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ТЕХНОЛОГІЧНІ МОЖЛИВОСТІ ВІДНОВЛЕННЯ ЧАВУННИХ ДЕТАЛЕЙ СУДНОВИХ ДИЗЕЛІВ

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Анотація. Застосування сучасних методів відновлення зношених чавунних деталей суднових дизелів є одним з необхідних ресурсів в судноремонті. З чавунних деталей виготовляють складні тяжко навантажені, високоцінні базові складові дизелів, від якості ремонту яких залежить роботоздатність вузла та агрегату в цілому. Для дослідження можливостей відновлення зношених чавунних кришок і поршнів суднових дизелів було досліджено зварюваність сірих і високоміцних чавунів та проведено металографічні дослідження наплавлених поверхонь. Проведені дослідження зварюваності сірого та високоміцного чавунів на імітаторах виявили можливості відновлення чавунних суднових деталей. Одержані результати дають можливість перейти до експериментальних досліджень по розробці технології відновлення на реальних суднових деталях.

Отримані результати дослідження демонструють, що технології відновлення зношених чавунних деталей суднових дизелів мають значний потенціал для покращення якості та тривалості роботи цих деталей.

Наплавлення є одним з найбільш ефективних методів відновлення, оскільки дозволяє точно відновити форму та розміри деталі, а також забезпечити необхідну твердість та міцність.

Висновки дослідження дають змогу розробляти оптимальні стратегії відновлення зношених чавунних деталей суднових дизелів, враховуючи вимоги до якості та ефективності.

Отримані результати можуть бути використані для подальшого удосконалення технологій відновлення, розробки нових матеріалів та процесів, що сприятимуть зростанню промисловості суднобудування та підтримці стабільності морського транспорту.

Ключові слова: суднові дизелі, відновлення деталей, чавун, зварювання, технологія відновлення.

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TECHNOLOGICAL POSSIBILITIES OF RESTORING CAST IRON PARTS OF MARINE DIESEL ENGINES

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Abstract. *The use of modern methods for the restoration of worn cast iron parts of marine diesel engines is one of the necessary resources in ship repair. Complex, heavily loaded, high-value basic components of diesel engines are made of cast iron parts, the quality of repair of which affects the performance of the unit and the unit as a whole. To investigate the possibilities of restoring worn cast iron covers and pistons of marine diesel engines, the weldability of gray and high-strength cast irons was studied and metallographic studies of welded surfaces were performed. The weldability studies of gray and high-strength cast iron on simulators revealed the possibility of restoring cast iron ship parts. The results obtained make it possible to proceed to experimental studies to develop a recovery technology for real ship parts.*

The study results demonstrate that the technologies for restoring worn cast iron parts of marine diesel engines have significant potential to improve the quality and service life of these parts. Surfacing is one of the most effective restoration methods, as it allows for precise restoration of the shape and dimensions of the part, as well as providing the required hardness and strength.

The conclusions of the study make it possible to develop optimal strategies for the restoration of worn cast iron parts of marine diesel engines, taking into account the requirements for quality and efficiency. The results obtained can be used to further improve recovery technologies, develop new materials and processes that will contribute to the growth of the shipbuilding industry, and maintain the stability of maritime transport.

Keywords: *marine diesel engines, parts recovery, cast iron, welding, recovery technology.*

Cast iron is one of the main structural materials in shipbuilding. An important task of ship repair is the restoration of cast iron parts of ship mechanisms. Cast iron is used to make complex, heavily loaded, high-value basic diesel engine parts, the quality of which determines the performance of the unit and the entire assembly.

Welding processes are widely used to restore cast iron parts. The quality of the welded joint depends on the welding method, surfacing and composition of the surfacing materials.

The main methods of repairing cast iron parts that ensure a high-quality connection are welding, surfacing with nickel-based electrodes, low-temperature brazing, mechanized welding with thin copper-based self-shielded wires, plasma methods, hot welding with electrodes, and flux-cored wire, where structural changes in the base metal are minimal.

