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Development of Technology to Protect the Surfaces of Military Equipment from Aggressive Environmental Factors and Operating Conditions

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Abstract

All types of military equipment (VT), operated at maximum operating loads and in various climatic zones, are subject to premature wear, corrosion of metal surfaces and destruction of rubber products that ensure tightness and sealing of working bodies in various subsystems (nodes and aggregates) and elements from their penetration into other environments. Based on the above, the main areas of research are: development of technology and equipment for the preparation of surfaces of subsystems of VT and the application of anticorrosive protection on them; improvement of the technology of restoration of elements of subsystems of military equipment, after changing their parameters and characteristics during operation.

Keywords: *military equipment, system, surface, technology, subsystem, protective coatings, aggressive factors, operating conditions.*

1. Introduction

In accordance with regulatory documents, the life cycle of any type of VT includes six stages: research, development, production, operation, overhaul and disposal. During the life cycle of military vehicles, the stages of "operation" and "overhaul" (CR) are the main ones in ensuring their constant combat readiness. Each of the above-mentioned stages of the life cycle of VT includes special stages and operations, which they are fully characterized by [1].

So, for example, the operation of a VT is understood as a stage of its life cycle, which is a set of the following stages: commissioning, bringing to a certain degree of readiness for use for its intended purpose, maintaining a certain degree of readiness for use, use for its intended purpose, storage and transportation.

2. Literature review and problem statement

The CRT stage is performed to eliminate malfunctions and achieve the required or close to full resource with the replacement or restoration of any of its subsystems or elements, including components and assemblies that are basic. KR VT includes the following stages: acceptance and inspection of technical condition; disassembly and defect of

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components and parts; repair; assembly and adjustment; running-in, commissioning and testing; painting and commissioning (Figure 1).

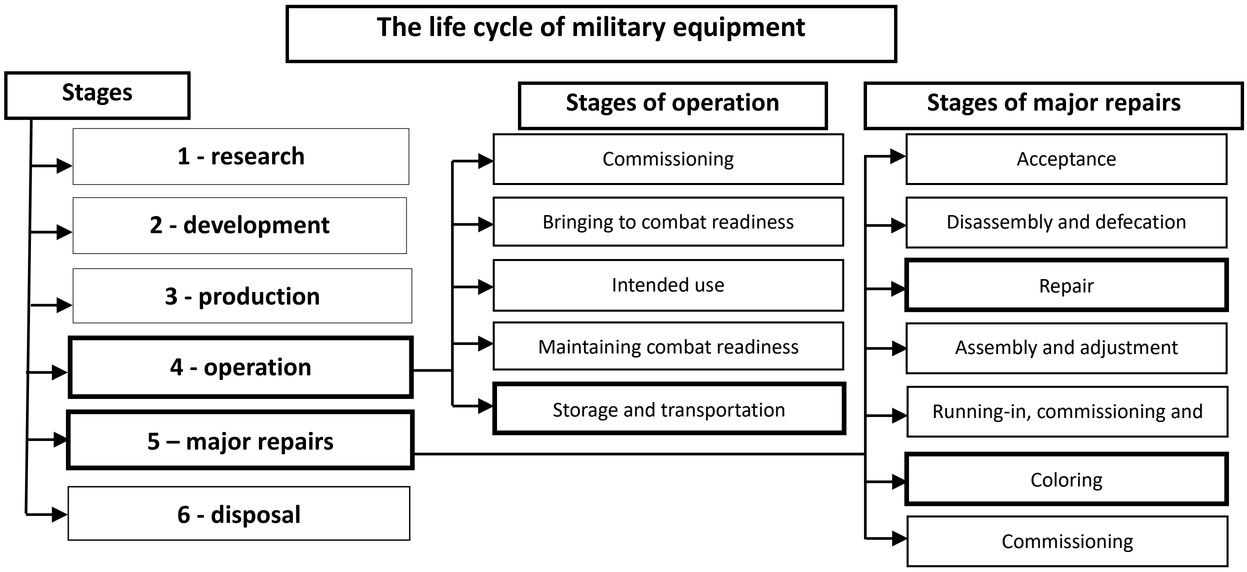


Fig. 1. Stages and stages of the life cycle of military equipment

It should be particularly noted that the interrelation and importance of these two stages "operation" and "overhaul" in the process of the life cycle of VT is due to a number of common and interrelated factors aimed at [2]:

- maintaining high combat readiness;

- ensuring the durability and safety of the military technical system by protecting the exposed and rubbing surfaces of the components from aggressive environments and operating conditions;

- increased service life.

