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THE INFLUENCE OF CORROSIVE ENVIRONMENT ON FATIGUE LIFE OF THE T-SHAPED WELDED JOINTS

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Summary. *The influence of corrosive environment (3% NaCl, high moisture and increased temperature and neutral salt fog and increased temperature) on the characteristics of fatigue resistance of T-welded joints of low alloy structural steel 15CrSiNiCu was investigated. Experimental curves of fatigue of T-welded joints under these conditions were built. It was shown that in the presence of corrosive environment and corrosion damages on specimens' surface the characteristics of fatigue resistance of T-welded joints reducing, on which the attention should be paid to during exploitation.*

Key words: *T-shaped welded joint, climatic factors, corrosive environment, neutral salt fog, fatigue, fatigue life.*

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Problem setting. Carrying capacity of welded steel engineering devices (bridges, overpasses, sea stationary platforms, etc.), operating under variable load, is determined by the resistance of welded components and fatigue connections. However, during prolonged use welded connections can be exposed to external variable load and corrosion-aggressive environment. Corrosion-mechanical destruction of welded joints reduces the service life of welded steel structures. To solve the evaluation and prediction tasks of the durability of the exploited welded metal structures it is advisable to experimentally determine the effect of environment and corrosion damage on the characteristics of fatigue resistance of welded joints.

We know that Ukraine is located in the macroclimatic region with temperate climate. In this climate, according to ISO 12944-2 maximum temperatures during the year may reach – 33 and +35°C; calculated time of the moderate humidity 80% at temperatures above 0°C – from 2500 to 4200 hours [1]. Along the coast of the Azov and Black Seas the country has maritime climate. The air in the areas with maritime climate is rich in salts of sodium and chloride.

Therefore, having based on the analysis of corrosive factors in operating conditions it is advisable to consider the impact of the most aggressive ones – increased humidity (industrial atmosphere) and neutral salt fog (sea atmosphere). According to the ND during the research to accelerate the corrosion processes was supported the temperature that does not change their mechanism: the high humidity at (40 ± 2)°C, the neutral salt fog exposure (35 ± 2)°C. Increased humidity (98 ± 2)% under these conditions contributed to the formation of phase films of moisture. Duration of the corrosion tests in such conditions was 1200 hours which equates to 12 years of operation.

Analysis of the known research results. Experimental study of the effect on corrosion protection characteristics as fatigue resistance of the base metal and welded connections can be made directly in solutions NaCl [2 – 11].

The authors of the studies [5 – 8] found that in 3% NaCl solution there is a decrease in the bounds of limited endurance cycles based on changes in stress tee welds 13...43% compared to the air. It should be noted that the tests on the corrosion fatigue in a NaCl solution in the corrosive environment ranged from 10 to 200 hours. In this case the sample surface was free from deep corrosion areas which can be observed in exploited metal structures. Therefore,

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together with the characteristics of resistance to corrosion fatigue of the tee welds in a solution of 3% NaCl it is advisable to assess the impact of climate factors on their cyclic durability.

The objectives of the research is to assess the impact of climatic factors on fatigue resistance properties of the tee welds of metal structures.

Task setting. The study was conducted on specimens of the tee welds of structural steel 15 *CrSiNiCu* of category 12, which is widely used to manufacture durable metal elements under cyclic loads and has increased strength, is well-welded, resistant to atmospheric conditions and operable in temperatures ranging from minus 70°C to plus 45°C.

