REPAIR OF SHIP HULL STRUCTURES OF ALUMINIUM ALLOY AMg6 USING ELECTRODYNAMIC TREATMENT

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The electrodynamic treatment (EDT) of welded joints from aluminium alloys AMg6 in ship hulls was carried out. The effect of 50–60 % reduction of initial stressed state was obtained at EDT of full-size samples of welded joints. Technological recommendations for EDT of ship welded hulls were worked out. A high process efficiency was shown by monitoring welded joints of hulls after EDT.

Keywords: *aluminium alloys, ship hull structures, butt joints, residual stresses, electric current pulse, electrodynamic treatment, technological recommendations, service life, impact loads, vibration loads*

Currently the welded hull structures of aluminium alloys are widely used in small-tonnage shipbuilding. It is connected with the fact that aluminium hulls as compared to steel ones and those of glass plastic have smaller weight at equal displacement, thus reducing the operational costs, in particular, for fuel.

Specific operational conditions of rapid ships, such as high level of vibration and impact loads, lead to damages of welded joints of hulls which are eliminated by repair welding. In number of cases the values of residual stresses (RS) in structural elements of a hull after repair exceed an admissible level which leads to fracture of welded joints and makes further operation of a ship impossible. Therefore it is necessary to conduct investigations of progressive and technological methods of controlling RS in the hulls of aluminium ships, which include treatment of structure using pulses of electric current of different duration and configuration. One of the methods of current influence is electrodynamic treatment (EDT) based on initiation of current charges in the workpiece causing formation of local fields of plastic deformations in it, facilitating relaxation processes in treated metal which in their turn results in decrease of general level of RS in the structure [1–4].

The purpose of this work is to study technological capabilities of EDT to control RS in repair welding of trailer cutters (TC) of aluminium alloy AMg6.

At the modern stage of development of small-size shipbuilding in Ukraine, TC became ever more popular due to mobility of movement on the land using special trailer trolley.

The welded TC (Figure 1), the hulls of which were the object of current investigation, had 7.70 × 2.63 × × 1.20 m dimensions in length, width and height, respectively. The necessity in minimizing the mass characteristics of hulls, connected with their transportation on the land, resulted in decrease of the thickness of applied sheet blanks from 5.0–6.0 to 2.5–3.0 mm which allowed decrease of mass of a hull by 30 %. The decrease in thickness of lining strakes is compensated by strengthening of rigidity of longitudinal-transverse load-carrying section, and the preset geometry of a hull in the area of a deck *1*, bottom *4* and forward tip of a keel *2* is provided by a rigid profile of a tubular section. The transverse rigidity in forward and stern tips is preset by vertical *3* and inclined *6* welded supports, and conjugating of stringer set of a bottom and boards with a stern is performed using plain links, i.e. knees *5*. The fitting out of a hull with longitudinal and transverse links provided its minimal deviation from its preset geometry. Therefore longitudinal bending did not exceed 5 mm, and transverse one — 3 mm, that contributed to achievement of the satisfied hydrodynamic characteristics of a ship. Meantime, the high rigidity of a hull in combination with small thicknesses of a load-carrying section and lining make it less resistant to impact and vibration loads in comparison with ships of a conventional design.

During service of a batch of TC, damages in welded joints appeared in some of them that did not allow the further service of ships. The location of characteristic damages of hulls is shown in Figure 2. In tip part the cracks were observed in welds of strengthening the tip winch *1*, joints of tip support *2*, *3* and in

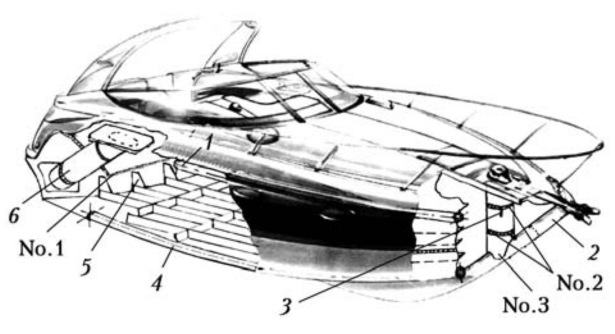

Figure 1. Scheme of welded structure of TC hull of alloy AMg6: *1* — strengthening of deck; *2* — tip tail of keel; *3* — tip support; *4* — bottom strengthening; *5* — knee; *6* — stern support; No.1 — stern strengthening weld; No.2 — support weld; No.3 — weld of support fastening at the stem