In addition, another important circumstance that indicates their relationship is that the VT, which has undergone major repairs, is usually put into storage. Storage of military equipment is a period of operation during which weapons and military equipment are not used, and the technical condition is maintained through the use of special methods and means of protection against environmental factors and the implementation of a set of organizational and technical measures [3].

Earlier in the published works, experts considered the factors of environmental impact during the storage of VT, the advantages and disadvantages of existing methods of sealing and preservation materials [4, 5]. In general, the applied methods of conservation, methods of sealing machines differ in the variety of materials used and technologies of work. The technologies currently used in the Armed Forces of the Republic of Kazakhstan for storing W with conservation methods and sealing methods are labor-intensive and have a fairly high resource intensity, since they were developed in the 50s-70s of the last century.

Repair of modern vehicles is a complex production process. Most parts of combat vehicles are made of steels of various classes, while protection from aggressive external influences is provided by applying special functional coatings and surface modification, which is economically feasible. Taking into account the current pace of the development of high-tech equipment, designers are putting forward new requirements for increasing the specific characteristics of materials, in particular to contact surfaces [5-9]. In this regard, the development of modern technologies requires materials that demonstrate high strength, plastic, elastic and other characteristics and parameters. Currently used traditional technologies and alloys that have exhausted their resource properties do not provide the required strength characteristics during the repair process. Therefore, there is a need to improve the technology and use other materials to solve the problems of effective restoration of operability, taking into account the requirements of reliability and efficiency.

Harsh operating conditions in various natural and climatic conditions and complex designs of the working elements of the VT require the creation of effective means of protection, both during storage and during the restoration of their parts of components (aggregates), and the use of technology for applying protective coatings to the VT parts will significantly increase their reliability due to flexible regulation of the properties of the raw materials and more operational repair and restoration work.

3. The aim and objectives of the study

The purpose of this work is development of technology to protect the surfaces of military equipment from aggressive environmental factors and operating conditions.

As part of the implementation of these studies, innovative solutions will be developed, which include:

- the technology of preparing the surfaces of VT for applying an anticorrosive solution to them;

- the technology of applying an anticorrosive solution on the surface of the VT to protect surfaces from the effects of natural and climatic factors for the "operation" stage and the "storage and transportation" stage;

- specialized equipment that can be used in the field to apply anticorrosive protection to the surfaces of subsystems of VT;

- justification of the choice of an anticorrosive solution to protect the surfaces of VT and solutions for their cleaning and degreasing.

4. Materials and methods

Currently, for all types of VT operated in various natural and climatic zones, the problems that significantly affect its life cycle are [1-3]:

- corrosion of metal surfaces and destruction of rubber products that ensure tightness and sealing of working bodies in various subsystems (nodes and aggregates) and elements from their penetration into various environments;

- wear of the outer surfaces of the parts in the interface nodes due to the emerging dynamic loads on the components and units of the VT in the process of their intended use.

The above causes the need for additional research to improve the technology and develop equipment to ensure anticorrosive protection of the surfaces of the subsystems of the VT. The object of the study is the surfaces of subsystems and elements of the VT, which are subject to destruction from the effects of various factors during their operation. The subject of the study is the technological support and technical systems for applying anticorrosive protection of the surfaces of the subsystems of the VT from the effects of natural and climatic conditions during operation. The purpose of this study is to develop technology and equipment to provide anticorrosive protection of the surfaces of subsystems in the Armed Forces of the Republic of Kazakhstan.

To obtain rational research results, it is necessary to solve the following tasks:

1) to analyze the existing methods of protection of the surfaces of VT exposed to climatic and operational impacts;

2) to improve the technology of preparation of the W surface, on which it is planned to carry out the application of anti-corrosion coatings;

3) to justify the choice of the composition of the solution for degreasing the surface before applying an anti-corrosion coating on metallic and non-metallic surfaces;

4) to justify the choice of the composition of the anti-corrosion coating solution and the technology of its application on the surface of the VT.

5. Results

In accordance with the operating modes of any technical systems and the characteristics of aggressive media, the following methods are used to protect the surfaces of individual groups of metals from corrosion [5, 8, 9]:

- ensuring the impact on the aggressive properties of media;

- application of various types of coatings on metal surfaces;

- combined.

Appropriate effects on the aggressive properties of the external environment will be able to provide:

- partial effect of corrosion activity;

- complete elimination of corrosion activity.

This method of ensuring the protection of metal surfaces of various types of technical systems is primarily provided by introducing corrosion inhibitors into a gaseous or liquid aggressive environment. Such materials include amines, ketones and ketimines, which slow down the processes of exposure of water and oxygen to the metal surface of technical systems, significantly reducing the rate of corrosion process on them. In some cases, to reduce the corrosive activity of the external environment, if possible in the technological process, lubricants are purged with gaseous substances: nitrogen, argon and helium, which, due to a chemical reaction, reduce the concentration of dissolved oxygen in it [4, 5].