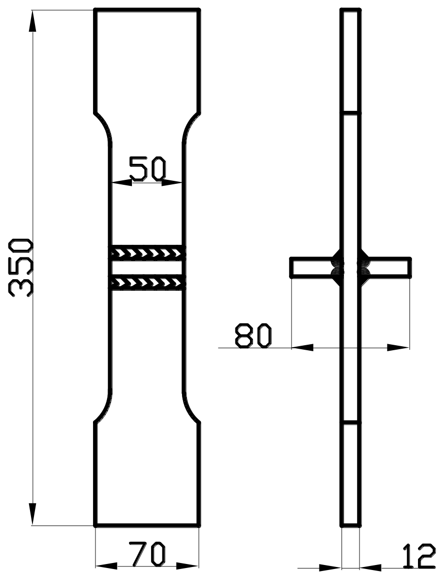

Figure. 1. Geometrical characteristics of specimens

The casts 350×70 mm for the specimen welds were cut from hot rolled sheet 12 mm thick (such specimens thickness is due to extensive use in welded steel sheet products with thickness 8... 14 mm). Taurus welds were made by welding manual arc with artificial electrodes UONE 13/55 to the plate of the transverse stiffeners ribs with angled seams on both sides from the center. The root seam was made with electrodes 3 mm in diameter and the facing seam had 4 mm in diameter. The shape and size of the geometric specimens of the tee welded joints are shown in Fig. 1. The width of 50 mm specimens was chosen considering the capacity of the tested equipment.

Mechanical properties of the tested steel and its chemical composition are presented in Table 1 and Table 2 respectively. The chemical composition of steel 15 *CrSiNiCu* was analyzed by the spectral method for optical emission spectrometer Spectrovac-1000.

Table 1

The mechanical properties of the steel 15 CrSiNiCu

σ_T, MPa	σ_B, MPa	δ, %	$KCU_{-40^0 C}$, J/sm^2
400	565	27	84

Table 2

The chemical composition of the steel 15 CrSiNiCu

Mass fraction of the elements, %							
C	**Si**	**Mn**	**S**	**P**	**Ni**	**Cr**	**Cu**
0,142	0,466	0,63	0,020	0,013	0,31	0,66	0,34

Fatigue testing of welded specimens was performed on a test machine URS 20 (with a maximum effort ± 20ts) under uniaxial tension with the alternating asymmetry of the cycle $R_\sigma = 0$. The frequency of the load was 5 Hz. For complete test criteria were used specimens of complete destruction or those which achieved cycle base $2 \cdot 10^6$ of stress changes.

Fatigue resistance characteristics were examined on tee welds specimens of four types:

- in the initial phase (no corrosion damage) in the air (the first batch),
- in the initial phase (without prior corrosion damage) in 3% solution of NaCl (second batch),
- specimens with corrosive damages formed by the impact of high humidity for 1,200 hours in the air (the third batch);
- specimens of corrosive damages formed after exposure to neutral salt fog for 1200 hours in the air (fourth batch).

To conduct tests in 3% NaCl solution there was developed and manufactured special equipment – removable stainless steel cell 12H18N10T that before the tests had been set directly on the sample in the unloaded position. The gap between the cell and the specimen was compacted with rubber and filled with silicone to avoid their interaction. The specimen of the cell was installed in the gripping devices of the testing machine, and then the cell was filled with 3% NaCl solution of about 1.2 liters. This design ensured continuous contact of the welded seam, heat-affected zone and the part of the main metal with the solution during fatigue testing. The average of the specimen, which contacted with the solution, was about 100...120 mm. Each specimen was tested in a new solution.

Accelerated corrosion testing of welded joints immediately after welding was performed in high humidity and neutral salt fog in accordance with GOST 9,308 1 with method [12].

Research results.

After testing in high humidity conditions for 1200 hours the specimens of welded joints were covered with a layer of brown corrosion products with some black patches. There were some patches on the surface without corrosion products. Those were hot rolled patches of the surface with a dark metal layer, Fig. 2, *c*. After the removal of the corrosion products some small corrosion spots were visible on the surface of a maximum depth of about 80 microns.

In the neutral salt fog conditions on the surface of the welded joints specimens a thick brownish-black layer (1...3 mm) of the corrosion products of the uneven thickness is formed, Fig. 2, *d*. Deep corrosion damaged areas of different sizes with the largest reaching 1 mm were visible after removal of corrosion products on the entire surface. The thickness of the specimen decreased in the welded seam and geometrical legs welded seam.