A large number of critical diesel engine parts are made of gray and high-strength cast iron. Harsh operating conditions (high temperature, pressure, etc.) lead to premature wear and destruction during operation. An analysis of some cast iron auxiliary marine diesel engine parts suggests that the bulk of the cylinder covers have a service life of 40-45 thousand hours. However, 40 % of the examined covers had a service life of only 10-20 thousand hours. This is not enough. The main defect of the examined cylinder covers is cracks between the injector holes and the exhaust channel socket. The results of the study of cast-iron covers of marine internal combustion engines are presented in Table 1.

Table 1

Results of the study of cast iron covers of marine internal combustion engines

№	Brand of internal combustion engine	Examined, samples	A, amount, samples	B, amount, samples
1.	8DR30/50	21	10	5
2.	6CHN18/22	14	12	–
3.	6CHN 25/34	4	–	4
4.	6CHN 36/15	3	1	–
5.	8VAN22	2	–	2
6.	4NVD24	1	–	–
7.	Total	45	23	11

A – a crack between the nozzle and the valve seat.

B – defect in the valve seat.

Other common causes of cylinder head failure include sinks and pits in the valve seats, defects in the seat pads, crumbling, breakage, structural changes, delamination, longitudinal cracks in the indicator hole area, and vertical cracks in the nozzle seat area. In addition, there is burnout of the landing pad during operation, corrosion damage to the sealing surfaces, etc. Sometimes there are cracks in the cover body on the side of the water-cooling cavity.

Thus, it makes sense to develop a technology for restoring cast iron covers of auxiliary diesel engines to restore all the places named in them.

In addition to gray cast iron, which is used for the manufacture of marine engine covers, high-strength cast iron has recently been used. For example, the main engine cover of MANK6Z57/80F and others are made of high-strength cast iron grade 42-12. During operation, these covers develop cracks on the side of the fire cavity, which also need to be restored.

The analysis of the examined cast iron pistons removed from ships according to the ship failure cards showed that the main defects for most of them are horizontal cracks and breaks in the piston head along the groove of the upper oil skimmer ring, cracks in the cap between the oil skimmer holes, cracks in the head between the first and second compression rings, head gaps, etc.

The 8DR30/50 and 6CH18/22 piston heads have cap wear above the permissible values.

The analysis of known defects in cast iron ship parts leads to the conclusion that the destruction of piston heads in the area of bosses, oil skimmers and compression rings, bottom burns, etc. cannot be repaired. The results of the examination of cast iron pistons of marine internal combustion engines are presented in Table 2.

Table 2

Results of the inspection of cast iron pistons of marine internal combustion engines

№	Brand of internal combustion engine	Examined, samples	Caps wear
1	6CH25/34	20	1
2	8DR30/50	17	12
3	6CH18/22	9	7
4	6RPN36/45	3	1
5	8VAN22	2	2
6	Total	51	23

In addition, it should be noted that in parts with an operating time of 30-35 thousand hours, there are cases of graphitization of the material, i.e., cementite disintegration with the release of structurally free carbon. The cast iron becomes more friable, which contributes to oxidation and changes in its structure. Therefore, it makes no sense to restore cast iron parts that have served no more than 35 thousand hours.

Studies have shown that one of the most common defects in piston heads is cap wear. 45% of the pistons examined had this defect. This type of wear is the most common, so the development of a technology to restore cast iron ship pistons with worn caps is of interest.