Non-metallic protective coatings are divided into coatings: polymer, rubbers, lubricants, pastes and other materials. Polymer anticorrosive coatings are made on the basis of polyvinyl chloride, polyethylene, fluoroplastics and other polymers, as well as rubbers and are applied to a pre-treated surface in order to provide better adhesion forces between them. This technology provides a sufficiently high degree of corrosion protection, resistance to mechanical damage and chemical influences of the external aggressive environment. Polystyrene, polyethylene, polypropylene, polyisobutylene, fluoroplastics and epoxy resins are used as the most common polymer protective coatings. In particular, the coating with bitumen resin can be carried out by dipping, gas-thermal or vortex spraying, as well as painting with a conventional brush [10].

Rubber anti-corrosion coating can be formed from soft or hard rubber, depending on the operating conditions of the product. Such coatings mainly consist in the application of rubber or ebonite and are used to protect various containers, pipelines, tanks, chemical apparatuses, tanks for the transportation and storage of chemicals from the external environment. The technology of applying rubber is that rubber is applied to a pre-cleaned and degreased surface, first treating it with rubber glue, then rolled with a roller, squeezing out the accumulated air, and then vulcanization is performed. The above-described process of applying a rubber anti-corrosion coating is called gumming [11].

Anticorrosive coatings in the form of pastes and lubricants are applied to the surface of the protected object with a brush, a special swab or spray, forming a protective film, and are mainly used for long-term storage or transportation of various metal products in the open air.

A review and analysis of the applied anticorrosive coatings and methods of their application made it possible to develop a classification based on the following main classification features (see Figure 2):

- types of protection (paint coatings, metallic and non-metallic coatings);
- paint and varnish coatings (varnishes, paints, enamels, primer-enamels, silicate enamels);
- metal coatings (tin, copper, zinc);
- non-metallic coatings (polymer, rubber, grease, pastes);
- conditions of use (for a special purpose, according to operating conditions);
- base of the coating material (silicates, polyurethane, polymers);
- method of application (dipping, painting with a brush, special swab, rubbing, spraying, vortex spraying, gas thermal spraying);
- service life of coatings (3-5 years, 5-10 years, 10-15 years);