The appearance of specimens after fatigue testing of the tee welded steel joints 15 *CrSiNiCu* for all the above conditions are shown in Fig. 2, fatigue curves in Fig. 3. The summary results of the studies on the influence of environment on the bound of limited endurance cycles based on $2 \cdot 10^6$ changes in stress of the tee welds are presented as a histogram in Fig. 4.

During the examination of the damaged specimens it was observed that in all cases the destruction took place through the transition of the welded metal to the base metal (Fig. 2), indicating a strong influence of mechanical stress fracture in comparison to the impact of the corrosion factor.

a

b

c

d

Figure 2. Appearance of the T-shaped welded joint specimen after fatigue testing: a – in air; b – in 3% NaCl solution; c – in air after testing in the conditions of an increased humidity during 1200 hours; d – in air after testing in the conditions of neutral salt fog during 1200 hours

After testing in 3% NaCl the surface of the specimens was covered with a thin layer of corrosion products which is typical for continuous uniform corrosion by total immersion. After removing corrosion products the surface remained fairly even, without local corrosion damage. The analysis of research results (Fig. 3, curve 2) found that the boundary of the limited endurance on the base $2 \cdot 10^6$ cycles reduced by 37% (from 179 MPa to 112 MPa), cyclic durability of the investigated range was about 4 times in comparison with the similar characteristics in the air (Figure 3, curve 1).

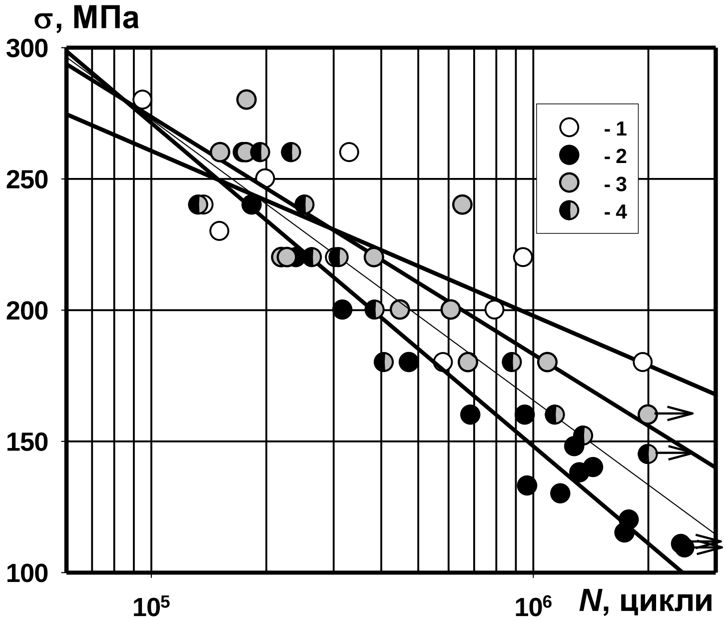

Figure 3. S-N curves of T-shaped welded joints of 15CrSiNiCu steel: 1 – in air; 2 – in 3% NaCl; 3 – in air after testing in the conditions of increased humidity during 1200 hours; 4 – in air after testing in the conditions of neutral salt fog during 1200 hours