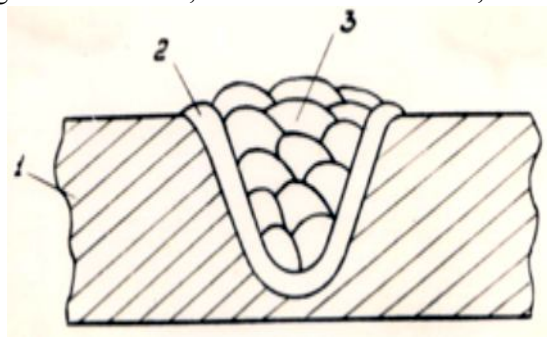
To investigate the possibilities of restoring worn cast iron caps and pistons of marine diesel engines, it is necessary to study the weldability of gray and high-strength cast irons and conduct metallographic studies of the welded surfaces.

Mechanized arc welding with PANCH-11 self-shielded wire allows the process to be performed in the cold [2]. In addition, cold welding requires significantly less energy

compared to hot welding and provides more favorable working conditions for the welder. However, welding of cast iron of large thicknesses, which is exactly what happens on the covers of marine diesel engines with PANCH-11 wire, faces a number of difficulties. They are primarily related to the fact that welding is performed in several passes. The multi-pass austenitic welds obtained in this way are prone to hot cracks.

Welding deformations must also be taken into account when welding [3]. The importance of this factor increases significantly when welding (surfacing) massive parts, such as main ship diesel engine covers and piston heads, especially when the part is not subjected to heat treatment. Therefore, the weldability of gray and high-strength cast irons was studied on technological plates mounted on devices that dramatically reduce the value of angular welding deformations.

Studies were carried out to select the most technological method [4] of cold welding of gray cast iron according to the following scheme: cladding the workpiece with PANCH-11 self-shielded wire and filling the workpiece with aggregate (Fig. 1), which was used as surfacing with MNCH-2; UONI 13/45 electrodes, etc.



a)



b)

*Fig. 1. Welding joint with the cladding
a) scheme of filling the development;
b) microstructure of the weld.
1 – base metal; 2 – cladding layer; 3 – filler.*

When studying the weldability of gray cast iron on technological plates with a size of 500x200x28, the cladding of the development was performed by semi-automatic welding at $I_w = 150-170$ A, $U = 16-18$ V with PANCH-11 wire, 1.2 mm in diameter.

Filling of the development was performed with MNCH-2 electrodes on a copper-nickel base $\varnothing 4$ mm at a constant current of reverse polarity $I_w = 120$ A. The weld formation is satisfactory, without pores and cracks. There are some undercuts.

Studies of the microstructure of the welded joint showed that there are no pores and cracks in the fusion lines of cast iron with nickel and in the fusion zone of nickel with copper-nickel filling (Fig. 2, a, b). At the same time, there are cracks in the austenitic cladding layer (Fig. 2, c).

