2. Corrosion-fatigue strength of 12Kh18N10T steel T-joints, made by argon arc welding, on base of 10^7 cycles was 100, on base of 10^8 — 83 MPa.

3. Plastic deformation using BPS increased the fatigue strength of steel 12Kh18N10T T-joints up to 140 and 150 MPa for manual and argon arc welding, respectively: fatigue life — 4–8 times for TIG-welded joints and 14–20 times for manual welded joints; corrosion-fatigue strength was increased up to 127 MPa on base of 10^7 cycles and up to 110 MPa on base of 10^8 cycles, i.e. 1.3 times; fatigue life at stresses 110–120 MPa was 14–30 times increased.

4. Hardening treatment of FC FS using BPS can be recommended to implementation at ship repair enterprises.

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INFLUENCE OF CONTENT OF IRON POWDER AND COMPOUNDS OF ALKALI METALS IN THE COMPOSITION OF ELECTRODE COATING ON THEIR SANITARY-HYGIENIC CHARACTERISTICS

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The dependence of the specific precipitations and chemical composition of a hard component of welding aerosol on content of iron powder in electrode coating was established. The effect of content of potassium compounds in coating of rutile and basic electrodes on their sanitary-hygienic characteristics was considered.

Keywords: *manual arc welding, electrodes, electrode coating, welding aerosol, coating composition, sanitary-hygienic characteristics, hard component, specific precipitations*

The manual arc welding with coated electrodes is challenging today and according to the forecasts of the specialists [1, 2] it will continue its existence due to a number of advantages, such as relatively moderate price of the process and consumable materials, possibility of welding in all positions and in hard-to-access places, lack of rigid requirements to welder skills. At the same time, already more than 50 years the searches for ways to improve the sanitary-hygienic characteristics of electrodes are being continued.

Table 1. Conditions of welding using coated electrodes of DZ series

Electrode index	U_w, V
DZ-0	26–28
DZ-1	26–28
DZ-2	25–27
DZ-3	24–26
Note. Welding current of 180 A.	

The factors were determined influencing the evolution of aerosol [3], which consists of a gas-like component of welding aerosol (GCWA) and a hard component of welding aerosol (HCWA). One of the main factors defining the level of specific precipitations and chemical composition of HCWA is composition of electrode coating as far as during heating and melting it is the main source of aerosol, i.e. 35–70 % of the total volume depending on the type of electrode coating [3, 4].

The iron powder, widely used in production of coated electrodes, allows enhancing labor productivity of welder, decreasing the cost of welding works, improving welding-technological properties of electrodes [5]. The increase of productivity is achieved due to increase of transfer

Table 2. Chemical composition of HCWA compounds of ANO-37 series electrodes with rutile coating, wt.%

Electrode index	Na_2O	SiO_2	TiO_2	MnO	Fe_2O_3	CaO	K_2O	Al_2O_3	P_2O_5	SO_3
DZ-0	2.85	18.20	2.91	11.08	50.28	0.53	13.03	0.17	0.60	0.38
DZ-1	2.73	22.38	2.76	8.94	51.87	0.56	9.68	0.18	0.51	0.35
DZ-3	2.65	22.73	2.11	6.50	50.80	0.48	13.60	0.16	0.50	0.50

of a metallic component of the electrode coating into the weld pool.

The investigation of effect of iron powder content in electrode coating on the sanitary-hygienic characteristics was carried out basing on the electrodes ANO-37 with rutile type of coating (the first series of experiments). The four batches of experimental electrodes with content of iron powder of 0, 10, 20, 30 wt.% (index of electrodes DZ-0, DZ-1, DZ-2, DZ-3, respectively) were manufactured.

The welding was carried out in a chamber [4] from the AC power source, i.e. transformer STSh-500 (Table 1). The sanitary-hygienic properties were evaluated in the following way: welding aerosol, formed in the chamber in the process of welding, was precipitated by a complete filtration on filters FPP-15-1.5, which were weighed before and after precipitation. The obtained difference in mass related to the mass of burnt-out part of electrode or time of arc burning represents the specific precipitations (D, g/kg) or intensity of precipitation (G, g/min) of HCWA, respectively.

Also, by precipitation of aerosol on cellulose filter and its mechanic removal into glass vessel the HCWA was additionally sampling for chemical analysis using method of X-ray fluorescent spectrometry (SRM-25) (Table 2, Figure 1).

The results of experiments prove the significant (more than 20 %) decrease of precipitations of HCWA due to adding of iron powder into electrode coating. This is explained by the following factors: change in temperature of a drop at the electrode tip [4], general relative decrease of components of electrode coating, actively participating in formation of welding aerosol (cellulose, ferromanganese, marble) which leads to a considerable decrease (almost twice) in content of toxic compound of manganese in the composition of HCWA (Table 2). The tests of welding technological properties of electrodes were also carried out which gave good results, as the addition of iron powder did not deteriorate the behavior of metal and slag in welding and did not influence the slag removal and metal formation.

