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PREDICTION OF RELIABILITY OF TECHNOLOGICAL EQUIPMENT OF AUTOMOBILE REFUELLING MEANS USED IN ARCTIC CONDITIONS

***Abstract**. Reliability is a property that refers to the specified operating conditions of the equipment. Failure is most likely to appear in cases where the technique is used at the limit mode of its technical characteristics. The probability of achieving such a sign of the limit state for a given period of operation of the machine can be determined at the design stage of a new machine by calculating all cases of machine operation at the limit mode, allowed by the technical characteristics and implemented under the action of its nominal parameters. Currently, there are no technical means of material support that can guarantee the troops to provide fuel, lubricants and water in cold (below minus 45 0C) and extreme cold (below minus 50 0C to minus 60 0C) climate. For the fuel service, the mobile refueling facilities will have to provide the technological process of the fuel Bay in their tanks, transportation and refueling of weapons and military equipment. For their reliable application in the Arctic conditions, special requirements are required for their technical parameters, ensuring the trouble-free and durable operation of technological equipment in the form of pumps, tanks, filters and fuel distribution systems. Justification of parameters of technical means of fuel service for the Arctic conditions will allow on the basis of a certain base area of the quality level to determine the optimal values of the parameters of the materials of parts used for the manufacture of Assembly units of the technological. Arctic climatic conditions can accelerate some processes of destruction of materials or structures of parts. This leads to the use of special methods for calculating the strength properties of materials and structures. The models presented in the article can be used to study the use of technical means of fuel service in the Arctic, separately justify the array of initial data, which should take into account the special conditions of the use of materials, parts and Assembly units of technological equipment.*

***Keywords**: military equipment, technological equipment means filling, reliability, refueling, vehicle refueling tool.*

In modern conditions, the Arctic is becoming more important in global politics and Economics, and the Arctic region itself is becoming an important arena for Russia's relations with foreign partners.To implement the plans outlined by the strategy, Russia needs to "improve the structure, composition, military, economic and logistical support of the armed forces and the development of infrastructure for their deployment in the Arctic" [1].

Readiness of the armed forces to perform the tasks is closely related to its material and technical support, which directly includes the provision of weapons, military and special equipment (vvst) fuel, oils, lubricants and special liquids [2,3].

Analysis of tactical and technical characteristics of the technical means of the fuel service (TS SG) and food service (FS) shows that currently, there are no samples able to provide troops (forces) of combustive-lubricating materials and water in cold (below minus 45 0C) and extreme cold (below minus 50 0C 60^0 C Dominus) climate [4,5].

For SG, mobile refueling equipment (PPE) will have to provide the technological process of fuel injection into their tanks, transportation and refueling with vvst fuel. Their reliable use in the Arctic requires special requirements for their technical parameters, ensuring trouble-free and durable operation of process equipment in the form of pumps, tanks, filters and fuel transfer systems.

To solve the problem of predicting the reliability and durability indicators, it is necessary to consider the properties of the structural material used for manufacturing process equipment parts, and the order of forming a reference quality level for the process equipment of ASZT.

To assess the reliability, depending on the stresses caused by pressure, temperature, vibrations, etc., it is possible to use the "load — bearing capacity" model, the basic idea of which is that under the influence of the load the load-bearing capacity of the system is gradually reduced until the system fails [6]. Its main disadvantage is that with a large number of factors acting on the system, finding the probability of failure turns into a complex mathematical problem, the solution of which even by numerical methods using computers is very laborious.

There are many approaches and different methods of reliability assessment, for example, in the works [6, 10] methods of reliability calculation by limiting States are presented using a mathematical model, as well as methods of calculation based on data on plastic deformations of structures and their stability.

Nevertheless, the presented methods are difficult to implement directly during operation, as in some cases it is necessary to constantly monitor the state of the metal for timely response and prevention of accidents.

Despite the vast number of existing methods for calculating reliability, currently there is no one that would allow you to quickly and objectively based on the state of the material to assess the durability of the structure and give recommendations for its use on the basis of internal defects of the material, covered all possible changes in weather conditions, the influence of the environment and would allow to monitor the state of the elements of the structure at any time.

At the moment, the most applicable method for assessing the probability of failure of the element, reliability and durability, based on the structural and energy failure theory [5,7]. Structural-energy failure theory makes it easy to assess the impact of structural factors (the number and size of sensitive structures of materials) on the shape of the curve of the function of the distribution of energy of destruction (Fig. 1), and therefore, the reliability of the elements and on this basis to develop specific recommendations for the technological support of a given level of reliability and quality of the elements.

