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LASER WELDING OF THIN-WALL FILTER ELEMENTS OF STEEL 08Kh18N10T*

V.D. SHELYAGIN, V.Yu. KHASKIN, A.V. BERNATSKY and **A.V. SIORA**
E.O. Paton Electric Welding Institute, NASU
11 Kazimir Malevich Str., 03680, Kiev, Ukraine. E-mail: office@paton.kiev.ua

The work is dedicated to increase of safety and service life of apparatuses of chemical production due to replacement of brazing process to welding in manufacture of the filter elements. Three methods of welding (argon arc, electron beam and laser) were compared applicable to joining of thin-wall tubular cone billets for the filter elements of stainless steel 08Kh18N10T steel. Defects, typical for indicated methods of welding, were investigated and procedures for their elimination were proposed. It is determined that laser welding has the largest productivity in combination with high weld formation stability that makes its application reasonable as industrial technological process in manufacture of thin-wall cone filter elements. 9 Ref., 5 Figures.

Keywords: *stainless steel, thin-wall products, laser welding, productivity, edges, technological fixture, mechanical properties, corrosion resistance*

Brazing is often used for joining thin-wall billets and requires application of expensive brazing filler materials [1] for producing critical joints at manufacture of corrosion-resistant metal structures in chemical, nuclear and other branches of industry. Replacement of brazing to welding allows reducing manufacturing cost of such joints as well as increasing their mechanical characteristics.

One of the peculiarities of welding of pipe fittings and filter elements of thin austenite stainless steel is a necessity of producing quality defect-free joints, which do not require further finish treatment. Also it is desirable to eliminate the welded product straightening. Obtained welded joints should to the maximum be close with the base metal on mechanical properties and corrosion resistance [2]. Another peculiarity of filter element welding can be necessity in consideration of looseness of abutting edges, caused by presence in them of the holes for end product filtering. All this requires thorough selection of welding method and technological mode. As a rule, indicated tasks are fulfilled with argon arc welding, more seldom laser or electron beam welding [3].

Aim of the present paper is rise of safety and service life of the filter elements of austenite stainless steel 08Kh18N10T by means of replacement of brazing process to welding one at their manufacture. For this a comparative analysis of three welding methods (argon arc, electron beam and laser) was carried out applicable to joining thin-wall tubular cone billets for filter elements; selection of a method providing high weld quality and the highest productivity; development of corresponding welding procedure; complex for testing the welded parts to validate adequacy of developed technology for further industrial implementation.

Cone tubular billets of filter elements of steel 08Kh18N10T [4] of $\delta = 0.5$ and 0.6 mm thickness (Figure 1) were used as welded specimens in performance of experiments on argon arc, electron beam and laser welding. Modes and equipment were selected taking into account recommendations of works [5–7].

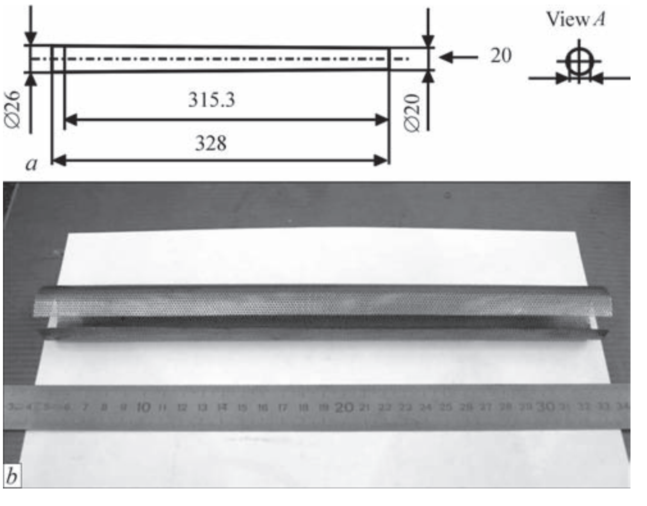

Figure 1. Sketch of tubular cone filter element of steel 08Kh18N10T ($\delta = 0.5$ and 0.6 mm) (*a*) and view (*b*) of billet being welded for its production