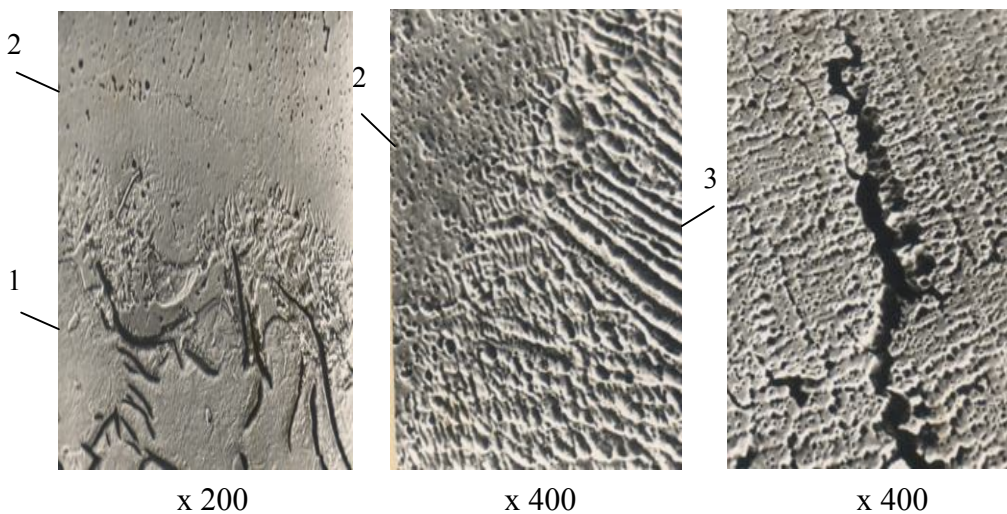


Fig. 2. Structure of weld metal with PANCH-11 wire cladding
a) the fusion boundary of the base metal and the cladding layer;
b) the fusion boundary of the cladding layer and the aggregate;
c) cladding layer.
1 – base metal;
2 – surfacing with PANCH-11 wire;
3 – surfacing with MNCH-2 electrodes

When filling the development with OZCH-2 electrodes (surfacing was performed at a constant current of $I_w = 140$ A, reverse polarity with a $\varnothing 4$ mm electrode), due to the high low-flow rate of the iron-copper alloy, the weld formation is unsatisfactory. There are undercuts and crusting is also unsatisfactory.

It is difficult to achieve a stable process. But at the same time, metallographic studies have shown the absence of cracks in the welded joint (Fig. 3). Along the line of fusion of the cladding layer with the base metal, there are hardened structures with a microhardness of 370 N μ . Fig. 4 shows the nature of changes in the microhardness of the joint.

Difficulties associated with good weld formation make it difficult to use OZCH-2 electrodes to fill the workpiece during multi-pass welding of thick plate joints.



Fig. 3. Microstructure of the weld metal, where they were used as filler electrodes OZCH-2

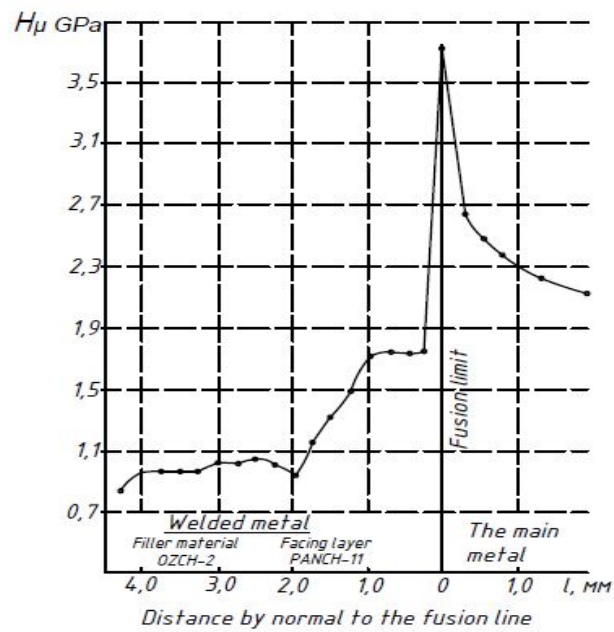
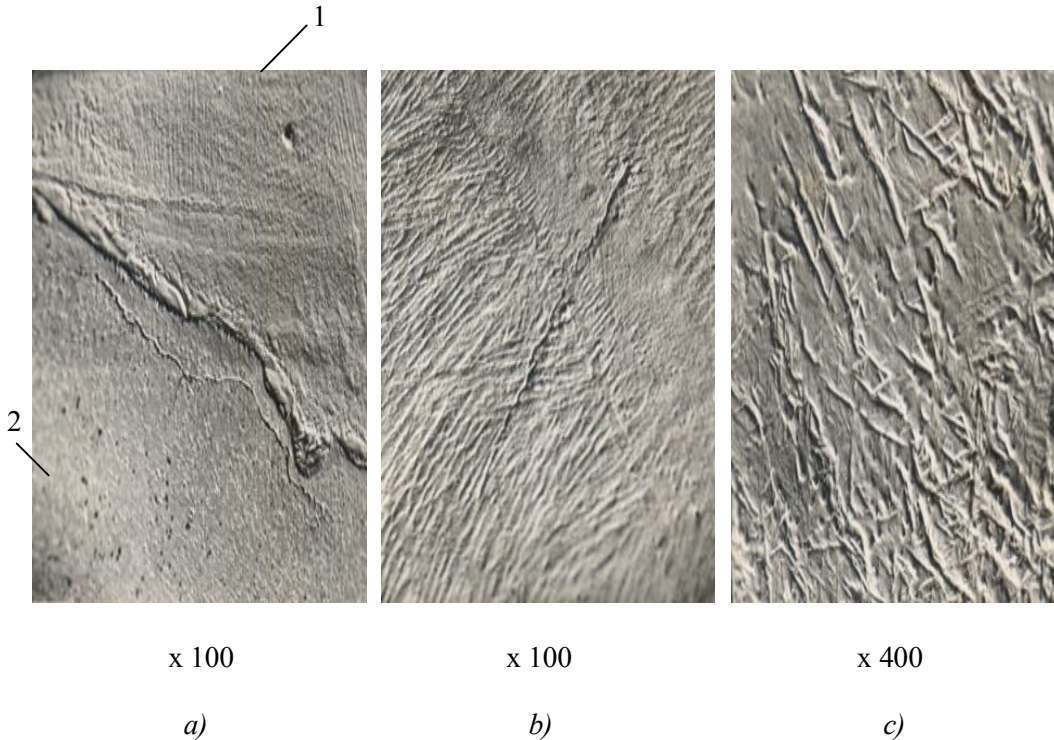


