DOI: http://dx.doi.org/10.15407/tpwj2019.04.01

INFLUENCE OF PARAMETERS OF ELECTRODYNAMIC TREATMENT ON RESIDUAL STRESSES OF WELDED JOINTS OF ALLOY AMg6

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The influence of parameters, determining the different duration of electrodynamic effect on reduction of level of residual stresses in welds of butt joints of aluminium alloy AMg6 as a result of electrodynamic treatment, was investigated. It is shown that the increase in electrodynamic effect duration, attained by the increase in inductance of a discharge circuit at constant amplitude values of a pulsed electric current, is characterized by a higher increase in time of current decay as compared with the period of its growing. At the same time, the increase in duration of electrodynamic effect leads to the increase in the method efficiency for reducing the level of residual stresses in welded joints of AMg6 alloy. It is noted that at the duration of $t \geq 0.7$ms the reduction in stresses is determined by the electromagnetic effect intensity and Joule heating of the plate surface. 5 Ref., 1 Table, 4 Figures.

Keywords: *electrodynamic treatment, aluminium alloys, electric current pulse, residual welding stresses, electrodynamic effect duration*

The methods of treatment of metallic materials and welded joints by the effect of pulsed electromagnetic fields have found spreading since the 2000s in regulation of a stressed state of the structure elements [1].

One of these methods is the electrodynamic treatment (EDT), based on the combined effect of a pulsed electric current and dynamic pressure on the welded joint. The electrodynamic effect on metal at EDT is realized by a contact of the working electrode to the metal surface at the moment of discharge of a capacitive energy storage. As a result of a combined effect of the dynamic load and pulsed electric current (PEC) the electric pulsed processes, connected with an electroplastic effect (EPE)[1], as well as dynamic processes, defined by the formation of elastic waves of deformations in the material, are initiated in the metal treated. The result of the combined proceeding of electroplastic and dynamic processes are the change in the stressed state of welded joints. The investigations were carried out on evaluation of effect on the efficiency of processing of such parameters of electrodynamic effect, as charging voltage and storage capacity, amplitude values of a pulsed current and dynamic pressure [2]. For all this, the system investigations of influence of duration of electrodynamic effects on EDT efficiency were not carried out until now. However, in accordance with data of works [3, 4], the duration of electric pulsed and dynamic effects, jointly defining the EDT controlling mechanism, has an influence on the stressed state level in structural materials. Coming from the above-mentioned, the study of influence of duration of electromagnetic effects on stressed state of welded joints seems to be rather urgent.

The aim of the present work was the investigation of influence of duration of electrodynamic effect at EDT, as well as the parameters, defining it, on stressed state of welded joints of aluminium alloy AMg6.

Procedure of carried out experiments. The influence of duration of electrodynamic effect at EDT on stressed state of 400×100×2 mm specimens of welded butt joints of alloy AMg6, made by automatic TIG (Ar) welding at the following values of arc voltage, welding current and process speed, respectively: U_w = 20 V, I_w = 170 A and v_w= 5.5 mm/s, was investigated.

To generate the electrodynamic effects, the source of a pulsed electric current (SPEC) with a variable inductance L was used, which was designed on the base of discharge-capacitor systems. The step adjustment of inductance allows changing the PEC duration t and, as a consequence, the intensity of electrodynamic effects [2].

To realize EDT, the electrode device (ED) was used, the appearance of which is shown in Figure 1. The working organ of ED is electrode *1*, the end of which during EDT contacts the welded joint surface. Electrode is fixed in a collet chuck *2,* mounted in a

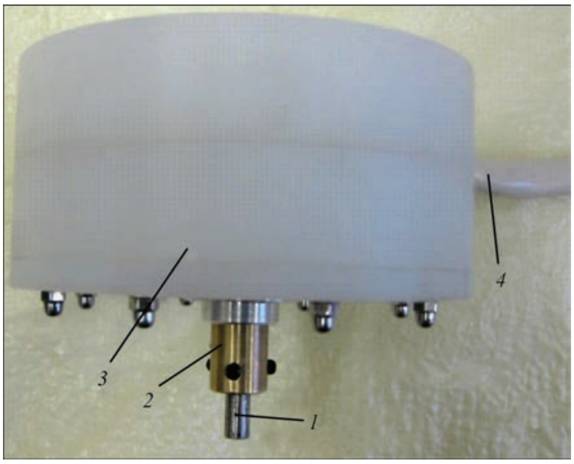

Figure 1. Electrode device for EDT (see designations in the text)

protective casing *3*, which contains the device, providing the effect of electric pulsed and dynamic components of EDT on the welded joint. Power cable *4* provided connection of ED to SPEC.