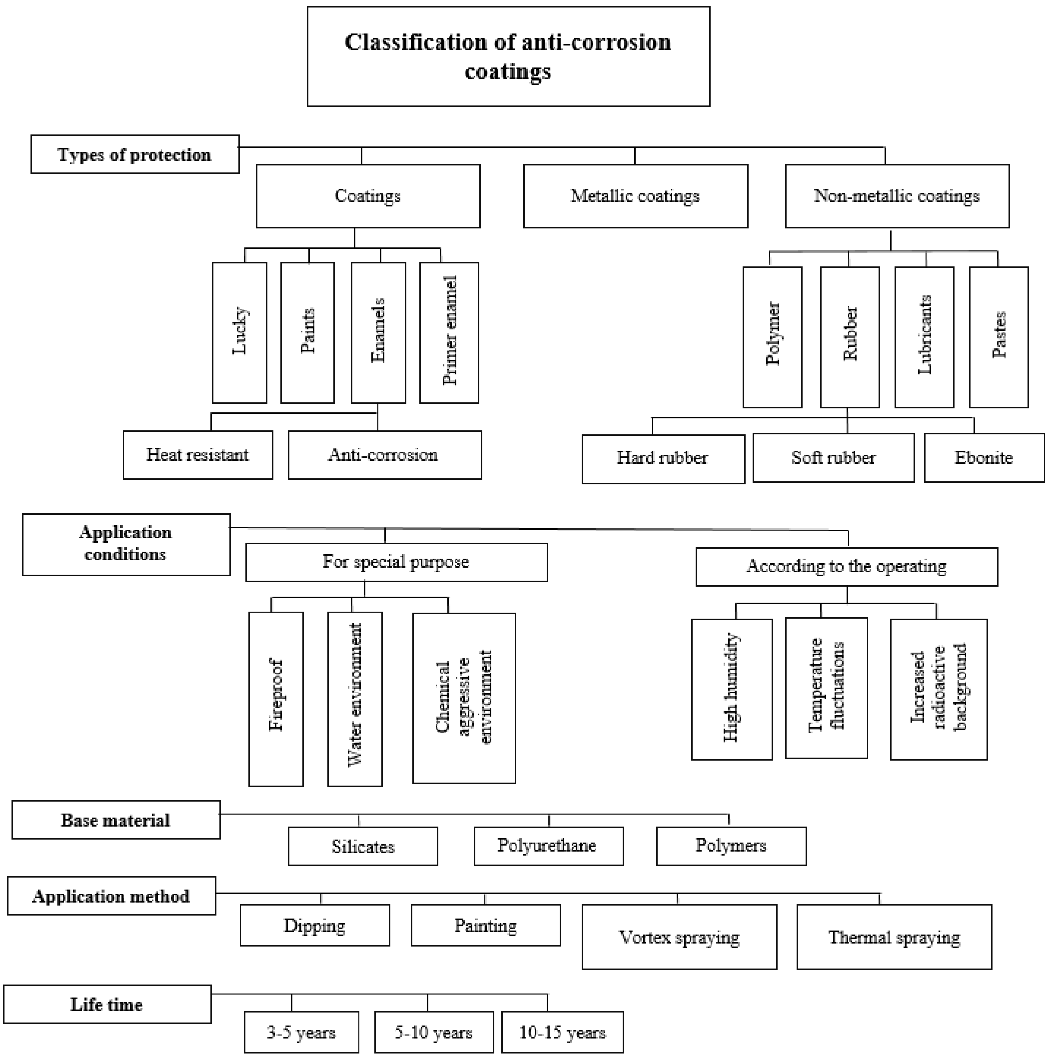


Fig. 2. Classification of anticorrosive coatings

The VT, which is in service, is operated in a variety of conditions of an aggressive external environment and in the presence of extreme loads on all their structural subsystems and elements. Therefore, in order to choose the most rational type of anticorrosive coating when applying it to the surface of the VT, it is necessary, first of all, to take into account the peculiarities of its operating conditions, physical and mechanical properties and characteristics of the protected surfaces. At the same time, one of the fundamental requirements of such a choice is the technological and economic and technical indicators of the use of anticorrosive coatings and methods of their application on the surface of the VT.

Based on the review and analysis of the applied anticorrosive coatings and taking into account the above operating factors, the following are recommended from existing paint and non-metallic anticorrosive coatings for use (see Figure 2):

- by type of protection: paint and varnish coatings (varnishes or paints) and/or non-metallic coatings (polymer);

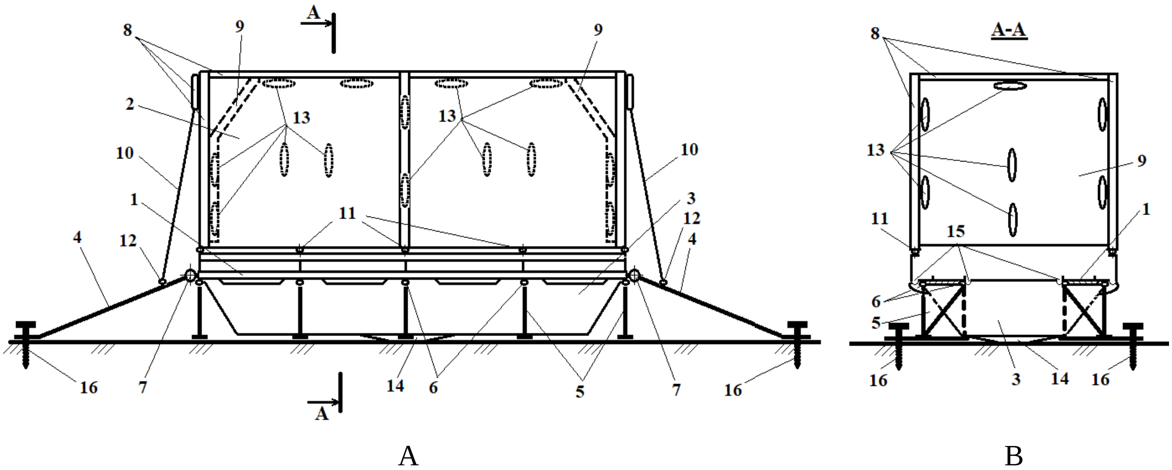
- based on the coating material (silicates, polymers);

- according to the method of application (painting or spraying).