Fig. 4. Change in microhardness along the welded joint sections when surfacing with OZCH-2 electrodes:
• – experimental values

The filling of the development on the cladding layer with UONI 13/45 steel electrodes was studied. The surfacing was carried out at a constant current of reverse polarity at $I_w = 140$ A with a $\varnothing 4$ mm electrode. The welding process proceeded stably, the weld formation was satisfactory, and no pores, undercuts, or cracks were detected during visual inspection. The slag crust separation is satisfactory.

At the same time, metallographic studies showed the presence of cracks in both the cladding layer (Fig. 5, a) and the filler (Fig. 5, b). The structure of the steel weld in the fusion line (Fig. 5, c) is a brittle tetragonal martensite along the grain boundaries, which contributes to the formation of cracks in the weld due to welding stresses accompanying the welding process.



*Fig. 5. Structure of weld metal with PANCH-11 wire cladding and UONI 13/45 electrodes filling:
a – fusion boundary of the cladding layer with the filler;
b – overlapping zone of steel rollers;
c – structure of the filler.
1 – steel aggregate; 2 – lining layer*

The change in microhardness in the welded joint is shown in Fig. 6. The presence of cracks in the cladding layer can be explained by the different shrinkage of the steel roller, which «undermines» the cladding layer and creates a crack in the weld joint.

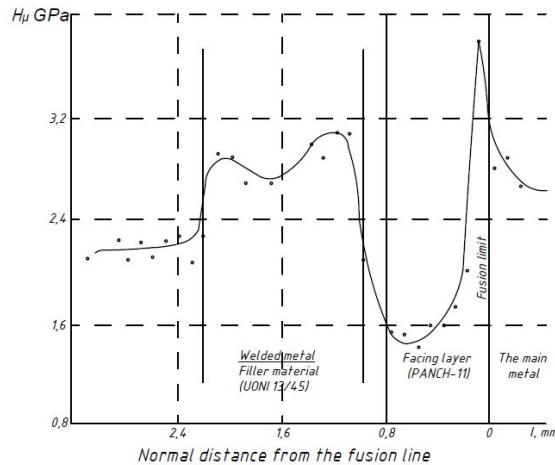


Fig. 6. Change in microhardness along the welded joint sections when surfacing with UONI 13/45 electrodes on PANCH-11 cladding:

• – experimental values

To reduce the role of the steel component in the weld, a welding method with alternating rolls made of PANCH-11 wire and UONI 13/45 electrodes was investigated. Metallographic studies have confirmed that the mixing of austenitic and ferrite layers eliminates the initiation of cracks in the welded joint. Along the fusion boundary between the cladding layer and the base metal, there are always hardened structures, such as lower bainite and martensite (Fig. 7, a).

