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INVESTIGATION OF THE LONG-TERM EFFECT OF ECONOMICAL MODIFICATION OF STEEL FATIGUE OF OFFSHORE DRILLING RIGS

Abstract. *The influence of calcium (from 0.001 to 0.01%) on the quality of low-alloy steel is studied, in particular, the corrosion-mechanical and long-term (tired) strength of the tested steel, which was designed for long life in aggressive marine environments, was determined.*
Keywords: *offshore drilling rig, steel, corrosion resistance of the metal, calcium.*

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ПОДОВЖЕННЯ ЕКСПЛУАТАЦІЙНОГО РЕСУРСУ МОРСЬКИХ БУРОВИХ ПЛАТФОРМ ШЛЯХОМ ПІДВИЩЕННЯ ТРИВАЛОЇ ВТОМЛЕНОСТІ МЕТАЛОКОНСТРУКЦІЙ

Анотація. *Досліджено вплив кальцію (від 0,001 до 0,01%) на якість прокату низьколегованої сталі та корозійно-механічну і тривалу (втомлену) міцність дослідної сталі, призначеної для тривалої експлуатації в агресивному морському середовищі.*
Ключові слова: *морська бурова платформа, сталь, корозійна стійкість металу, кальцій.*

Introduction. As is known from numerous literature data [1 – 6], practice and experience of the authors of this article, low-alloy building steels are currently characterized by insufficiently high and stable corrosion-mechanical properties, as well as resistance to fatigue failure during prolonged operation in aggressive environments (marine salt water, especially in the presence of bacteria). This condition is due to insufficient deoxidation and desulfurization of molten steel. It is established that the introduction of calcium into steel deoxidized by aluminum, usually leads to the appearance in the cast metal of non-metallic inclusions, which may contain oxides, sulfides and oxysulfides, which contributes to the clogging of the rolled product.

However, from metallurgical sources [4, 5] it is known that at optimal introduction into liquid molten metal of calcium impurities in the amount of 0.002-0.004% at a temperature of 1600C liquid calcium aluminates give the formed non-metallic inclusions a globular shape, which easily coagulates and is rapidly removed from crystallization metal, which, in turn, contributes to a significant reduction in contamination of rolled steel with harmful non-metallic inclusions.

It should be noted that the role of calcium when added to the metal during smelting is not only to change the shape and dispersion (quantity and size), but also to the ability to significantly affect the mechanical properties of steel due to phenomena associated with intercrystalline internal adsorption [4]. Therefore, changes in the structure of cast steel, economically doped with calcium, due to the fact that calcium, being a surface-active element, adsorbed on the surface of growing branches of dendrites (crystals) delays their growth, thereby promoting the growth of high-order branches and new crystallization centers. The consequence of this action of calcium is disoriented growth of dendrites and fragmentation of the dendritic structure.

In addition, calcium as a surfactant tends to leave the volumes of phases and crystallites on the formed new surface. In [7], estimates of the quality of the macrostructure of 13G1SU cast steel billets treated with calcium-containing wire are presented, which are characterized by almost complete absence of defects in the liquation bands of point inhomogeneity, axial and cuboid cracks and surface carburization.

The aim of the study was to study the effect of calcium (from 0.001 to 0.01%) on the quality of rolled low-alloy steel, in particular to determine the corrosion-mechanical and long-term (tired) strength of test steel, which was intended for long life in aggressive marine environments.

Materials and research methods. For the study used rolled sheets with a thickness of 50 mm of strong shipbuilding steel of industrial smelting brand 10HSND, to which in the smelting process was added (in the bucket) before pouring ferroalumocalcium ligature. In the ladle sample, the concentration of aluminum and calcium was 0.007-0.009%, respectively, and calcium, depending on the melting from 0.001 to 0.01%. Modifying treatment of steel was performed directly by feeding into the bucket by means of an automated installation flux-cored wire with a diameter of 15 mm. As a powder used ferroalumcal calcium ligature composition of 40% Ca; 40% Al and 20% Fe [7].

