Methodology and results of comparative atmospheric tests of experimental conservation composition

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Abstract. The article presents the results of full-scale comparative tests of various protective compositions, for which the Movil car preservative, Litol-24 grease, PVC grease, K-17 preservation oil, experimental preservation compound (EKS-1) were used. The objects of conservation are steel plates of grades U8, 65G, 45, 40X, and St3. After the tests, etching, weighing, measuring the surface roughness of the samples were performed, and metal losses were determined. Tests of EKS-1 show protective efficacy comparable to that of greases, and in some cases, it significantly exceeds it. It is proved that the area of corrosion and metal loss during the test of the composition on these materials was not more than 4.7 % and 5.3 g/m² per year, respectively. The research results show that the use of the protective composition EKS-1, due to its manufacturability, significantly reduces the complexity of work during the conservation of agricultural machinery, as well as ensures the protection of metal products during both short-term and long-term storage.

1 Introduction

Environmental exposure has an aggressive effect on agricultural machinery during storage, and electrochemical corrosion begins to develop on its surfaces. Corrosion processes reduce fatigue strength, provoke the formation of microcracks, which can subsequently lead to a loss of working capacity by the technique. There are many technical solutions to protect equipment from corrosion. The most common solution is to use protective coatings. The addition of corrosion inhibitors can significantly improve the effectiveness of protective coatings. During the operation of agricultural machinery, as well as during storage, it is affected by various aggressive environments. In particular, aggressive media include the juice of plant residues of transported goods, mineral or organic fertilizers, precipitation, and much more. These substances reduce the durability of the paint film, which leads to the development of corrosion processes on the surfaces of parts of the working bodies of machines.

The situation also becomes aggravated by the presence in the design of machines of such compounds in which corrosion processes can proceed most actively: welded, threaded, butt, and other types of machines. The corrosion process in these areas provokes the formation of microcracks, which leads to the destruction of the joints and, as a consequence, the loss of machine performance [1, 2].

The presence of moisture on the working bodies surfaces of machines also leads to the development of corrosion processes. In this case, a moisture film on the surface equipment, which formed in the process of dew or precipitation, absorbs various contaminants and gases from the atmosphere of the surrounding air. As a result, a moisture film on the surface of the technique acquires the properties of an electrolyte, and corrosion processes begin to develop under it. Besides, the chemical heterogeneity of the metal also affects its carozine processes [1].

All of the above leads to huge irreversible metal losses, which globally annually exceed 2.5 trillion dollars. The fight against metal corrosion in developed countries is an expense equal to 4 % of GDP [3].

Thus, an important task from a scientific and practical point of view is the development of highly effective means of corrosion protection, as well as technical means for their preparation and application.

Many modern technologies ensure high safety of agricultural machinery from corrosion during storage. Such technologies include the use of individual sealed shelters [4], protective heat shields [5], the use of tread protection based on compositions containing zinc powder [6], the improvement of washing and cleaning of parts in preparation for storage [7] and other technical solutions [8, 9].

At the same time, the development of anti-corrosion compounds that are capable of forming resistant protective films on the surfaces of metal parts is a
priority in the research of domestic and foreign scientists [10–12].

One of the ways to protect agricultural machinery from corrosion is the use of bitumen and fuel oil compositions. Improving the protective properties of agricultural machinery is due to the addition of the corrosion inhibitor Emulgin [13]. Improving the protective properties of fuel oil compositions occurs due to the introduction of KO-SGK and cannon fat into the composition [14, 15]. These compositions are characterized by high adhesion to metal and excellent anti-corrosion properties.

There are developments to improve the anti-corrosion properties of used oils, which often cover the working damage of agricultural machinery [16]. Inhibitors Mobin-3, Emulgin, POOM significantly increase the protective properties of agricultural machinery [17].

The task of protecting the building structures of livestock buildings has led a team of domestic scientists to develop a volatile inhibitor of the IFK Han series. The IFK Han series volatile inhibitor effectively prevents corrosion of low-carbon steels operating in an atmosphere with high humidity and saturated with aggressive gases [18, 19].

The developer team focused on the task of creating environmentally-friendly and natural corrosion inhibitors. This task is associated with the research of scientists from around the world [20]. In particular, the authors presented are interested in successful studies to determine the protective ability of inhibitors obtained from plant materials of natural origin [21–23], as well as their mixtures [24].