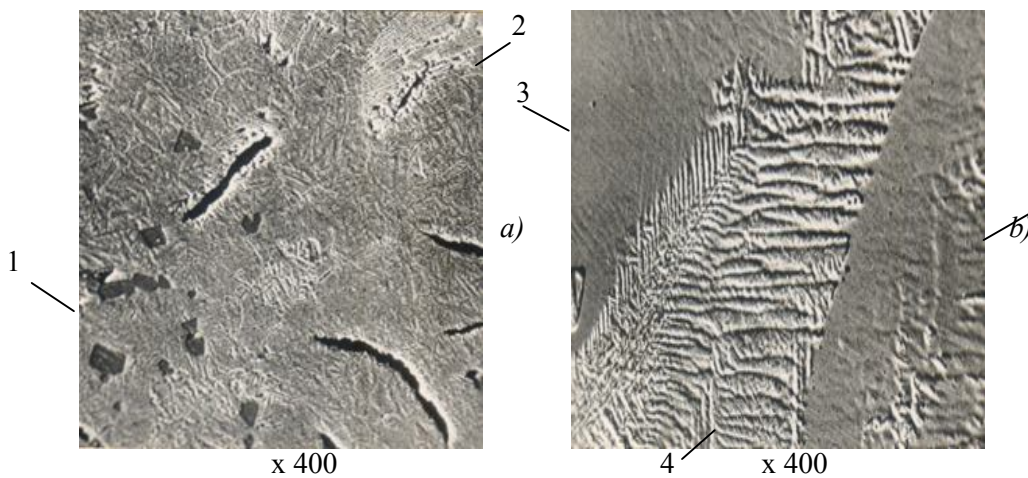


Fig. 7. Structure of weld metal with cladding with PANCH-11 wire and filling with UONI 13/45 electrodes and wire:
a – fusion boundary of the cladding layer with the base metal;
b – mixing zone of ferrite and austenite layers;
1 – base metal; 2 – facing layer; 3 – austenitic layer; 4 – ferrite layer

Fig. 7, b shows the mixing zone between the ferrite and austenite layers. The microhardness study is shown in Fig. 8.

One of the ways to increase the ferrite component in the weld is to introduce iron powder or its mixture with carbon into the weld (it is possible to use cast iron powder-crumbs).

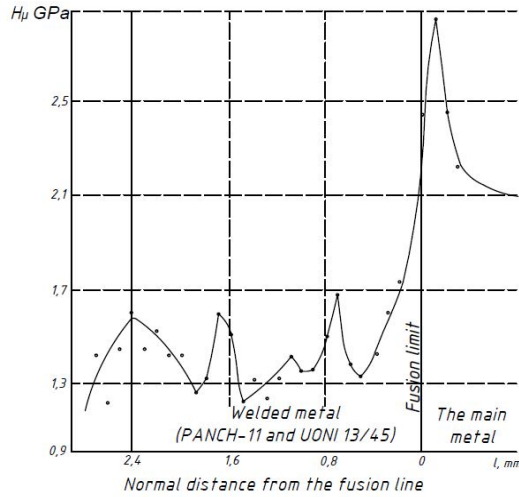


Fig. 8. Change in microhardness of a welded joint with PANCH-11 cladding wire and filling with UONI 13/15 electrodes and PANCH-11 wire:

• – experimental values

The rationality of this is confirmed by research conducted at the Paton Institute of Electricity and Technology, which shows that in welds made with steel and iron-nickel electrodes, the solubility of graphite along the fusion boundary increases. This ensures the high-quality fusion of the base and deposited metal.