Studies of the microstructure were performed on longitudinal microgrinds using a scanning electron microscope "JSM-35CF" (firm "Jeol", Japan), "SEM-515" with a microanalyzer "Link" from "Philips". The sections were examined after chemical etching of the polished section in a 4% solution of nitric acid in ethyl alcohol.

Contamination of the metal with non-metallic inclusions was evaluated by the method of comparison with the scales of GOST 1778-70 (method W4) at 100-fold magnification on undigested microsections. The size of the actual grain was determined by comparison with the scale №1GOST5639-82 at 10-fold magnification. X-ray microanalysis of the composition of non-metallic inclusions was performed on microgrinds without etching using a scanning electron microscope "JSM-35CF" (firm "Geol", Japan), "SEM-515" with an analytical attachment - microanalyzer "Link" firm "Philips". The number of non-metallic inclusions in the selected field of view of 1 mm2 was determined using a television scanner model "Metal Reachers" (France). The super-low concentration of calcium (in thousands of percent by weight) in steel ingots was determined spectrally.

Experimental high-precision equipment was used in the experiments, in particular, a micro-X-ray spectrum analyzer “Superprobe-735” from Jeol (Japan), an X-ray diffractometer “Drone-3” (Russia), and an optical microscope “MM-6” from Leitz (Germany).

Detailed metallographic analysis of the structure and geometry of defects was performed on longitudinal and transverse sections. Phase X-ray diffraction analysis of corrosion products was performed in Coα-radiation. Shooting mode: U = 28kV, I = 10mA. The phase composition was determined by comparing the values of interplanar distances d with the tabular values of interplanar distances of elements and compounds. The quantitative relationship between the phases was determined by comparing the integral intensities of their diffraction lines.

The results of research and their brief discussion. The results of experimental research are shown in Fig. 1 – 6.

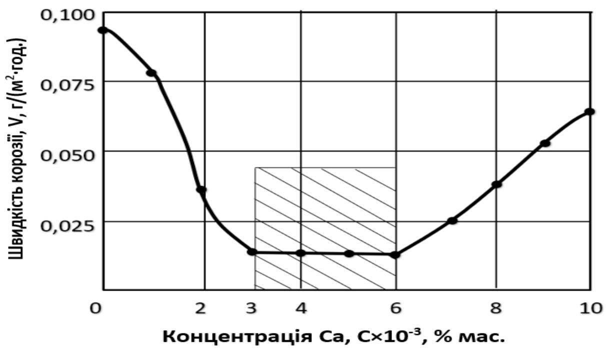

Figure 1 – Influence of calcium concentration on corrosion rate of experimental steel in model aggressive environment: 200 g / l NaCl, Pco2 = 1.0 MPa, t = 40 C. Tests in autoclave installation

Figure 2 – Fatigue resistance ratio based on N = 107cycles in salt water (5% NaCl) in the torsion test (1), axial load (2) and bending (3)

Analysis of the above graphs shows the following. Thus, Fig. 1 shows that the introduction of calcium in a complex way affects the corrosion resistance of the modified test steel. In particular, the highest corrosion resistance is possessed by steels modified with calcium in the amount of 0.003-0.006%, lower or higher concentrations or reduce corrosion resistance, or slightly increase it.

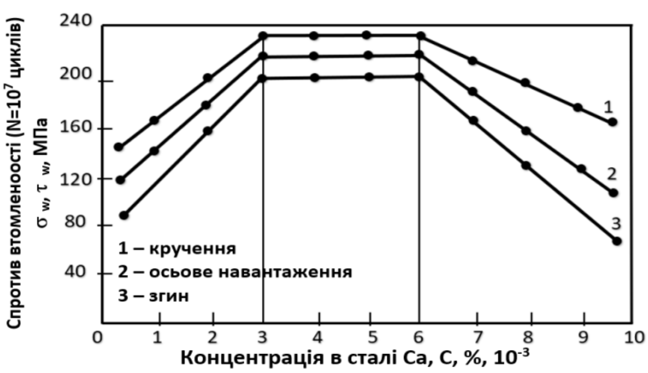

Figure 3 – Relationship between calcium concentration in steel and fatigue resistance based on 107 cycles at torsional deformations (1), axial load (2), and bending (3)

