening with two-tiered plows equipped with deep softeners and working bodies with deep softeners.

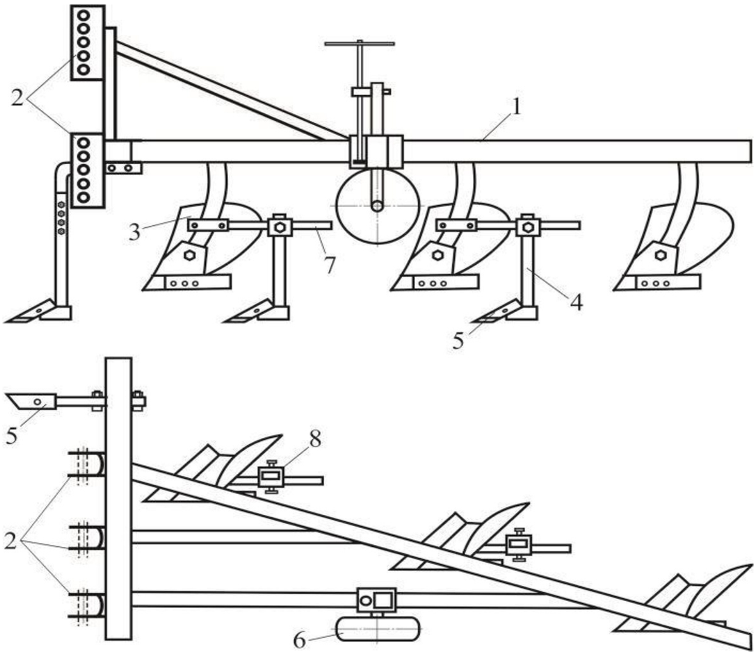
Based on the above, reducing the energy consumption of this process by improving the technological process of deepening the subsoil along with plowing is one of the urgent problems in the agricultural sector [5].

## 2 Materials and methods

In order to study this problem and solve the problem, a laboratory-field device was developed. The device was made in hanging version for assembly with 3-4 class tractors (MX-135, MXM-140, MXM-240, New Holland T7060).

Figure 1 shows the constructive scheme of the laboratory-field device,

Figure 2 shows its general appearance, and picture 3 shows it hanging on a tractor.




*1-frame, 2-hanging mechanism, 3-body, 4-soil deepener, 5-needle softener, 6-base wheel,7-longitudinal hammer, 8-crane*

**Fig. 1.** The experimental plug with a soil deepener.

Consists of a frame 1, a hanging mechanism 2, a body 3, a soil deepener 4, a needle softener 5, a base wheel 6, a longitudinal hammer 7 and a crane 8. and it is possible to change the longitudinal distance between the plug body and the soil dredging machine installed behind it, the distance between the soil dredging machine installed behind the tractor wheel and the first body of the plug, as well as the depth of the soil dredging operation (Figure 2)

**Fig. 2.** The appearance of soil deepener plug from the side.

**Fig. 3.** The appearance of soil deepener plug hanging on track.

Based on the results of theoretical studies, in the experiments, the angle of entry of the soil deepener into the soil was changed from 25° to 40° in 5° intervals while maintaining its lifting height, its width was 70 mm, and its length was 15 cm. The speed of the unit was 6, 0 and 8.0 km/h were accepted [6-10].

The results of the experiments are presented in Table 1 and Figure 6.

The data presented in Table 1 and Figure 5 show that increasing the α angle from 25° to 30° at both movement speeds of the aggregate improved the quality of soil compaction, and increasing it from 30° to 40° led to deterioration of this indicator. This can be explained by the fact that the size (step) of the pieces separated from the soil under the influence of the working body changes depending on the angle α. When α=30°, the size of the slices may have a minimum value.

**Table 1.** The results of experiments based on learning entry angle of the soil deepener into the soil.

| **T/r** | **Indicators names** | **The value of indicators** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **The entry angle of work, °** | | | | | | | |
| | | **25** | | **30** | | **35** | | **40** | |
| | | **Movement speed of aggregate, km/h** | | | | | | | |
| | | **6** | **8** | **6** | **8** | **6** | **8** | **6** | **8** |
| 1 | Depth of treatment, km/h | | | | | | | | |
| | $M_{o'r}$ | 15.0 | 14.8 | 15.2 | 15.3 | 14.9 | 15.0 | 14.7 | 14.8 |
| | $\pm\sigma$ | 1.18 | 1.04 | 1.24 | 1.43 | 1.17 | 1.11 | 1.30 | 1.24 |
| 2 | Sizes (mm) the amount of fraction, % | | | | | | | | |
| | >100 | 5.9 | 5.5 | 4.6 | 4.5 | 4.7 | 5.7 | 8.2 | 7.8 |
| | 100<50 | 16.8 | 15.3 | 13.6 | 11.6 | 15.5 | 12.6 | 16.2 | 14.8 |
| | <50 | 77.3 | 79.2 | 81.8 | 83.9 | 79.8 | 81.7 | 75.6 | 77.4 |
| 3 | Traction resistence,kN | 0.80 | 0.96 | 0.74 | 0.86 | 0.78 | 0.91 | 1.00 | 1.24 |

