A rctic protective materials based on complex oxides of
titanium

I A Sologubova, M K Kotvanova and S S Pavlova

Yugra State University, Federal State Budgetary Educational Institution of Higher Education,
Khanty-Mansiysk, 628012 Russia

E-mail: i.a_sologubova@mail.ru

Abstract. This paper presents the components and method for obtaining an effective protective
coating. The coating has chemical and thermal stability in a wide range of temperatures, and
has good mechanical characteristics. It was found that one of the important factors determining
the properties of the coating is the degree of dispersion of powders of the starting materials. The
optimal average particle size is 60 nm.

1. Introduction
Corrosion of metals causes significant economic and ecological damage to the national economy. The
issue is getting worse while operation of metal structures and items in Arctic regions. In this regard the
requirements to the maintenance engineering reliability and corrosion resistance of structural materials
and metal structures as well as methods of their protection have been improved.

There are many ways to protect steel from corrosion, however, as a rule, each of them is aimed at
protecting from any specific effects, without providing comprehensive protection. Also often, many
methods are expensive or intractable. Thus, the using of composite aluminium-oxide coating is
complicated by the requirement of the control its porosity [1]; diffusion zinc coating as a method of
protecting a metal surface requires use of large amounts of expensive zinc [2].

In this article an attempt to obtain a protective coating meeting the requirements of the Arctic
materials resistant to low temperatures, intense wind and wave and ice dynamic loads, corrosion and
erosion impact has been made.

It is known that complex oxides of d-elements have a high chemical resistance to aggressive
environments. Complex oxides of titanium (oxide bronze) of \( K_xTiO_2 \) composition, where \( x = 0.06-0.12 \) were used as the basis of the protective coating in this study.

2. Experimental
Mechanochemical synthesis was performed in a planetary mill AGO-3 with 1200 rotations of the shell
at min. Steel balls with a diameter of 8 mm were used as grinding media. The ratio “reaction
mixture:grinding body” was 10:220 by weight. The charge mixture was calculated according to the
equation \( TiO_2 + xKI = K_xTiO_2 + x/2I_2 \). The duration of the synthesis was 400 s. The product of the
synthesis was purified with concentrated nitric acid from impurities of iron which gets into the
reaction mixture from the surface of the grinding bodies.

For coating steel base were cleaned with sandpaper M40 and degreased with acetone. The suspension
was prepared in a weight ratio of \( H_2O:Na_2SiO_3 \) (in NaOHwater):\( K_xTiO_2 = 1:0.05:0.05 \). The resulting
suspension was poured evenly on the steel base and dried during the day. Heat treatment was carried out using a gas burner (temperature range 1100–1200°C).

3. Results and discussion

It was found that one of the important factors determining the properties of the coating is the degree of dispersion of powders of the starting materials.

The coating prepared from powders with an average particle size of 60 nm, has a smaller thickness and porosity, and more continuity. The small thickness of the coating contributes to its adhesion to the steel core, thus reducing the consumption of coating material.

The obtained protective coating was subjected to test for adhesion by the method of separation \( \sigma = 120 \text{ H/m}^2 \); the peeling of the coating occurred when bending of the metal substrate by 20°. The following indicators of coatings were obtained: the force of static friction \( F_{st} = 0.70 \text{ N} \); the force of sliding friction \( F_{sl} = 0.59 \text{ N} \).

In addition, coatings were tested for resistance to high and low temperatures. Exposure to high temperatures was carried out using a gas burner (the temperature range 1100–1200°C) – coating was destroyed due to the deformation of the steel plate. Cracking of the coating at low temperatures (–70°C) occurred with prolonged exposure (3 months).

Chemical resistance of the obtained coatings was evaluated by the corrosion rate of the samples. The results are presented in table 1.
Table 1. Chemical properties samples of the resulting coatings.

| Reactive atmosphere | Corrosion velocity of the sample, g/min |
|---------------------|----------------------------------------|
|                     | Without coating | With coating  |
| HNO$_3$, $\rho = 1.48$ g/cm$^3$ | 0.037 | 0.015 |
| H$_2$SO$_4$, $\rho = 1.83$ g/cm$^3$ | 0.044 | 0.018 |
| HCl, $\rho = 1.19$ g/cm$^3$ | 0.236 | 0.113 |

Thus, we succeeded in obtaining a protective coating having chemical and thermal stability in a wide temperature range, and having high mechanical characteristics. On the basis of conducted research it can be concluded that the presented method of protecting steel from corrosion can be used in hard environmental conditions, including the Arctic regions.

References

[1] Pat. 90440 Russia Suminov I V Composite aluminium-oxide coating to protect steel from corrosion and wear applicant and patentee OOO "Innovative technological center "NANOMER" No RU2009135311U; Appl. 23.09.09; publ. 01.10.10

[2] Pat. 2147046 Russia Method of thermal diffusion galvanizing applicant and patentee Institute of high temperature electrochemistry, Ural branch, RAS No. 98115707/02; Appl. 17.08.98; publ. 27.03.00