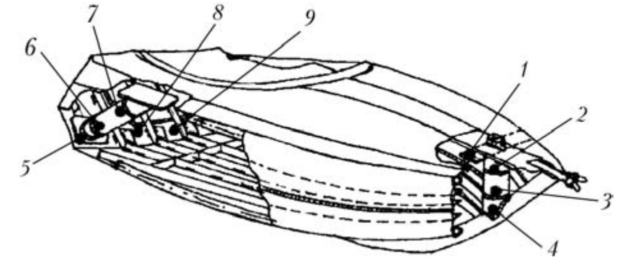

Figure 2. Location of characteristic damages of TC: *1* — tip winch strengthening; *2–4* — damages of tip support; *5–7* — places of damages of stern support; *8*, *9* — stern strengthening under the engine

the places of its fastening at the keel *4*. In stern tip the damages occurred in fasteners of supports to the stern *5* and in welds of supports *6*, *7* and also strengthening under the engine *8*, *9*.

The operability of structures was renovated using repair technologies developed for manufacturing large-size hull of oceanic race yacht of aluminium alloy AMg5M [5]. After the defect was determined its marking was conducted by a marking tool with further mechanical preparation using disc milling cutter for all thickness of a joint. The V-shape crack trepanning with an angle, not exceeding 30°, was used. The length of repair weld exceeded the length of prepared area by 30 mm on each side for guaranteed remelting of microcracks. The butt joints *2–4*, *6*, *7* (see Figure 2) during repair of circumferential welds of tip and stern supports with thickness of wall of up to 3 mm were performed for one pass by manual non-consumable electrode welding in argon using filler rod of 2 mm diameter of the SvAMg6 grade. Welding current was 120 A, and argon consumption — 7 l/min. Rectilinear areas of overlapped welds of thickness (3 + 6) mm during repair of strengthening of winch *1* and stern supports *5* were performed by welding at current 200 A with filler wire of 3 mm diameter. The similar condition was applied for repair of T-joints of stringers of stern strengthening *9* of the thickness (3 + 6) mm (Figure 3). The damages in the corners of stern strengthening *8*, welded of sheets of different thickness (3 + 6) mm, were eliminated using mechanical

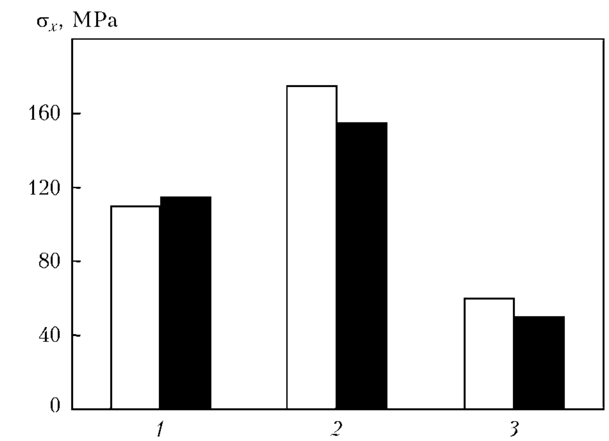

Figure 3. Longitudinal RS in the specimens of longitudinal (white columns) and circumferential (black) welds: *1* — initial RS; *2* — after repair welding; *3* — after EDT

V-groove preparation for the depth of 3 mm from a face surface of welds with further pre-welding at the current not exceeding 150 A.

After completion of repair procedures the damage of repaired welds at minimal run of ships was observed in some cases. The repeated repair welding led to overheating of metal which deteriorated its mechanical properties. Basing on the analysis of service damages it was suggested that their possible reason was high level of RS in renovated joints. This was connected with the fact that ships were manufactured using method of unit-by-unit assembly, providing free shrinkage of welds in welding and, as a consequence, minimal level of RS in the joints. Repair procedures were carried out in ready bodies under the conditions of «rigid fastening» of damaged elements, which excluded free realization of shrinkage shortenings and, as a result, increased the level of RS. The combination of impact and vibration loads with high level of RS in renovated elements of a body leads to damageability of a ship at minimal run.