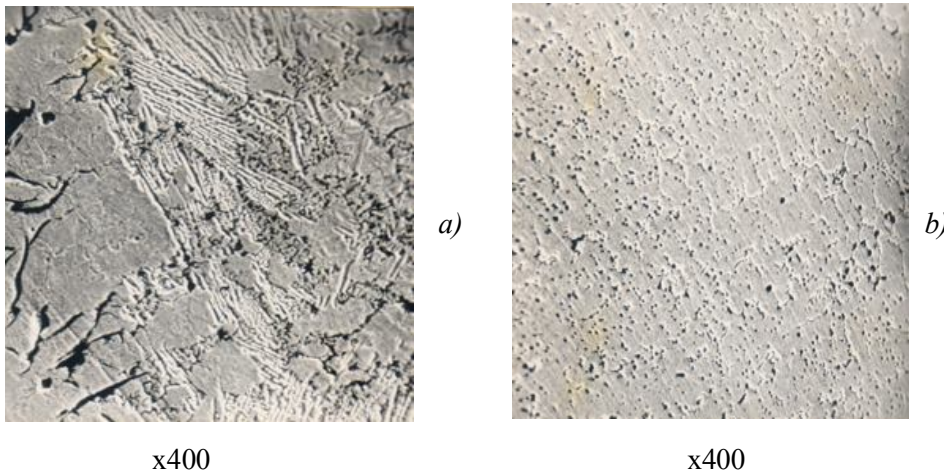


Fig. 9. Microstructure of the welded joint, cut from a cast iron lid:
a - fusion limit; b - deposited layer

In our case, the welding of cast iron samples in a workpiece lined with PANCH-11 wire was carried out over a thin layer of iron or cast iron powder (crumbs). The weld formation is satisfactory. Metallographic studies have confirmed the absence of cracks in the welded joint made on the cover of the 6CH18/22 diesel engine (Fig. 10). The change in microhardness in parts of the welded joint is shown in Fig. 10. The introduction of iron powder into the weld pool increased the hardness of the weld, which will have a positive effect on its strengthening qualities.

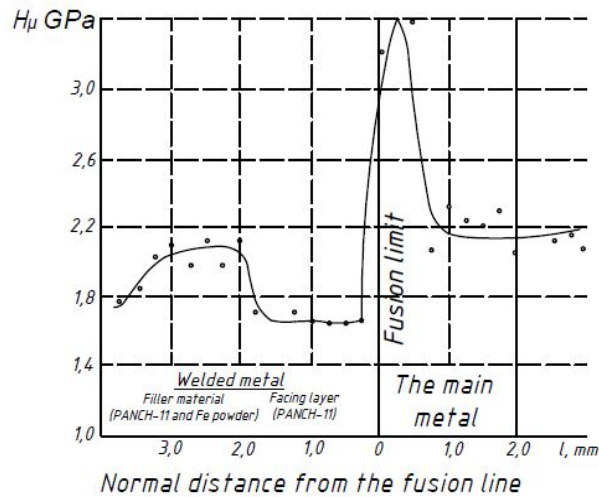


Fig. 10. Graph of changes in the microhardness of sections of a welded joint cut from a cast iron lid:

• – experimental values

The weldability of high-strength cast iron was studied (Fig. 11) on samples cut from the cover of the MAN6Z57/80F diesel engine. Welding was performed by a semiautomatic machine at $I_w = 100 - 180$ A, $U = 18 - 20$ V.