5.1 Method and equipment for applying anticorrosive coatings on military equipment in the field

The technical result of the method for applying anticorrosive coatings on VT in the field is achieved by the fact that it contains two stages:

The I-th stage is preparatory and contains stages for the installation of equipment for applying anticorrosive coatings on the VT, which (see Figures 3 - a and b) includes [12]: a collapsible trestle 1; an inflatable cover 2; a pallet 3 with a sump 14; ramps 4; supports 5; hinges 6 mounting supports 5; hinges 7 for mounting the ramps 4; main 8 and additional 9 inflatable elements; folding canopies 10; fastening elements 11 of the inflatable cover 2 to the overpass 1; fastening elements 12 of the folding canopies 10 to the ramps 4; nozzles 13 for spraying anti-corrosion solution; channels 15 for the discharge of unused anticorrosive solution into the pallet 3; screw anchors 16.



A - general side view; B - cross section A-A

Fig. 3. Equipment for applying anticorrosive coatings to military technical systems

1. The ground surface is leveled, on which a pallet is first installed, designed to collect excess multicomponent solutions in its sump that have merged from the surface of the VT, and then an overpass is mounted above it, to which ramps are pivotally attached, which are rigidly fixed with screw anchors to the ground.

2. An inflatable tent cover with basic and additional inflatable elements is laid out on a flat surface.

3. Next to the created structure, a VT equipped with a high-pressure compressor or a compressor with an individual drive is installed.

4. A high-pressure compressor VT is connected to the one-way intake air locks located on the inflatable tent cover and the main and additional inflatable elements using air ducts with special quick-release tips.

5. In the process of supplying compressed air from the high-pressure compressor VT through the air ducts to the intake air locks of unilateral action, the inflatable tent cover due to its design with the main and, if necessary, additional inflatable elements forms the necessary volume with the required internal shape to accommodate the VT in it.

6. The inflatable tent cover is lifted, evenly placed and fixed along the edges of the overpass and ramps in the form of a sealed chamber.

7. The folding canopy is pulled aside and into an inflatable tent cover on the ramps on the overpass comes VT.

8. Connect the exhaust pipe/(s)/(b) VT by means of the exhaust duct casing and the exhaust gas supply pipe through the valve to the separator with a neutralizer:

- designed to purify the toxicity of exhaust gases and with further supply of heated air through nozzles for cleaning and preparing the surface for applying anticorrosive coatings on it;

- ensuring that the spraying of a multicomponent solution is maintained in the required operating temperature range;

- contributing, if necessary, to the formation of the anticorrosive effectiveness of a mixture of a multicomponent solution;

- carrying out, after applying the anti-corrosion mixture, due to the temperature of the purified exhaust gases, the drying of the liquid film formed on the surface of the technical system for its polymerization at the specified temperature and time parameters in order to obtain a solid anti-corrosion coating.

9. The hydraulic control system for the supply of anti-corrosion mixture for surface treatment is switched on.:

- a hydraulic pump from a pressurized hydraulic tank feeds a multicomponent solution through the mains to the spray nozzles located evenly on the inner surface of the inflatable tent cover and its main and additional inflatable elements designed to form a continuous shower, in order to obtain a uniform anti-corrosion coating on the surface of the tent;

- when filling the pallet with the water drained from the surface and the cleaned anti-corrosion mixture with an additional hydraulic pump, it is pumped from the pallet into the hydraulic tank for subsequent use.

The II-th stage is a working one, which includes the stages of preparing the VT surfaces and applying anticorrosive coatings on them.

1. A valve is turned on that regulates the supply of exhaust gases through a separator with a neutralizer through the air ducts to the nozzles, in order to clean and prepare the surface.:

- the exhaust gases under pressure pass through the nozzles fixed on the inner surface of the inflatable tent cover and on its main and additional inflatable elements, and clean the surface of the VT, blowing off particles of dust, dirt and water from it;

- further, if necessary, preliminary temperature preparation of the W surface for the application of an anti-corrosion coating is carried out;

- after preparing the surface, the valve is switched off and the exhaust gases are discharged out of the inflatable tent cover through an adjustable direct-acting safety valve.

2. A hydraulic control system is connected for the supply of a multicomponent anticorrosive solution having the required temperature and homogeneous viscosity, for its spraying on the surface of the VT with the formation of a liquid film by one of the following methods:

- through nozzles for spraying multicomponent anticorrosive solution by feeding it with a hydraulic pump along the pressure line through a two-section hydraulic distributor along the supply lines without heating or with additional heating;

- through nozzles for spraying an anticorrosive solution with simultaneous application of temperature pneumatic action of purified exhaust gases exiting under pressure from nozzles to form a viscous solution without heating or with additional heating.

3. After uniform spraying on the surface of the anti-corrosion solution with the formation of a liquid film, the hydraulic pump for feeding it from the hydraulic tank is turned off.