As far as there are no conditions for realization of free shrinkage during repair of welded joints of TC to control the level of RS, the EDT was applied. To evaluate the influence of repair welds and their further treatment on the level of RS in damaged units of TC the full-scale specimens of structural hull elements were manufactured. The specimens of longitudinal butt joint of strengthening of stern of variable thickness (3 + 6) mm of the size 400 × 400 (see Figure 1, weld No.1), and a pipe of 300 mm length, 100 mm diameter with wall thickness of 3 mm with central circumferential weld as a support specimen (Figure 1, weld No.2) were used. Conditions of manual welding of specimens were in compliance with accepted ones in manufacturing of hulls. The measurements of initial values of longitudinal RS along the central axis of a weld were carried out using mechanical strain gauge with 30 mm base. The technological operations of preparation and rewelding of damages at regular condition accepted during repair of ship stern were carried out on specimens. Then EDT of specimens were carried out using a series of current pulses. The treatment was performed using manual tool representing cylindrical electrode of copper of the grade M1, which is arranged in the isolated casing [2]. The energy of current pulse at EDT is transferred during touch of manual tool in a specified area of the surface being treated.

After repair welding and treatment the current measurements of RS in welds were carried out, the results of which are presented in Figure 3. Basing on the data of the Figure it is possible to conclude: if the beginning level of RS in welds did not exceed 120 MPa, then after the repair of circumferential and longitudinal welds it increased, respectively, by 35 and 60 % and reached 155–175 MPa, which can negatively influence the service characteristics of material. After performance of EDT the values of RS decreased more than by 65 % and did not exceed 50–60 MPa which is proved by efficiency of this kind of treatment.

On the basis of results of the carried out experiments on EDT of specimens of longitudinal and circumferential butts the following technological recommendations on pulsed treatment of problematic welded elements of hulls of small ships of alloy AMg6 were worked out: before EDT of welds in the compartment of a ship it is necessary to clean the area being treated from foreign objects, tool, cable and hose lines; to provide access of manual tool to the area of treatment at the distance of not less than 20 mm from the fusion line of a weld; not to admit positioning of manual tool in a specified point of treated surface for more than one current discharge; to perform EDT in lower and horizontal position of manual tool in the direction from middle to edges of a weld; to perform EDT of circular and circumferential welds in broken order.

On the basis of developed recommendations the treatment of structural elements of welded hulls of TC of alloy AMg6 in the amount of seven units was performed. The EDT of welded joints of tip and stern compartments and also some areas of load-carrying section after repair welding was performed (Figure 4).

In the period of navigation of 2009 the monitoring was made on welded joints of ship hulls, where EDT after repair welding was performed. The results of inspection showed that for the current period TC ran without damages from 300 up to 1320 km, no traces of damages in a form of microcracks in treatment area were detected.

Figure 4. EDT of welded joints of stern strengthening of TC hull

Therefore it can be concluded that EDT is the efficient method of prolonging the service life of thin-wall hull structures of aluminium alloys after repair welding.

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HIGH-QUALITY HOSE PACKS FOR UNDERWATER WELDING AND CUTTING

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Considered are examples of design of special cable products to be used with mechanized equipment for semi-automatic welding, surfacing and cutting. Possibilities of new cable developments for manufacture of hose holders are shown, their advantages and technical characteristics are analyzed, and fields of their efficient application were outlined. Special attention is given to cables employed to power semi-automatic systems operating under extreme conditions.

Keywords: *arc welding, semi-automatic devices, service lines, cable, hose holder, structure, manufacture, service conditions*

The mechanized equipment for welding, surfacing and cutting is traditionally upgraded through improving characteristics of welding current sources, feed mechanisms, control and regulation systems [1, 2] etc. Consideration is also given to other components of this type of the equipment. These are the elements of service lines (welding cables, hose holders), which are based on special cable [3]. The problems addressed with the help of semi-automatic devices are so diverse (various electrode wires, environment and service conditions etc.) that they require a special approach to elements of the service lines and, naturally, determine differences in their designs. And whereas the problem of selection of welding cables for conventional conditions is solved through a choice of what is already commercially manufactured in sufficient quantities and proved good (for example, flexible trailing weld-