Pilot installation for applying protective coating on the surface of the agricultural equipment

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Abstract. Agricultural machinery is operated in difficult conditions and severe environment. Due to contact with road surfaces, soil, plants, fuels and lubricants, as well as fertilizers and pesticides, when changing temperature conditions and under the influence of a number of other factors, surfaces of agricultural machinery become old and corroded, which reduces their performance and worsens some of its parameters. Most agricultural machines are operated from 10-15 to 55-60 days during the year, and for the remaining time, they are subject to high-quality storage. During long-term storage, the dimensions of parts change due to corrosion, as well as the quality of their material decreases due to structural transformations and residual deformations caused by the machine’s own weight. Efficiency and its service life can increase by 10-15% due to the application of a protective coating on the surface of agricultural machines, which reduces the influence of external factors on their safety. The use of a developed spray gun in the design of a hydraulic installation for applying a protective coating on the surface of agricultural machinery allows one to reduce unit costs by 13.8% and electricity costs by 12.3%. The economic effect of using a hydraulic coating system with the developed spray gun will amount to 75,539.3 rubles per year when processing 124.9 m² of agricultural machinery surface.

1. Introduction
Currently, Russia is implementing the State Program for the Development of Agriculture and the Regulation of Agricultural Products, Raw Materials and Food Markets for 2013-2020. This problem cannot be solved without the widespread use of modern agricultural machines, the peculiarity of which is seasonal operation. Agricultural machinery is operated in difficult conditions and severe environment. Due to contact with road surfaces, soil, plants, fuels and lubricants, as well as fertilizers and pesticides, when changing temperature conditions and under the influence of a number of other factors, surfaces of agricultural machinery become old and corroded, which reduces their performance and worsens some of its parameters. Most agricultural machines are operated from 10-15 to 55-60 days during the year, and for the remaining time, they are subject to high-quality storage. During long-term storage, the dimensions of parts change due to corrosion, and the quality of their material decreases due to structural transformations and residual deformations caused by the machine’s own mass. Efficiency and its service life can increase by 10-15% due to application of a protective coating on the surface of agricultural machines, which reduces the influence of external factors on their safety [1–4].
Improving the quality of storage of agricultural machinery when seasonal use is relevant for all farms in the agricultural sector of Russia [5, 6].

The widespread use of protective coatings dictates the need to improve the technology of their application. Existing methods of applying a protective coating before storage make it possible to achieve high performance in compliance with the quality indicators of the applied layer. This operation is performed manually or pneumatically in most cases. It is possible to increase the storage efficiency of agricultural machinery by applying a protective coating hydraulically. At the same time, it is necessary to improve the devices for its application and justify their parameters, which reduce the cost of labor and funds for applying a protective coating, which proves the relevance of this area of scientific research [7–10].

Thus, justification of parameters of the installation for applying a protective coating in a hydraulic manner, increasing the uniformity of application on the surface of agricultural machines, is an important national economic task.

2. Materials and methods

High-quality preparation of the surfaces of machines and their components for storage is achieved by a set of equipment and mechanisms that ensure proper preparation of equipment for storage. To solve the current situation and ensure the preparation of equipment for storage, constructive-technological schemes of guns for applying a primer to the surface have been developed. A model of one of possible spray guns was implemented in a pilot installation by employees of TET Department and is presented in Figure 1 (utility model patent No. 147131, published 10.27.2014, Bull. No. 30).

![Figure 1. The designed spray gun](image)

To conduct laboratory investigations, a pilot installation was created (Figure 2) with main parameters, the possibility of changing the parameters within the limits that affect the quality indicators of the application and distribution of the protective coating on the surface of the object. A chamber is proposed for applying protective coatings to a sample (Figure 3).

The pilot installation includes pumps 5 with electric motors with the possibility of regulating the working pressure (Figure 2); tanks for liquid primer material 1; high pressure tanks 2; power (pressure) regulators with an electric network breaker 4.

The principle of operation of the installation with a pump and a pressure regulator is as follows. The installation pump draws liquid primer material from the tank, feeds it along the highway to the high pressure tank and to the working body. When a predetermined pressure is pumped in the tanks supplying the mains, the circuit breakers are activated, the pumps turn off and the pressure is kept at a certain level in the tanks. When applying a protective coating, the pressure drops and the pumps turn on. Each pump operates separately in its own system of mains and pressure tanks.