Besides, work continues improving coatings based on polymers [25, 26] and epoxies, by replacing zinc chromates with more non-toxic zinc phosphate [27] in the latter or by adding graphene oxides [28].

There is a description of "smart" anticorrosion coatings [29]. "Smart" anti-corrosion coatings are obtained by enclosing corrosion inhibitors in so-called nanocontainers. This technology makes it possible to achieve its more efficient and economical use.

The analysis of the above literature sources shows that the use of corrosion inhibitors both separately and as part of complex compositions significantly enhances the protective ability of anticorrosion compounds, which encourages scientists to search for cheaper and more affordable components for their manufacture [30, 31].

2 Materials and methods

Atmospheric tests based on Open Joint-Stock Company «Plodopitomnik» Lyskovsky district of the Nizhny Novgorod region were associated with several tasks:

- verification of the protective properties of the experimental preservation composition made based on the developed inhibitor [32],
- comparing it with the most common preservative formulations used for treatment surfaces stored in open areas.

The studied samples are the metals most often used in the manufacture of working bodies and other parts of agricultural machinery, such as steel U8, 65G, 45, 40X, and St3. The characteristics of the samples were determined before testing (Table 1).

Pre-weighed and polished to a roughness of Ra 0.63, plates of size 150x100 were processed with the following compositions:

- Auto preservative "Movil" TU 2384-148-04001396-2006;
- Litol-24 greasing GOST 21150-87;
- Preservative "Cannon Lard" TU 0254-003-15301184-2004;
- Preservation oil K-17 GOST 10877-76;
- Experimental preservation composition EKS-1 (17 % inhibitor in vegetable sunflower oil).

| Compositi on | The total area of the processed samples, m² | The mass of the processed samples, gr |
|--------------|------------------------------------------|-------------------------------------|
|              | U8          | 65G   | 45 | St3 | 40H |
| Movil        | 0.0753      | 394.1 | 8  | 272.4 | 6  | 487.3 | 8  | 457.8 | 7  | 471.1 |
| K-17         | 0.0752      | 416.3 | 9  | 282.0 | 6  | 491.8 | 7  | 460.8 | 5  | 462.9 |
| Cannon Lard  | 0.0751      | 276.6 | 7  | 393.2 | 5  | 430.1 | 8  | 456.6 | 9  | 463.8 |
| Litol 24     | 0.0754      | 420.2 | 8  | 280.5 | 1  | 491.3 | 1  | 187.0 | 5  | 429.2 |
| EKS-1        | 0.0752      | 411.8 | 8  | 305.2 | 6  | 498.0 | 8  | 456.5 | 7  | 474.5 |

For weathering tests, samples treated with protective compounds were fixed at an angle of 45° on a corrosion stand located in an open area (Fig. 1). Tests of all processed samples were carried out continuously, starting from November 2018 for 12 months.

A layer of a protective coating was removed from the surface of the samples by dipping into a solvent (gasoline of the brand Regulator-92 (AI-92)) to determine the corrosion losses and the area of metal damage. Then the samples were weighed. A grid with a mesh size of 5 × 5 mm was superimposed on the samples, and the area of corrosion lesions and darkening of the surface were calculated. The foci of corrosion smaller than 3 mm² were considered individually for each plate.

Then, corrosion products were removed from the surface of the samples by etching in a solution of NaCl (30 g) + H₂SO₄ (200 g) per liter of distilled water at a temperature of 23°C for 60 minutes (Fig. 2). The samples were washed with water, treated with acetone, and weighed on a laboratory balance VLKT-500-M.

The change in roughness from the initial Ra 0.63 was determined using the model 170622 profilometer (Fig. 3). The measurements were carried out separately for each sample by measuring five times along two axes.
of the same plane at arbitrary points and averaging the obtained values.

3 Results

The following parameters were important for assessing the protective properties of the compositions: the area and the number of corrosion centers, changes in surface roughness, and metal loss. The results of measurements of the area of corrosion damage were obtained (Table 2 and Fig. 4).

Table 2. Corrosion surface area of samples, %

| Composition | Steel grade | U8  | 65G | 45  | St3 | 40H |
|-------------|-------------|-----|-----|-----|-----|-----|
| Movil       |             | 9.72| 12.64| 16.17| 23.13| 6.74|
| K-17        |             | 82.67| 87.7 | 78.15| 96.84| 90.65|
| Cannon Lard |             | –   | 2.57 | 7.18 | 8.54 | –   |
| Litol 24    |             | 6.75| –   | 11.13| 8.34 | 5.11|
| EKS-1       |             | 4.71| 3.54| –   | –   | 2.56|

Fig. 4. Corrosion surface area of samples

Data analysis (Table 2) shows the following results:

• when using the experimental composition EKS-1 on samples of steel 45 and St3, the corrosion area is close to zero;

• when protecting specimens from U8 and 40H plates of steel, the composition was inferior only to cannon fat.