The EDT (Figure 2) of external surface and root of weld of test specimens was carried out. The treatment was made in the conditions of a «rigid fixation». To realize if the surface of plate *2* before EDT was fixed by a distributed load *q* on the assembly plate *3*, avoiding possible angular deformations of the specimen. This scheme of fixation, according to [5], provided the maximum efficiency of the electrodynamic effect at other equal parameters of the EDT mode. To realize EDT, ED *1* was mounted on the weld surface and provided its guaranteed electrical contact at closing the discharge circuit.

By switching-on of power switch K the discharge of capacitive energy storage C through ED into material treated was initiated. The time distributions of pulsed current *I* were recorded by using Hall sensor *4*, built-in into the discharge circuit, as shown in Figure 3. During EDT fulfillment the ED was moved over the weld surface at 3 mm step. The number of electrodynamic effects provided the electroplastic deforming of the region treated.

The effect of EDT parameters on change in longitudinal (along the weld line) component σ_x of residual stressed state of welded plates of alloy AMg6 at equal amplitude values of pulsed current *I* and variations of *t* was investigated**.** Equality of values *I* at different duration of effect *t*, preset by change in *L*, provided the growth in values of charge voltage U_{ch}. As a basic amplitude value of the pulsed current *I*, *I* = 1.0 kA was selected. Growth in U_{ch} resulted in increase of stored energy of charge E_{ch}.

Using the method of electron speckle-interferometry the values σ_x in weld center of welded plates were determined in initial state and after EDT [2].

Results of experiments and their discussion. The modes of EDT of plates at growth in values *L* and U_{ch}, providing *I* = 1.0 kA at accompanying increase in effect duration *t* and stored energy E_{ch}, are given in Table.

The time distributions of a pulsed current *I* of equal amplitude, corresponding to different effect duration *t*, are given in Figure 3. By analyzing the data of Table and Figure 3, it can be seen that increase in *L* leads to the growth in *t*. Here, the growth of *L* has the greatest influence on time of decay and duration of *t* of PEC, than on time of its growth, that is especially noticeable in comparison of curves *2* and *3*. At the same time, according to [4], namely in the phase of growth the dynamic effect has the most noticeable influence on stress-strain state of metallic materials.

Value σ_x in the weld center in initial state (without EDT) is determined by column 4 in Figure 4, where it is seen that the initial level of residual welding stresses reached 100 MPa. A low level of σ_x before treatment is explained by a small width of used plates.

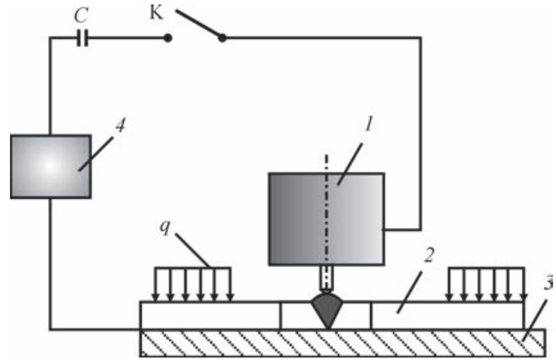

Figure 2. EDT of specimens of welded joints of alloy AMg6 at «rigid» fixation: *C* — capacitive energy storage; K — power switch; *q* — fixing load; *1* — ED; *2* — specimen; *3* — assembly plate; *4* — Hall sensor

Parameters of EDT of welded plates of alloy AMg6 of 400×100×2 mm sizes

No.	Inductance *L*, μH	Voltage of PEC U_{ch}, V	Amplitude of PEC *I*, kA	Duration of PEC *t*, ms	Energy of PEC E_s, J
1	5.3	185	1.0	0.7	94
2	20	388	1.0	1.75	413
3	71.5	726	1.0	4.5	1449

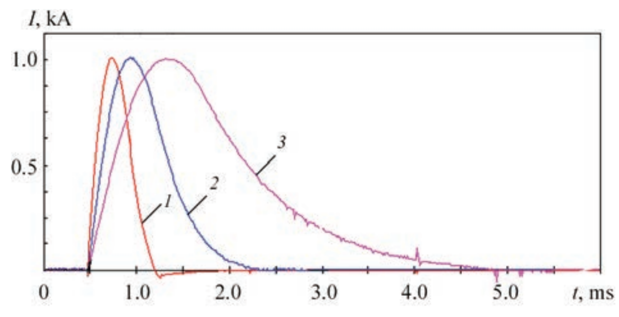

Figure 3. Time distribution of pulsed current *I* of equal amplitude at EDT of welded plates of alloy AMg6 of 400×100×2 mm sizes, where numbers of curves correspond to numbers of Table lines