The dependence of the probability of failure on the magnitude of the energy impact will be a simple exponential [6]:

$$q(\mathrm{e}) = 1 - \exp(-be), \quad (1)$$

where b - is the variation of the sizes of sensitive structures;

e — is the magnitude of the energy impact.

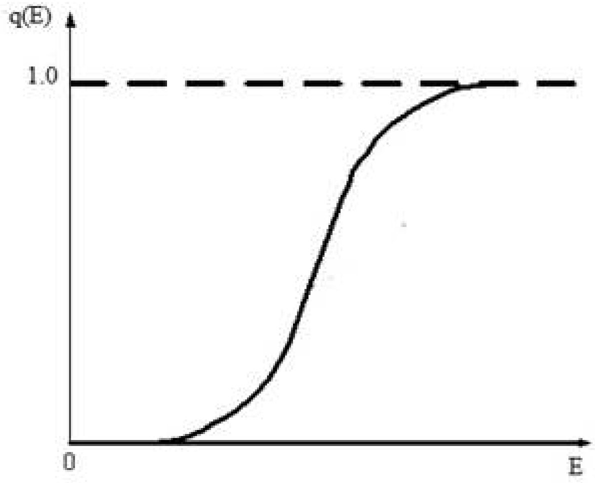

Fig. 1 - distribution Function of energy of destruction

The probability of failure P(t) is the inverse of the failure probability and is defined as follows:

P (t) = 1-q(e) (2)

Using the following equation, it is possible to determine the uptime of the most critical parts of the process equipment TS SG:

$$P(t) = \exp(-\alpha It)\sum_{i=0}^{n-1}\frac{(\alpha It)^i}{i!} \quad (3)$$

where I — is the value of the temperature effect;

α— coefficient of transition from one state to another;

t — is the time of operation of the element.

The transition coefficient α is determined as follows:

$$\alpha = \frac{t_{cp} - t_0}{I \cdot \sigma_t^2} \qquad (4)$$

where t_{cp} — is the average time before failure of elements;
t_0 — guaranteed working time of the element;
σ —the variance of the energy failure.

The presented evaluation method was tested on thin–walled samples, 0.1-0.5 mm thick, and on larger parts and elements experiencing heavy loads.

For TS SG the tightness of capacity for fuel which can be broken as a result of excess of mechanical loadings over strength is of special importance. As a result, the main function is lost - short-term storage and transportation of fuel to the place of refueling of military equipment. At the same time, repair in some cases is difficult due to the complexity of the technology of repair work and the need for specific repair equipment.

An important indicator on which the technical characteristics of AST depend is the geometric dimensions of the tank, for which it is necessary to know the cross-sectional area and the length of the tank, which largely depend on the chosen shape of the shell and the bottoms.

Currently, the industry produces tanks, boilers and tanks with shells of cylindrical, elliptical, trapezoidal and rectangular shapes. Each of these forms has its advantages and disadvantages, which must be taken into account when choosing them (Fig. 2).

Bottoms as well as shells can be flat, elliptical and hemispherical (Fig. 3). The most widely tank with flat beaded bottoms, reinforced vystupovanie ridges. On GTMZ trapezoidal form of the tank is applied (Fig.4).

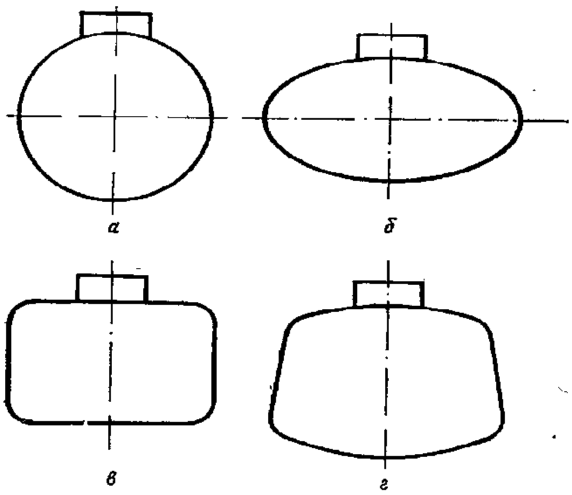

Fig. 2 - Shape of the cross sections of the tanks:
a – cylindrical; b, elliptical; rectangular; d– keystone