The compounds of alkali metals in the composition of electrode coating can be in a form of

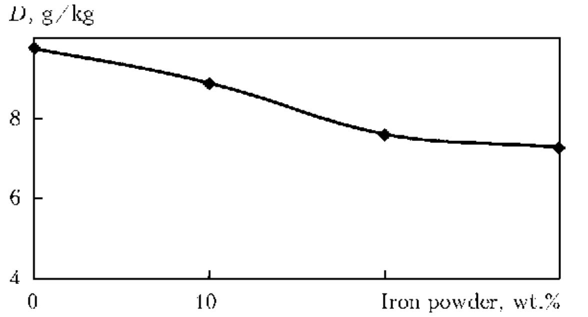

Figure 1. Dependence of specific precipitation of HCWA on the content of iron powder in electrode coating

a binder (water-soluble silicates) and also as a stabilizing component as they have low electronic work function.

Table 3. Composition of components in the coating in rutile electrodes, wt.%

Coating components	E1	E2	E3	E4	E5
Potassium titanate	–	–	4	8	12
Iron powder	10	10	6	2	–
Type of liquid glass	Na	K	K	K	K

Table 4. Conditions of welding using coated electrodes of series E

Electrode index	U_w, V
E1	26–28
E2	24–26
E3	21–23
E4	20–22
E5	20–22
Note. Welding current of 185 A.	

Table 5. Chemical composition of HCWA compounds of series E electrodes with rutile coating, wt.%

Electrode index	K_2O	SiO_2	TiO_2	MnO	MgO	CaO	Fe_2O_3
E1	4.46	11.70	2.82	16.30	1.72	0.54	49.10
E2	9.75	16.30	3.44	16	1.72	0.50	48.60
E3	13.04	13.60	3.77	14.70	1.69	0.50	45.60
E4	14.40	15	3.46	13	1.58	0.59	45.90
E5	22.40	11.73	3.43	9	1.51	0.40	47.90

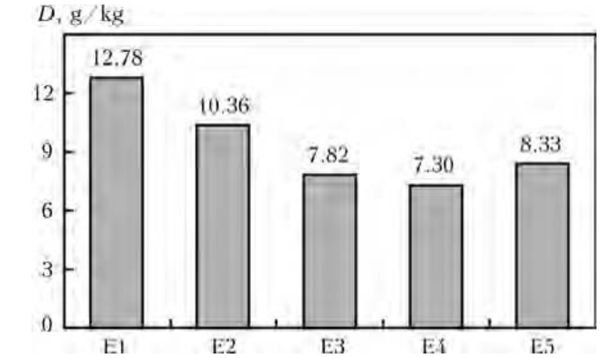

Figure 2. Specific precipitation of HCWA of electrodes with rutile coating

The contents of compounds of potassium and sodium affect greatly the gross precipitation and chemical composition of HCWA, as they are characterized, on one hand, by a high pressure of saturated steam and, on the other, they affect the rated arc voltage and, thus, the temperature conditions in the arc zone.

To determine the effect of content of compounds of alkali metals on sanitary-hygienic characteristics of electrodes with rutile coating, the series of investigations was carried out.

The compounds of alkali metals in the form of potassium titanate were added to the electrode coating of rutile electrodes (series E) by decrease of content of iron powder (Table 3). The content of components used in coating and not given in Table 3 was not changed. Besides, in electrode coatings of this series the silicates of sodium (E1) and potassium (E2–E5) were presented in the composition of dry remnant of liquid glass which is used as a binder. Using electrodes the welding was performed at alternating current from the transformer STSh-500. In the course of welding the specific precipitation of HCWA was determined, and samples were taken for determination of chemical composition of HCWA using the above-described procedure. The changed contents of components of coating are given in Table 3, welding conditions — in Table 4, chemical composition — in Table 5, specific precipitation — in Figure 2.

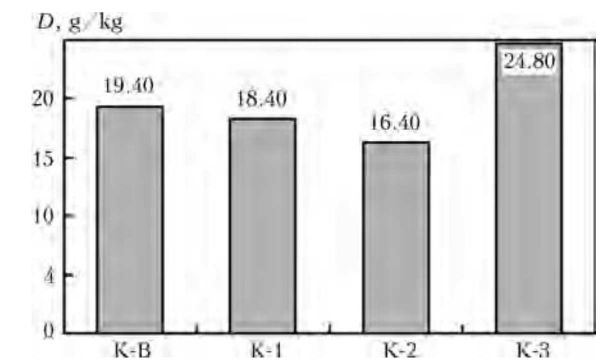

Figure 3. Specific precipitation of HCWA of electrodes with basic coating

Analysis of results of experiment shows that with growth of content of compounds of potassium in the electrode coating, the specific precipitation of HCWA is decreased that can be explained by the decrease in voltage (see Table 4) due to increase in number of ions of potassium in the arc column. This leads to the decrease in power of arc discharge and reduction of intensity of evaporation of molten particles of metal and slag. However, at high content of compounds of potassium (E5) the speed of evaporation is increased in spite of decrease in arc power which leads to the growth of specific precipitation of HCWA, i.e. the factor of growth of concentrations of compounds of potassium in the slag melt operates. The content of K_2O in HCWA is increased and content of toxic compounds of manganese is decreased (see Table 5).