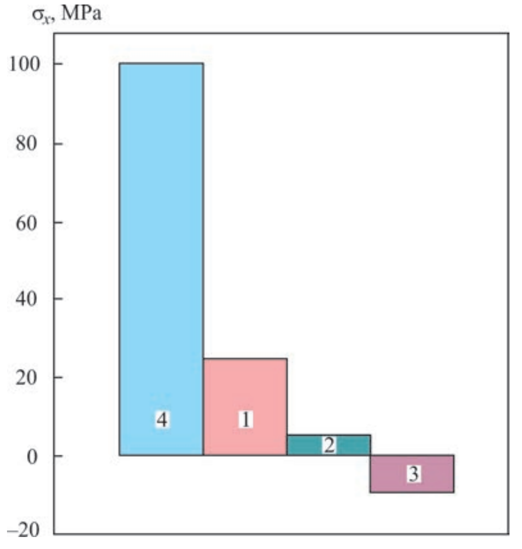

Figure 4. Peak values of stresses σ_x in weld center of welded plate of alloy AMg6 of 400×100×2 mm size, where numbers of columns *1–3* of values σ_x correspond to numbers of curves in Figure 3 (column 4 — σ_x without EDT)

During EDT at a mode, corresponding to minimum inductance (Figure 3, curve *1*), the decrease in stresses is observed in the treatment zone to 22 MPa (column 1). With increase in L (curve *2*) σ_x in the treatment zone is decreased almost to zero values (column *2*). At the further increase in L (column *3*) the stresses are transferred to the compression region, and values σ_x are close to k – 10 MPa (curve *3*). By analyzing the data of Table and Figures 3 and 4, it can be concluded that with the growth in L the effect is increased.

It should be noted, that the increase in EDT efficiency is determined by growth of values E_{ch}, required for keeping conditions I = 1 kA at large values L and, respectively, larger duration period t. In addition**,** during EDT at modes, corresponding to lines 2 and 3 of Table, there was a local fusion of metal in the zone of contact interaction of electrode with plate surface, being treated, due to the Joule heating [1]. Thus, the conclusion can be made, that at EDT of duration t > 0.7 ms, the decrease in level of residual stresses is determined by an electrodynamic effect under the conditions of a local Joule heating of the plate surface.

It should be noted that positive EDT effect on stressed state of welded plates under conditions of high levels of PEC energy is accompanied not only by heating, but also a local damage of the surface treated, which has a negative influence on the cyclic strength of alloy AMg6 [5]. Thus, it can be concluded that the increase in temperature in the zone of PEC effect it is possible to increase the EDT efficiency, avoiding its negative influence on the surface quality. Therefore, the application of EDT directly in the process of welding seems to be promising, that will be future direction of our further investigations.

Conclusions

1. On the basis of the developed procedure the influence of parameters of electrodynamic effect for reducing the level of residual stresses of welded joints of aluminium alloy AMg6, as a result of EDT, was investigated.

2. It was found, that increase in level of electrodynamic effect energy leads to increase in EDT efficiency for regulation of level of residual stresses in welds of butt joints of alloy AMg6. It is shown that at duration of current pulse for more than 0.7 ms the level of stresses is defined by the treatment intensity under conditions of the Joule heating.

3. It is rational, to carry out the further investigations for determination of efficiency of EDT application directly in the welding process.

1. Baranov, Yu.V., Troitsky, O.A., Avramov, Yu.S., Shlyapin, A.D. (2001) *Physical principles of electropulse and electroplastic treatments*. Moscow, MGIU [in Russian].
2. Lobanov, L.M., Pashchin, N.A., Cherkashin, A.V. et al. (2012) Efficiency of electrodynamic treatment of aluminium alloy AMg6 and its welded joints. *The Paton Welding J*., **1**, 2–6.
3. Strizhalo, V.A., Novogrudsky, L.S., Vorobiov,E.V. (2008) *Strength of materials at cryogenic temperatures taking into account electromagnetic fields*. Kiev, IPS [in Russian].
4. Belova, M.M., Protsenko, S.S., Ivanov, A.V. (1987) Dynamics of deformation of elastic-plastic layer in impulse energy release. *Problemy Prochnosti*, **12**, 87–91 [in Russian].
5. Lobanov, L.M., Pashchin, N.A., Yashchuk, V.A., Mikhoduj, O.L. (2015) Effect of electrodynamic treatment on fracture resistance of aluminium alloy AMg6 under cyclic loading. *Ibid*., **3**, 91–98 [in Russian].

Received 24.01.2019