4. The control of the supply of exhaust gases purified from harmful impurities from the engine through the exhaust duct casing through the exhaust gas supply pipe through a valve and a separator with a neutralizer through the air ducts to the nozzles is activated, in order to dry the liquid film located on the surface of the engine for its polymerization at specified temperature and time parameters in order to obtain a resistant anti-corrosion coatings.

The equipment for applying anticorrosive coatings consists of three control circuits:

1st circuit - air supply control scheme for pressurizing the tent cover, its main and additional elements;

The 2nd circuit is a control circuit for the supply of exhaust gases purified from harmful impurities to prepare the surface of the VT for applying an anticorrosive coating on it and drying the resulting liquid film on the surface of the technical system in order to polymerize it at specified temperature and time parameters;

The 3rd circuit is a hydraulic control circuit for the supply of an anticorrosive solution for the treatment of the VT surface and its preparation for use.

5.2 Surface preparation for applying anti-corrosion solution to military equipment

Any VT located in the field is subject to operation in various climatic conditions and extreme regime loads, which necessarily requires prior preparation of the surfaces of its subsystems before applying anticorrosive solutions [13-15].

To ensure the process of applying a high-quality coating with high protective properties, the correct technological sequence of preliminary surface preparation is necessary, during which all adsorbed substances must be removed from the surface and its activation is performed. It should be particularly noted that the correct preparation of the surface of the VT significantly affects the corrosion resistance of the product as a whole.

For example, traditional metal surface preparation includes cleaning from grease, oxide films, dirt, dust, etc. The following methods of surface preparation for the application of anticorrosive coatings on VT are used:

- washing with water;

- mechanical cleaning;

- degreasing;

- etching.

Depending on the contamination of the surface of the products for their cleaning, each of the above methods can be used separately, or all together, and in case of severe contamination, individual subsystems of products can be subjected to the degreasing process two or three more times. In this regard, the entire technological process of preparing the W surface before applying anticorrosive solutions to it includes three stages:

1) cleaning of metallic and non-metallic surfaces from water drips, dust, dirt, oxide films, corrosion particles and old paint coatings;

2) degreasing or etching of the surface;

3) control of the condition of the surface prepared for the application of anticorrosive coatings.

The first stage of surface preparation in accordance with the operating conditions of the VT can be carried out in two ways: in the form of jet or abrasive-jet cleaning. In the process of jet cleaning, the surface of the products is treated with a jet of compressed air, and in the second case - in special protective chambers, in which a hopper with abrasive particles intended for abrasive-jet cleaning is additionally installed [14, 15].

Since the parameters of the VT surface treatment mode significantly affect the adhesive strength of the applied coatings, they must be chosen rationally in accordance with the technology and conditions for the formation of the applied layer of anticorrosive coating.

At the first stage of preparing the surface of the VT located in the field, the most economical is the jet method of surface cleaning, in which it is planned to use purified exhaust gases from diesel engines, after passing them sequentially through a neutralizer and separator in order to remove harmful emissions and reduce their temperature from 600-700 ° C to 70-90 ° C. In this case, such a temperature regime and the high-speed pressure of the exhaust exhaust of directional action from the injectors will allow cleaning metal and non-metallic surfaces from dust, dirt, corrosion particles, water drips, oxide films and old paint coatings.

The second stage of surface preparation in accordance with the operating conditions of the VT before applying an anticorrosive coating requires its degreasing or etching [15, 16].

One of the main disadvantages of using organic solvents for degreasing surfaces is their high cost and toxicity [14, 15]. Based on the above, the most acceptable in the field is the use of aqueous alkaline solutions, since the alkalis themselves are solid substances that are well soluble in water bases. In the practice of industrial production, the following alkalis are most widely used: sodium hydroxide (NaOH), potassium hydroxide (KOH) and barium hydroxide [Ba(OH)2)]. Of all the above-listed alkalis, sodium hydroxide (caustic soda) is the most common and widely used alkali in practice [15].

Production of sodium hydroxide is possible by pyrolytic method based on the chemical reaction of interaction of sodium oxide (Na2O) with water [16]:

$$Na_2O + H_2O \rightarrow 2NaOH + Q, \quad (1)$$

It should be noted that this chemical reaction is an exothermic reaction accompanied by the release of a large amount of heat, which can also be used to heat solutions used both for surface preparation and for applying anticorrosive solutions during seasonal periods of low temperatures.

Etching, as a method of preparing the surface for applying special coatings to it, is used both for degreasing and for removing rust, scale and other corrosion products of many metals and is divided into chemical and electrochemical. The most affordable method of etching is chemical etching, which is carried out in dilute or concentrated acids and their mixtures. In order to intensify the process of removing impurities from the surface of the products, the solution intended for etching is heated to the required temperature, while the etching process can last from five minutes to half an hour, depending on the contamination of the surface. For example, concentrated hydrochloric acid is heated to 40°C, which ensures effective etching of carbon steels. Basically, etching is carried out in solutions [16-18]:

- acids with and without additives of acid corrosion inhibitors;

- alkalis.