At the same time, when protecting a specimen made of 65G steel, EKS-1 showed good results comparable with the protective properties of greases and significantly exceeding the Movil and K-17 compounds. It should be noted that for a comprehensive assessment, it is necessary to take into account the number of corrosion centers that originate in local areas. Corrosion in local areas further provokes and enhances the development of surface corrosion. The results of measurements of the number of corrosion centers were obtained (Table 3 and Fig. 5).

Table 3. The number of foci of corrosion, pieces.

| Composition            | Steel grade | U8 | 65G | 45  | St3 | 40H |
|------------------------|-------------|----|-----|-----|-----|-----|
| Movil                  |             | 134| 72  | 82  | 34  | 51  |
| K-17                   |             | 41 | 23  | 46  | –   | –   |
| Cannon Lard            |             | 18 | 24  | 42  | 28  | 24  |
| Litol 24               |             | 22 | 16  | 14  | 31  | 37  |
| EKS-1                  |             | 47 | 35  | 42  | 12  | 51  |
The data obtained indicate that, despite the small corrosion area of the test samples treated with the composition EKS-1, the number of corrosion centers is quite large. Continuous corrosion begins to nucleate in the foci of occurrence but does not actively develop on the surface. Presumably, this can be explained by the “tears” of the protective film obtained on the metal surface due to atmospheric precipitation. However, the inhibitor continues to perform its function along the edges of the gap, and therefore no further development of corrosion on the metal surface occurs.

Fig. 5. The number of centers of corrosion on the surface of the samples

The value “zero” on samples of steel St3 and 40H coated with composition K-17 (Table 3 and Fig. 5) indicates that, due to continuous corrosion of the surface, the number of foci was not calculated. The degree of depth of metal damage can be indirectly estimated by the change in surface roughness (Table 4 and Fig. 6).

Table 4. Change in surface roughness of samples from the initial Ra0.63, microns

| Composition   | Steel grade |
|---------------|-------------|
|               | U8 | 65G | 45 | St3 | 40H |
| Movil         | 0.684 | 0.672 | 0.676 | 0.655 | 0.648 |
| K-17          | 0.756 | 0.717 | 0.736 | 0.754 | 0.738 |
| Cannon Lard   | 0.684 | 0.676 | 0.680 | 0.661 | 0.658 |
| Litol 24      | 0.658 | 0.648 | 0.651 | 0.642 | 0.644 |
| EKS-1         | 0.646 | 0.651 | 0.639 | 0.635 | 0.641 |

Fig. 6. Change in surface roughness of samples

As can be seen from the graph, the composition of EKS-1 in almost all steels surpasses the rest of the protective compositions. That is, despite the numerous formation of foci of corrosion, their depth is insignificant, which practically does not lead to a change in the surface roughness of the protected metal. The results of the change in metal losses during the year are obtained (Table 5 and Fig. 7).

The test results show that when applying St3 and 45 steel samples to the surface, metal losses amount to 2 g/m² per year, which exceeds the performance of all the compositions involved in the experiment. When protecting specimens from U8 and 40H plates of steel, the experimental composition is second only to cannon fat, and in the case of 65G steel only to Litol-24, which indicates its high efficiency.

Table 5. Loss of metal, g / m²

| Steel grade | U8 | 65G | 45 | St3 | 40H |
|-------------|----|-----|----|-----|-----|
| Movil       | 14.7 | 12.7 | 18.7 | 27.3 | 12 |
| K-17        | 18.7 | 15.3 | 22.7 | 36.7 | 35.3 |
| Cannon Lard | 4.8 | 7.3 | 11 | 10.7 | 1.3 |
| Litol 24    | 7.4 | 2.7 | 12 | 9.3 | 4.5 |
| EKS-1       | 5.3 | 4.6 | 1.7 | 1.9 | 3.6 |

Fig. 7. Annual metal loss

4 Conclusion

The research results show that the use of the protective composition EKS-1, due to its manufacturability, significantly reduces the complexity of work during the conservation of agricultural machinery, as well as ensures the protection of metal products during both short-term and long-term storage.

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