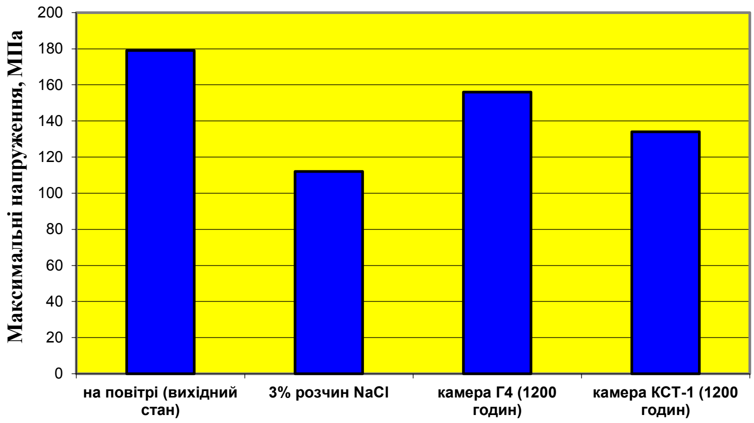

Figure 4. The breaking point of the T-shaped weld-joints of *15CrSiNiCu* steel on the base of $2 \cdot 10^6$ cycles in different environments

After exposure to high humidity for 1200 hours, decrease in fatigue resistance characteristics of the tee welds was observed, Figure 3, Curve 3: the bound of limited endurance cycles based on $2 \cdot 10^6$ cycles was 13% (from 179 MPa to 156 MPa), cyclic durability in the range $4 \cdot 10^5 ... 2 \cdot 10^6$ cycles was about 2 times.

Previous influence of neutral salt fog for 1200 hours (Fig. 3, curve 4) led, as in the above cases, to reduction of the fatigue resistance characteristics of the tee welds: bound of the limited endurance on the basis $2 \cdot 10^6$ cycles decreased by 25% (from 179 MPa to 134 MPa), cyclic durability in a range of cycles $2 \cdot 10^5 ... 2 \cdot 10^6$ decreased by about 2.5 times (Fig. 3).

Thus, the presence of corrosive environment and corrosive damage on the surface reduces fatigue resistance characteristics of tee welded joints, which must be taken into consideration during the exploitation.

Conclusions.

Corrosion fatigue failure and fatigue failure of T-welded joints of *15CrSiNiCu* steel with corrosion damages run through the alloying line of the weld metal with the base metal, which indicates dominant influence of mechanical stress in the fracture in comparison with the corrosion factor.

Under conditions of corrosion-fatigue failure the limit of limited endurance on the base of $2 \cdot 10^6$ cycles is reduced by 37% (from 179 MPa to 112 MPa), the fatigue life – about for 4 times in comparison with similar characteristics in the air.

It was shown that the exposure of welded joints at high humidity conditions for 1200 hours, at which local corrosion damages were similar to damages formed at industrial atmosphere leads to reduction of the limit of the limited endurance on the basis of $2 \cdot 10^6$ cycles by 13% (from 179 MPa to 156 MPa), and the cyclic durability in the range of $4 \cdot 10^5 \ldots 2 \cdot 10^6$ cycles reduces by about 2 times. It was established that the forming of local corrosion damages during previous exposure in neutral salt fog for 1200 hours (similar to marine atmosphere) assists in reducing the limit of the limited endurance on the base of $2 \cdot 10^6$ cycles of T-welded joints about by 25% (from 179 MPa to 134 MPa), while fatigue life in the range $2 \cdot 10^5 \ldots 2 \cdot 10^6$ cycles reduces up to 2.5 times.

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ВЛИВ КОРОЗІЙНОГО СЕРЕДОВИЩА НА ЦИКЛІЧНУ ДОВГОВІЧНІСТЬ ТАВРОВИХ ЗВАРНИХ З'ЄДНАНЬ

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Резюме. *Досліджено вплив корозійного середовища (3% NaCl, підвищеної вологості й температури та нейтрального соляного туману і температури) на характеристики опору втомі таврових зварних з'єднань низьколегованої конструкційної сталі 15ХСНД. Побудовано експериментальні криві втоми зварних з'єднань за цих умов. Показано, що корозійне середовище та наявність на поверхні корозійних пошкоджень сприяє зниженню характеристик опору втомі таврових зварних з'єднань, на що треба звертати увагу під час експлуатації.*

Ключові слова*: таврове зварне з'єднання, кліматичні чинники, корозійне середовище, нейтральний соляний туман, втома, циклічна довговічність.*

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