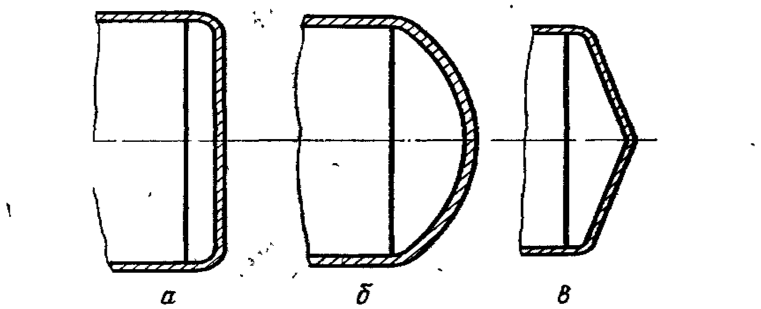

Fig. 3 - Shape the bottoms of tanks:
a – flat with the frame; b, elliptical; C – hemispherical

As presented in the source [5], there is a list of defects in the elements of the tank, which leads to loss of tightness.

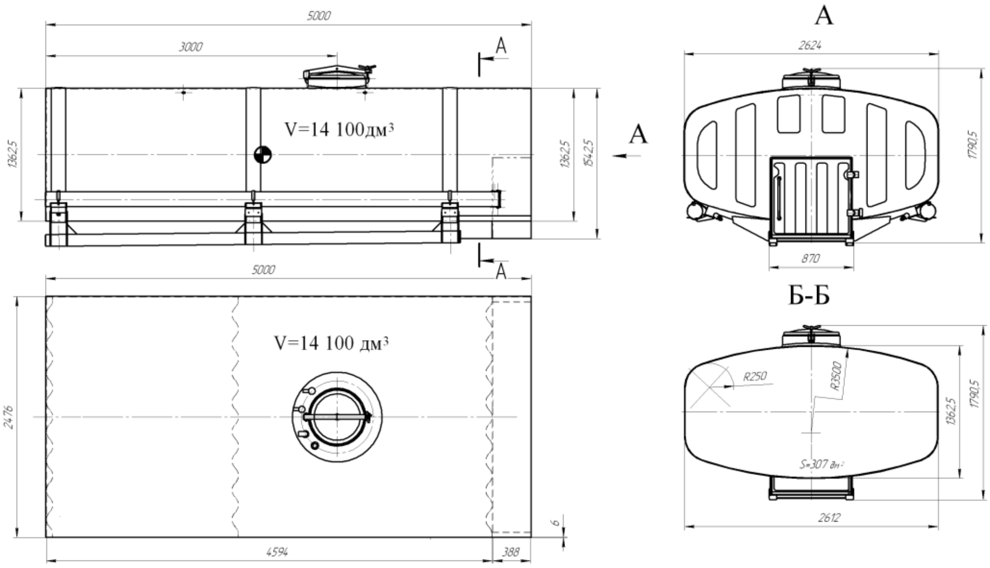

Fig. 4 - Tank for fuel GTS

Given that the approach of approximate calculation of the reliability of the tank is used, it can be assumed that sudden failures occur due to partial or complete destruction of the shell of the boiler through microcracks and welds, taking into account cold resistance.

The reason for the gradual failures, leading to loss of tightness, as experience shows, are mainly fatigue stresses in the walls of the boiler and welds. But, in the Arctic conditions, the plasticity and fluidity of materials deteriorate significantly, which dramatically reduces the level of reliability of technological equipment as a whole.

When determining the reliability of parts with respect to fatigue failures, it is necessary to take into account the nature of the load. Figure 5 shows the loading plot of the tank mounted on the vehicle base chassis.

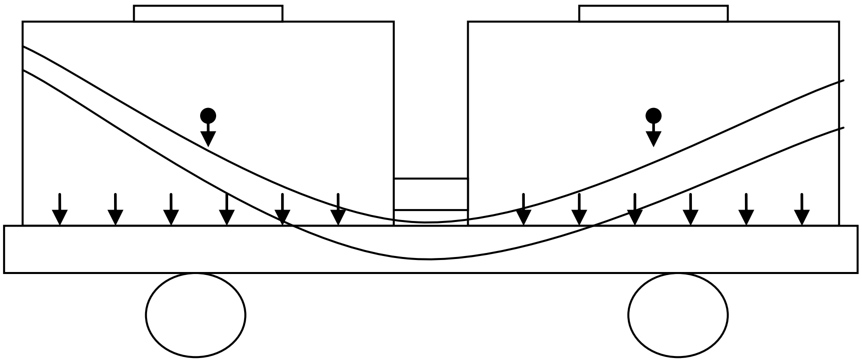

Fig. 5-Plot of loads acting on the tank from the liquid side

On the other hand, it is necessary to take into account the variability of the strength parameters of the part or structure, the randomness of the characteristics of materials or the need to ensure certain strength reserves. At the same time, the gradual accumulation of damage leading to the emergence and development of cracks and subsequent destruction of the structure, should be described in the following manner.