The use of etching is primarily associated with the removal from the surface of products of oxides or more complex compounds found in aqueous solutions of acids, acid salts or alkalis. It should be particularly noted that the choice of the method, the composition of the etching solution, the modes of the etching process itself depend on the physical and mechanical properties of the oxide substance and the material of the product, its thickness and other factors. Basically, aqueous solutions of sulfuric (5-10%), hydrochloric (5-20%) acids or mixtures thereof are used for etching products made of carbonaceous, low-alloy and other steels [13, 14].

5.3 Applications of exhaust mixtures of internal combustion engines for degreasing the surfaces of military technical systems

Numerous studies have established that the waste generated during the operation of diesel and gasoline engines of technical systems includes exhaust mixtures consisting of two components: exhaust gases (carbon monoxide, nitrogen oxide, sulfur oxide, aldehydes, ozone) and soot [18-27].

Each of the above components contains mixtures of toxic chemicals, which include:

1) nitrogen oxides (NOx);

2) Hydrocarbons (CnHm);

3) Carbon oxides (Co):

- Carbon monoxide (CO);

- carbon dioxide (CO_2).

4) sulfur dioxide (sulfur dioxide SO_2);

5) Aldehydes (R-CHO):

- formaldehyde;

- acetaldehyde.

At the same time, it should be noted that the exhaust mixture in VT diesel engines, depending on the type of diesel fuel used, in percentage terms consists of approximately [18]:

- 90% monoxide and nitrogen dioxide;

- 8% water and oxygen vapor;

- 1% sulfur oxide, carbon monoxide and dioxides, aldehydes, benzopyrene;

- 1% soot.

Due to the passage of spent exhaust mixtures of internal combustion engines through a separator and a neutralizer of specialized equipment for applying an anticorrosive coating on the surface of the vehicle in the field, it is possible to obtain the following acid solutions by chemical reaction: nitric, sulfuric and carbonic acid.

One of the harmful emissions of exhaust gases from internal combustion engines is nitrogen monoxide NO, which does not interact with water. At normal temperature, NO can combine with oxygen to form NO2 [14, 15].

$$2NO + O_2 \longrightarrow 2NO_2 \qquad (2)$$

Nitric oxide NO2 (nitrogen dioxide) under certain temperature conditions reacts with water to form a mixture of the corresponding nitric and nitric acids by the following chemical reaction:

$$2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2, \qquad (3)$$

HNO2 is a weak monobasic highly toxic nitric acid, which is unstable under standard conditions.

The use of chemical reaction (3) is an insufficiently rational approach in the process of nitric acid formation, since monobasic highly toxic nitric acid is also present in the resulting solution. Therefore, it is more expedient to convert nitrogen dioxide into nitrogen oxide (V) beforehand, since nitrogen oxide N2O5 (diazote pentoxide) easily dissolves in water to form nitric acid HNO3. In this case, the production of an aqueous solution of nitric acid is carried out in two stages:

1) conversion of nitrogen dioxide to nitrogen pentoxide;

$$2NO_2 + O_3 \longrightarrow N_2O_5 + O_2 \qquad (4)$$

2) obtaining a solution of nitric acid from nitrogen pentoxide, since it easily dissolves in water:

$$N_2O_5 + H_2O \longrightarrow 2HNO_3. \qquad (5)$$

Another harmful substance that is excreted together with emissions into the exhaust gases of internal combustion engines is sulfur dioxide (sulfur dioxide SO2), which, when interacting with oxygen at a temperature of at least 4500C, forms sulfur oxide [20, 21]:

$$2SO_2 + O_2 \longrightarrow 2SO_3 \qquad (6)$$

When passing SO3 through water, the chemical reaction is completely accompanied by the formation of an aqueous solution of sulfuric acid

$$SO_3 + H_2O \longrightarrow H2SO4 \qquad (7)$$

When carbon dioxide CO2 is dissolved in water, an equilibrium mixture of a solution of carbon dioxide and carbonic acid is formed. In this case, the equilibrium is strongly shifted towards the decomposition of the acid under the condition of an increase in the temperature of the solution and / or a decrease in the partial pressure:

$$CO_2 + H_2O \rightleftarrows H_2CO_3, \qquad (8)$$

Since carbonic acid exists in aqueous solutions in equilibrium with carbon dioxide and under normal conditions the equilibrium is strongly shifted towards acid decomposition, then for its effective use in the process of etching the surface of products, it is necessary to lower it to low temperatures. Given the instability of the carbonic acid solution and the complexity of its cooling before use, carbon dioxide, as harmful emissions of spent fuel, should be passed through a neutralizer for further use in jet cleaning.