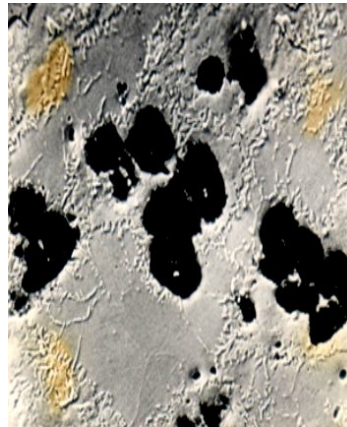


Fig. 11. Structure of high-strength cast iron from the cylinder head of the MAN6Z57/80F diesel engine

The study of the microstructure showed that there are hardened structures in the heat-affected zone (HAZ) (Fig. 12), but with preheating of the cover to 150° with a gas torch (microhardness values are shown in Fig. 12, b). No cracks in the surfacing and HAZ were found, so this welding method can be recommended for the restoration of the main cylinder covers of the MAN6Z57/80F diesel engine from high-strength cast iron.

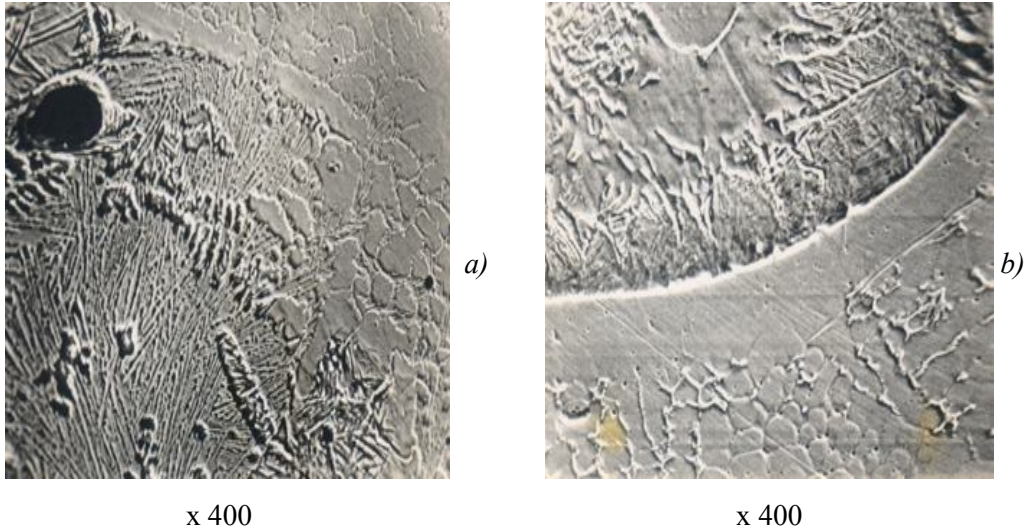


Fig. 12. Microstructure of a welded joint of high-strength cast iron:
a – welding without preheating; b – welding with preheating up to 150 °C

Microhardness studies are shown in Fig. 13.

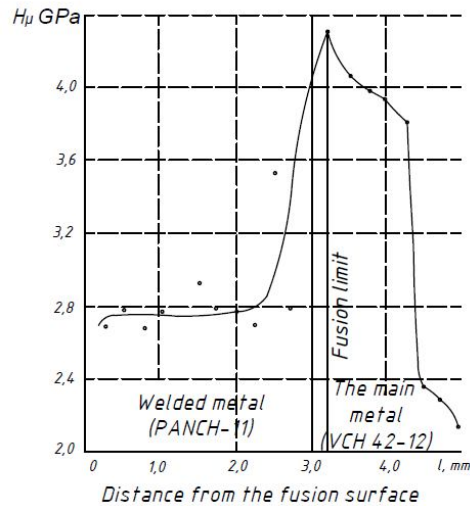


Fig. 13. Graph of microhardness measurements at sections of a high-strength cast iron welded joint (surfacing with preheating to 150 °C):

• – experimental values

Thus, the study of the weldability of gray and high-strength cast iron on simulators revealed the possibility of restoring cast iron ship parts.

The results obtained make it possible to proceed to experimental studies to develop a recovery technology for real ship parts.

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