Development of an adjustable safety lock with glass and plastic rods used for a reversible plow

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Abstract. The article deals with a design of the adjustable lightweight safety device made from composite materials and used for reversible plows. Initially, a design scheme was developed. It was theoretically and experimentally investigated. Research was conducted by the Department of Tractors and Agricultural Machines of the Gorsky State Agrarian University. As a result, software was developed. It is used to determine rational values of the main parameters of the safety lock. The following values of the parameters were obtained: the diameter of fiberglass rods \( d_r = 16 \) mm; the rod length \( l_r = 0.85 \) m; the number of rods \( n_r = 16 \) (8 in each spring); the height of the center of the stop \( e = 0.15 \) m; the radius of the crank \( r_r = 0.12 \) m; the rod length \( l_r = 0.25 \) m; the initial value of the angle of crank rotation \( \alpha_{cro} = 30 \ldots 700 \). During the laboratory experimental studies, using the strain gauging method, we studied a change in the traction resistance of a section when it is deepened, and reliability of obstacles of various heights. The traction resistance was 7800 ... 11600N, which is sufficient to ensure reliable operation of the plow section in the North Caucasus region. In all experiments, a decrease in the traction resistance was observed when the section returned after deepening to its original position, which was caused by the gravity section and hysteresis losses in the composite rods. Field tests of the upgraded model of the reversible plow PON-3 confirmed high efficiency of the safety lock design.

1. Introduction

Despite the fact that the plow is the oldest agricultural machine, its design is being studied and improved [1–5]. However, in order to ensure high quality of treatment of stone-clogged soils, the elements of the plow sections must have certain parameters [6]. To prevent breakdowns, each section should be equipped with a safety lock. Safety locks with fiberglass rods ensure good performance of driven-type plows [7]. fiberglass rods and springs are studied by many authors [8–10]. All researchers confirm efficient physical and mechanical characteristics of elastic elements made of composites. In safety devices of reversible plows, elastic elements made from composites are not used. Therefore, the development of such a device is a relevant issue.

2. Section scheme for a reversible plow with an adjustable fuse with rods made from composites

A diagram of the section with the adjustment mechanism is shown in Figure 1. The bed of section 1 resting on the upper and lower supports 2 is held on the support bracket by hinge 3 with central link 4 and arm 5, which is connected to cranks 8 of elastic links 9 by means of symmetrical connecting rods and hinges 7 of elastic links 9.
Rear cranks of elastic elements are mounted on the bed with hinge joints 10 symmetrically to each other and connected by axes to bracket 11. The safety device can be adjusted by linear movements of the axes of cranks 12 with bracket 11 along the axis of the bed by means of movements of bilateral nut 13 by threaded screw 14 connected to the bed by transverse hinge 15.

![Diagram](image)

**Figure 1.** Scheme of the section of a reversible plow with a spring-type safety lock with a crank-slide mechanism: 1 – section bed; 2 – upper and lower supports; 3 – joint; 4 – center link; 5 – bracket; 6 – symmetrical connecting rods; 7 – joint; 8 – crank; 9 – elastic links; 10 – front spring supports; 11 – crank bracket; 12 – support crank spikes; 13 – persistent bilateral nut; 14 – tension bolt; 15 – way hinge; 16 – body plow.

When plow body 16 meets the stone, ridges 1 rotates relative to upper support 2. Central link 4 compresses and bends composite elastic links 7 through connecting rods 6 and cranks 8. After the obstacle has been passed, the system returns to its original position.

3. **Methods**

All studies were conducted by the Department of Tractors and Agricultural Machines of the Gorsky State Agrarian University. Theoretical studies were carried out using methods of theoretical mechanics, taking into account the results of the study of fiberglass rods and previously obtained data [2]. Their main goal was to determine rational parameters of the safety system, providing the most favorable change in traction resistance of the plow section during the bypass of the obstacle.

Experimental studies were carried out in laboratory and field conditions. We used a special stand and a MTZ-80 tractor with a universal testing machine. The diameter of the rods varied within 0.016 ... 0.018 m, the length was 0.85 ... 1.05 m, the angle of crank inclination was 40 ... 700. All sensors and the electronic dynamo meter were calibrated.

4. **Results and discussion**

A method for calculating an adjustable safety system, a program in the MS Excel shell were developed and calculations were made. More than 100 different options were analyzed. Based on our calculations, we chose a design with the following parameters: the rod diameter \(d_r = 16\) mm; the rod length \(l_r = 0.85\) m; the number of rods \(n_{pcs} = 16\) (8 rods in each spring); the height of the center of the stop \(e = 0.15\) m; the radius of the crank \(r_{cr} = 0.12\) m; the length of the connecting rod \(l_r = 0.25\) m; the initial value of the angle of rotation of the crank \(\alpha_{cr} = 30\) ... 700. An increase in traction resistance at which the plow body began to deepen with a decrease in the angle of the crank from 700 to 400 = 3.8 kN.
Experimental studies were conducted to study the traction resistance of a plow section equipped with a developed safety device. Figure 2 shows the oscillograms of changes in traction resistance depending on the deepening of the section.

![Figure 2](image-url)

**Figure 2.** Experimental dependences of the force change on the plow body deepening when dynamizing the section with connecting rods at an initial installation angle of crank links (450) and the number of rods n = 16.

In all experiments, a decrease in traction resistance was observed when the section returned to its original position. This is due to the gravity of the section and hysteresis losses in the composite rods.

Table 1 summarizes experimental results.

| Angle of installation of crank-spikes, degrees | The force on the plow toe at a depth of 0.01m Loading, N | Unloading, N |
|----------------------------------------------|------------------------------------------------------|--------------|
| 70                                           | 7800...8200                                          | 6000...6400  |
| 65                                           | 8000...8500                                          | 6000...6600  |
| 60                                           | 8500...9300                                          | 6400...6600  |
| 55                                           | 8600...9400                                          | 6400...6600  |
| 50                                           | 9200...9600                                          | 6400...6800  |
| 45                                           | 9600...1050                                          | 6600...6800  |
| 40                                           | 10800...11600                                        | 7100...7600  |

An increase in the values of the effort with a change in the crank angle from 70 to 400 can reach 3.8 kN, which is quite sufficient for reliable operation of the plow in various conditions of the North Caucasus region. In the process of deepening by up to 0.35 m, the traction resistance can reach 9600...11800N, that is, it changes insignificantly with respect to the value of traction resistance at which the process of deepening begins.

The comparison of experimental and calculated data revealed a divergence within 5%.

We checked the reliability of the safety device when hitting an artificial obstacle at different speeds.

At the next stage, we upgraded the PON-3 plow, having installed safety systems made from composite materials (Figure 3). The last section of the plow was equipped with an adjustable safety device.
Figure 3. Upgraded PON-3 plow

We tested the PON-3 plow on stony soils of the Gorsky State Agrarian University. The safety system ensured a reliable bypass of stones. It was easily adjusted to specific operating conditions, which made it possible to reduce stone turning to the surface when working on soils with low hardness values and dry soils.

5. Conclusion

An effective design of the adjustable safety lock with rods made from composite materials was developed for reversible plows used on stone-clogged soils. The rational values of the main parameters of the safety lock were determined.

The patterns of traction resistance of the upgraded section of the reversible plow were studied during deepening. It was established that the safety lock can be adjusted within 7.8 ... 11.6 kN.

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