Based on the above, it should be noted that the etching process during the preparation of the surfaces of the VT in the field is possible by the formation of acid solutions from toxic chemicals, such as nitrogen oxide and sulfur dioxide, formed during the operation of internal combustion engines in the form of exhaust gases. In this case, the use of specialized equipment for applying an anticorrosive coating on W in compliance with the technology of degreasing their surfaces using solutions of nitric or sulfuric acids formed by chemical reactions (5) and (7) are among the possible options that will be the most effective and less costly in the economic aspect.

5.4 Features of monitoring the condition of the prepared surface for the application of anticorrosive coating

The third stage includes monitoring the condition of the prepared surface for applying an anticorrosive coating, which boils down to checking the quality of the prepared surface for roughness using [13-15]:

• wiping the surface with a white cloth;

• profilographers or standards;

• by spreading the droplet;

• control of the value of the surface potential.

Traditionally, two types of control are used in industrial production: roughness assessment and the presence of adsorbed contaminants on the surface [15]. The easiest way to assess the quality of the surface from contamination is to wipe the surface with a cloth (calico, cambric and other cotton fabrics). Each of these types of control has its own specific requirements for the prepared surfaces, which are primarily due to the properties of materials that perform protective functions in the form of anticorrosive coatings. For example, special requirements are imposed on the roughness of the surfaces of products on which powder coatings are applied.

In the case when the prepared surface has a low roughness, then in order to ensure sufficient adhesion forces of the particles of the applied anticorrosive coating with the surface of the product, its preliminary temperature heating is necessary, which ensures the production of coatings with increased adhesive strength. To do this, one of the main technological requirements of a high-quality coating is compliance with the condition of the ratio of the sizes of the sprayed particles, which should be smaller than the depressions on the rough surface of the product.

In the technology of using jet cleaning of metal surfaces of high-speed VT with the help of a high-speed pressure of purified exhaust gases, it is possible to carry out an adjustable temperature regime of its preheating to the required temperature.

6. Discussion of results

Currently, non-metallic materials that have good resistance are used to protect all mechanical engineering products from the corrosive and erosive effects of the external environment and operating conditions. A number of anticorrosive coatings have low strength when exposed to shock loads, and also require complex technological preparation and the duration of the application process on the surface, which limits their use. Such coatings include enamels, pastes and lubricants. The most acceptable anticorrosive coatings of metal surfaces of military technical systems are paint and/or non-metallic polymer coatings.

Based on the review and analysis of the applied anticorrosive coatings and methods of their application, a classification has been developed that takes into account the following classification features: types of protection, types of paint coatings, non-metallic coatings, conditions of use, the basis of the coating material, the method of application and the service life of coatings.

Despite the various types of anticorrosive coatings and methods of their application, it is necessary to improve the technological processes of surface preparation, manufacture and application of new materials that allow for corrosion protection throughout the life of military systems, regardless of environmental influences. In order to protect the surfaces of military equipment located in the field from corrosion, their preparation is carried out beforehand, which includes three stages: cleaning, degreasing or etching the surface and its control of the state of readiness for applying an anticorrosive coating.

7. Conclusion

The use of specialized equipment for the application of anticorrosive coating allows you to consistently perform the technology of surface preparation in accordance with the specified stages. It is recommended to perform the first stage of surface cleaning in the form of jet cleaning by streams of purified exhaust gases at a temperature not exceeding 70-90 °C. The temperature regime and the high-speed pressure of the purified exhaust gases of directional action from the injectors of the equipment will allow cleaning metal and non-metallic surfaces from dust, dirt, corrosion particles, water drips, oxide films and old paint coatings. It is recommended that the second stage of surface preparation, associated with degreasing or etching, be performed using chemical reactions to obtain aqueous solutions of nitric or sulfuric acids, which are formed from the interaction of nitrogen pentoxide and sulfur dioxide with water. Since nitrogen oxide and sulfur dioxide, which are components of harmful exhaust gas emissions from internal combustion engines, their use when passing through the separator – neutralizer system will provide the required aqueous acid solutions. Considering that the exhaust gas temperature of internal combustion engines can reach 600-700 °C, it can be used to intensify the processes of jet cleaning and obtaining aqueous acid solutions.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, au-thorship or otherwise, that could affect the research and its results presented in this paper.

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