Fatigue failure in the details occur as a result of the appearance of microcracks in the material at alternating loads of cyclic nature [7]. The probability of failure-free operation with respect to fatigue failures is described by logarithmic-normal law [8]

$$P_{уст}(t) = \frac{1}{2}\left[1 + \Phi\left(\frac{\ln n_{\text{пр}}\theta - \ln t}{\sigma_R(\ln t)}\right)\right], \qquad (7)$$

where $n_{пр}$ - is the limit of the number of alternating cycles;

θ- the period of one cycle;

σ_R - mean square deviation

Since the properties of low-carbon and low-alloy steels, as well as welded joints, change most noticeably when the temperature drops [9], the mathematical expectation of the bearing capacity of the part will be taken as a function of the ambient temperature.

The probability of failure-free operation with respect to gradual failures mainly depends on wear, fatigue failure, and corrosion processes, and is on the following formula

$$P_{\Pi}(t) = \sum_{i=1}^{K} P_u(t) P_K(t) P_{уст}(t) \qquad (8)$$

where $P_u(t)$ is the probability of failure-free operation with respect to wear and tear;

$P_K(t)$ - probability of failure-free operation with respect to corrosive processes;

$P_{уст}(t)$ - probability of failure-free operation with respect to fatigue failure.

Due to the variety of equivalent factors operating during operation, on the basis of the Central limit theorem, it can be argued that the probability of failure-free operation of parts under wear and corrosion failures is subject to the normal distribution law with a mathematical expectation equal to zero, and dispersion, σ^2 ie .

$$P_{u,k}(t) = \frac{1}{2}\left[1 + \Phi\left(\frac{\mu_{\text{пi}} - \bar{\alpha}_i t}{\sigma_i t}\right)\right], (9)$$

where $\bar{\alpha}_i$ *- is the average speed of wear or corrosion processes;*

$\mu_{\text{пi}}$ *- limit value, ensuring the" strength " of the part;*

t *- total operating time of the sample.*

When determining the reliability of parts with respect to fatigue failures, it is necessary to take into account the nature of loads that can be described by a random loading process. On the other hand, it is necessary to take into account the variability of the parameters of the strength of the part or structure, the randomness of the characteristics of materials or the need to ensure certain strength reserves.

When determining the reliability of parts with respect to fatigue failures, it is necessary to take into account the nature of loads that can be described by a random loading process. On the other hand, it is necessary to take into account the variability of the parameters of the strength of the part or structure, the randomness of the characteristics of materials or the need to ensure certain strength reserves.

Fatigue failure in the details occur as a result of the appearance of microcracks in the material at alternating loads cyclic nature. The probability of failure-free operation with respect to fatigue failures is described by logarithmic-normal law [5]

$$P_{\text{уст}}(t) = \frac{1}{2}\left[1 + \Phi\left(\frac{\ln n_{\text{пр}}\theta - \ln t}{\sigma_{\ln t}}\right)\right], (10)$$

where $n_{\text{пр}}$ *- limit number of alternating cycles or revolutions;*

θ *- the period of one cycle;*

$\sigma_{\ln t}$ *- mean square deviation.*

The value can be determined by a fatigue curve, or by using the safety factor in the case when the spectrum of load is below the fatigue limit. In this case

$$T^{\text{пр}}_{\text{уст}} = n_{\text{пр}}\theta = \bar{n}_s T_{\text{тр}}, (11)$$

where $T_{\text{тр}}$ *-required resource;*

$\bar{n}_s$ *- safety factor.*

Thus, the models described above can be used to study the use of HS in the Arctic and to justify separately an array of input data, which should take into account the special conditions of use of materials, parts and Assembly units of process equipment.

In this issue, an important role is played by climatic conditions, which can accelerate some processes of destruction of materials or structures of parts. This leads to the use of special methods for calculating the strength properties of materials and structures, but the General methodological approach of assessing the gradual accumulation of damage leading to the origin and development of macro cracks and subsequent destruction of the tank structure remains the same.

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