Increasing the speed of the unit from 6 km/h to 8 km/h has led to the improvement of the quality of soil conditioning.

Changing the tiller angle in the range of 25-40 degrees did not significantly affect the working depth.

The traction resistance of the work changed depending on the angle of soil tilting in the form of a concave parabola, i.e. it decreased at an angle of 25-30° and increased at an angle of 30-40°.


**Fig. 4.** Excavators with different angles of soil penetration (au).

This can be explained by the fact that the size of the pieces coming out of the soil under the influence of the hammer decreases, and the amount of energy used to break it down decreases, while the size of the pieces increases, and the amount of energy increases.

## 3 Results and Discussion

The degree of soil compaction, namely the fraction of soil particles smaller than 50 mm, and the variation of the body's resistance to gravity depending on the angle of soil tilting, can be expressed by the following empirical equations [11-22]:

a) when the movement speed of aggregate was 6.0 km/h

$$F_{<50} = -5.935 + 5.513\,\alpha_i - 0.087\,\alpha_i^2.\ \%\quad (R^2 = 0.9587) \tag{1}$$

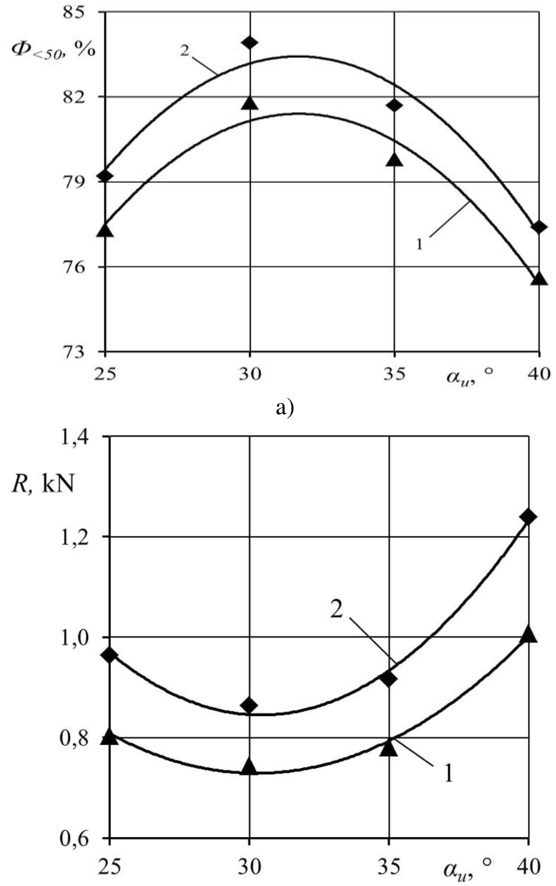
$$R = 3.3513 - 0.1734\,\alpha_i - 0.00287\,\alpha_i^2.\ \text{kN}\,(R^2 = 0.9716) \tag{2}$$

b) when the high speed of aggregate was 8.0 km/h:

$$F_{<50} = -6.76 + 5.698\,\alpha_i - 0.09\,\alpha_i^2.\ \%\qquad (R^2 = 0.9526) \tag{3}$$

$$R = 4.7608 - 0.2575\,\alpha_i + 0.00423\,\alpha_i^2.\ \text{kN}\,(R^2 = 0.9309) \tag{4}$$

$\alpha_i$ –the entry angle of soil deepener
$\alpha_i$= between 25° and 40°).




*1,2- speed of work 6 and 8 km/h*

**Fig. 5.** Graphs of changes in the soil insulation quality F (a) and the resistance of the device R (b) depending on the angle of soil tilting.

## 4 Conclusion

After extensive research on expressions (1)-(4) which denote the drag resistance of the earthmoving machine [6-7], it was established that the optimal angle for the base of the earthmoving machine should range between 30°40’ and 33°25’. This adjustment ensures the attainment of both maximum and minimum values of soil digging resistance.

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