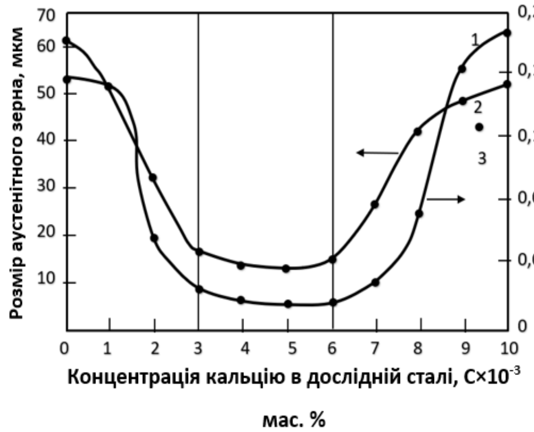

Figure 4 – Influence of calcium concentration on austenitic grain size and dispersion of non-metallic inclusions

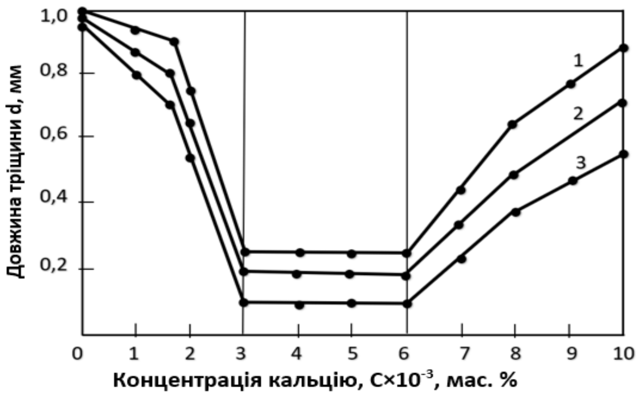

Figure 5 – The effect of calcium concentration on the crack length in the axial section of the sample: 1 - when tested for bending deformation; 2 - axial load; 3 - torsional deformation

However, it follows from Fig. 1 that stably (visible plateau) high corrosion resistance in the aggressive environment of the autoclave installation was evidenced by samples of steel, economically modified with calcium in the range of 0.003-0.006%.

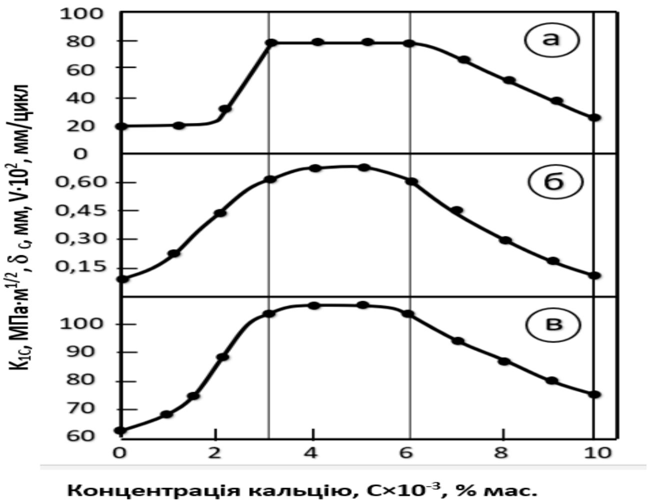

Figure 6 – The effect of calcium concentration in the test steel on the crack growth rate in samples (a), on the coefficients dC (b) and K1C (c) when testing samples in air at t = -40C

Similar results were obtained when testing the susceptibility of steel samples modified with calcium to failure in an aggressive model environment prepared according to the recommendations of the International Corrosion Association (NACE) and in the air (Fig. 2-5). The same trend is observed in the experimental testing of test steel samples for crack resistance (coefficients K1C, δC and ν) - Fig. 6.

Conclusions. As can be seen from the above results of experimental studies, calcium, which economically modified shipbuilding steel 10HSND, had a very positive effect on increasing the corrosion resistance of the metal. This was especially evident when testing samples in a biologically aggressive environment (bacterial).

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