In the second series of experiments (series K) the influence of content of compounds of potassium on sanitary-hygienic characteristics of electrodes with the basic coating was evaluated. As a source of potassium compound the potash (K_2CO_3) was used which was added to the coating in the amounts of 0, 2, 4 and 8 % (Table 6). The content of components, used in the coating and not given in the Table, was not change.

Table 6. Composition of components in coating of basic electrodes, wt.%

Coating components	K-B	K-1	K-2	K-3
Iron powder	30	28	26	22
Potash	–	2	4	8
Type of liquid glass	Na	Na	Na	Na

Table 7. Conditions of welding using coated electrodes of K series

Electrode index	U_w, V
K-B	26–27
K-1	25–26
K-2	24–25
K-3	23–24
Note. Welding current of 190–200 A.	

Table 8. Chemical composition of HCWA compounds of electrodes with basic coating, wt.%

Electrode index	Mn	Si	K	Na	Ca	Al	Fe	F
K-B	4.1	1.9	5.2	14.0	15.0	0.33	16.9	23.2
K-1	3.6	1.5	12.0	12.7	11.6	0.35	18.1	18.1
K-2	3.3	1.4	13.8	11.8	10.7	0.27	17.9	18.3
K-3	2.6	1.2	19.6	9.4	9.6	0.20	17.1	20.3

The welding was carried out at direct current of reverse polarity from the rectifier VD-306. The conditions of welding are given in Table 7, the chemical composition of HCWA — in Table 8, specific precipitation of HCWA — in Figure 3.

The results, as in previous series for electrodes with rutile coating, show that increase in content of alkali metals in electrode coating leads firstly to decrease in precipitation of HCWA and at high content of potassium compounds — to the growth of HCWA precipitation. Such dependence is explained by the effect of two opposite acting factors: on the one hand, by decrease in arc power as a result of drop of voltage and, respectively, the decrease in temperature of melts of metal and slag that leads to the reduction in intensity of evaporation, and, on the other hand, by increase in content of compounds of alkali metals with high vapor pressure in slag that leads to the growth of evaporation intensity. At the certain stage (at high content of potassium compounds) the second factor is prevailed and leads to the growth of precipitation of HCWA (K-3).

It was found using X-ray fluorescent analysis of chemical composition of HCWA that with the growth of content of compounds of potassium in the electrode coating of the basic type the content of potassium in HCWA is increased, whereas content of manganese, silicon, sodium and calcium is decreased (Table 8).

The carried out investigations prove the possibility of improvement of sanitary-hygienic characteristics of electrodes due to regulation of composition of coating. The obtained results represent a practical interest and will be used in future development of universal electrodes with coating of a rutile type.

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MODERN WELDING MARKET OF THE NORTH AMERICA

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In the article the statistical data characterizing the state-of-the-art and main trends in development of welding market in the North America are given.

Keywords: *welding equipment, welding consumables, main values, market, statistics*

The market of welding equipment of the North America is one of the largest regional markets in the world (30 % of the world welding market). According to the data of the American Bureau of Statistics, in the USA in 2011 the cost volume of the production of equipment (excluding transformers) and accessories for welding and brazing, such as equipment for arc, resistance, gas, plasma, laser, electron beam, ultrasonic welding; welding electrodes, welding wire (coated and with a core); equipment for brazing (except manual soldering irons) amounted to 4.9 bln USD (2009 — 3.6 bln USD, 2010 — 4.1 bln USD). The volume of import from 76 countries of the world amounted to 1.4 bln USD, and export — 1.8 bln USD (163 countries). Thus, the cost volume of consumption of equipment and materials for welding and brazing in the USA in 2011 amounted to 4.6 bln USD. It should be noted that in spite of 25 % annual growth of production the welding industry of the USA in 2011 did not reach the pre-crisis volume of production which amounted to 5.1 bln USD in 2008 [1].

In Figure 1 the structure of production of the main types of products for welding and brazing in the USA in 2011 is presented.

In the structure of US production 79 % account for the equipment and accessories for welding and brazing and 21 % — materials. The main share of production of welding equipment (about