The developed spray gun was used for the application of protective coatings, as well as for testing nozzles with various diameter sizes (Figure 4).
Figure 2. The pilot installation: 1 – containers with primer material; 2 – high pressure tanks; 3 – manometers; 4 – power (pressure) regulators with an electric network breaker; 5 – high pressure pumps with electric motors

Figure 3. The coating chamber: 1 – high-pressure feed lines; 2 – chamber body; 3 – platform that allows one to change the position of the spray gun; 4 – ruler; 5 – platform for mounting the sample; 6 – spray gun

Figure 4. Nozzles for the developed spray gun

The proposed design ensures the operation of the gun in the following modes: with alternately open transport channels and with two simultaneously open transport channels. Thus, one can use two different materials separately or a two-component mixture.
3. Results and discussion

As a result of the field studies of the installation of hydraulic deposition of protective coatings on the surface of agricultural machinery by the developed spray gun, the graphical dependencies of changes in the influence of the nozzle diameter of the developed installation on the productivity of the installation (Figure 5), as well as the change in the productivity of the developed installation on the speed of the nozzle relative to the surface of agricultural machinery (Figure 6) are presented.

These graphical dependencies confirm the results of previous theoretical studies and show that when the nozzle diameter of the spray gun is in the range from 1.0 to 1.1 mm, the rational performance of the hydraulic unit is ensured when a sufficient protective coating of 0.02 mm on the surface of agricultural machinery is applied, since a further increase in the thickness of the protective coating reduces its adhesion to the surface and contributes to the delamination of the protective coating.

![Figure 5](image1.png)

**Figure 5.** The dependence of the change in productivity of the developed installation on the nozzle diameter of the developed spray gun at a pressure of 21.75 MPa

![Figure 6](image2.png)

**Figure 6.** The dependence of the change in productivity of the developed installation on the speed of the nozzle relative to the surface of agricultural machinery
When applying a protective coating to the surface of the equipment, as a rule, three types of coatings are used: single-layer, two-layer and three-layer ones. Data on the approximate thickness of various layers for different types of protective coating are presented in Table 1. Depending on the type of damage, partial, external or complete application of protective coatings to the surface of the equipment is assigned.

Table 1. Approximate coating thickness when applying a protective coating

| Material                             | Type of coating | single-layer | two-layer | three-layer |
|--------------------------------------|-----------------|--------------|-----------|-------------|
| Base coat                            | 20-100 μm       | 20-100 μm    | 20-100 μm |
| Base enamel (color base)             | -               | -            | 10 μm     |
| Enamel                               | 50 μm           | 20 μm        | 20 μm     |
| Lacquer                              | -               | 50 μm        | 50 μm     |

Estimated indicators of the process of applying a protective coating to the surface of equipment of brands: MTZ80, KamAZ-55102 and Rostselmash AKROS 530 are shown in Figure 7 as the cost per square meter of the treated area (surface) of the equipment using the following spraying options: by hydraulic spraying with a standard spray gun and the pilot installation spraying with the developed spray gun.

Figure 7. Unit costs of protective coating on machinery surface

Figure 8. Change in specific energy consumption when applying a protective coating to the surface of
the machinery

As can be seen from the graphical dependencies reflected in Figure 8, the values of the specific energy consumption of the pilot installation, when applying a protective coating to the surfaces of agricultural machines, are reduced by 12.3% when compared with a hydraulic installation with a standard spray gun for applying liquid materials.

Costs are determined by formula 1:

\[ C = S_{total} \times O \times UC \]

where \( S_{total} \) is the total coated area of agricultural machinery, \( m^2 \); \( O \) is the annual installation operation, \( h \); \( UC \) is unit costs for processing 1 \( m^2 \) of agricultural machinery surface, \( rubles/m^2 \).

Then for the basic installation, the costs will be:

\[ C = 124.9 \times 168 \times 26.02 = 545,982.86 \text{ rubles} \]

For the new installation, the costs will be:

\[ C = 124.9 \times 168 \times 22.38 = 470,443.34 \text{ rubles} \]

The annual economic effect will be:

\[ E_a = 545,982.64 - 470,443.34 = 75,539.3 \text{ rubles} \]

The developed installation will pay off in 1.78 years.

4. Conclusion

The use of the developed spray gun in the design of a hydraulic installation for applying a protective coating on the surface of agricultural machinery allows reducing the specific costs of applying a protective coating by 13.8% and the cost of electricity by 12.3%. The economic effect (the total one from applying a protective coating to the surface of equipment of brands: MTZ 80, KamAZ-55102 and Rostselmash AKROS 530) from the use of a hydraulic installation for applying a protective coating to the surface of agricultural machinery with the developed spray gun will amount to 75,539.3 rubles per year when processing 124.9 \( m^2 \) of agricultural machinery surface.

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