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Argon arc welding. Filler wire Sv-08Kh18N10T (1.0 mm diameter) was used for producing sound welds taking into account presence of gaps between the edges being welded. Welding was carried out employing equipment of «Kemppi» Company (Finland), namely power supply «MasterTig MLS 3000» (welding current 5–300 A) and torch «TTC-250WS» (designed for up to 250 A current), and also automatic device was used for filler wire feed. The torch was moved relatively to part with the help of one-coordinate manipulator.

The results of carried investigations showed that a copper substrate with forming cavity should be used for formation of lower reinforcement bead and elimination of welded edges raising in argon arc welding of edges of mesh filter elements. Besides, it is necessary to increase heat sink by application copper pressure plates, which should press welded edges along the whole length at a distance not more that 3 mm on either side of the joint. Lack of penetration and burning through are the typical defects of argon arc welding of mesh filter elements. For their elimination welding should be carried out on the following modes, i.e. welding current $I = 15$ A, arc voltage $U = 20$ V; welding rate $v_w = 15$ m/h, wire feed rate $v_{wire} = 35$ m/h, shielding gas consumption (argon) 10–15 l/h. Sound welds were formed as a result. A zone of mode stability in quality argon arc welding is sufficiently narrow, i.e. indicated mode parameters should be kept with high stability and accuracy.

Electron beam welding. The following equipment were used for experiment performance, namely vacuum chamber with one-coordinate manipulator for movement of an electron beam gun, vacuum aggregate for chamber pumping up to $133.3{\cdot}10^{-5}$ Pa, power source V-250A and electron beam gun UL-119. Sound welds were received only under conditions of presence of solid firmly pressed edges. For this purpose the billets of mesh filter elements were made with previously performed solid edges, having a distance not less than 1 mm till the filter holes. It was determined in course of the investigation that the best welds are formed in welding with the following mode, namely beam current $I = 10$ mA, voltage $U = 21$ kV, welding rate $v_w = 10$–12 m/h, beam defocusing in a spot of around 1.5 mm diameter.

Laser welding. This process allows the gaps between the welded edges in the case of its performance by filler powder material feeding [8]. Granular powders of steel 08Kh18N10T or self-fluxing nickel alloys PG-10N-04 or PG-NCh3 [8] having granules up to 150 μm diameter [9] were used as such. Welding was carried out on a copper substrate without forming cavities. Nd:YAG laser of DY044 model of up to 4.4 kW radiation power from «Rofin-Sinar» Company (Germany), one-coordinate manipulator, welding head and filler powder dosing unit were used in the experiments.

It was determined during the experiments that laser welding also can provoke appearance of lack of penetration and burning through. Selection of modes of filler powder feed in combination with specific values of power and rate allowed obtaining defect-free welded joints (Figure 2). The following area of technological process stability were determined at that, namely radiation power $P = 0.5$–0.6 kW, welding rate $\nu_w = 140$–160 m/h; defocusing value $\Delta F = -15$–-20 mm; filler powder consumption $G_p = 0.2$–0.3 g/s. Such sufficiently wide spread of mode parameters indicates significant stability of laser welding and allows predicting low percent of reject at process industrial application.

It is determined that productivity of argon arc welding of cone specimens of filter elements of 08Kh18N10T steel makes up to 20 filter elements per working shift (8 hours), when laser welding productivity is up to 40 filter elements per working shift. At that, in the first case percent of reject makes up to 20 % and in the second case it is more than 2.5 %.

Comparison of considered three variants of welding of cone specimens of filter elements of steel 08Kh18N10T (δ = 0.5 and 0.6 mm) shows that laser welding has the highest productivity (10–15 times higher welding rate in comparison with competitive methods) in combination with high stability of weld formation. This is the method, which is reasonable

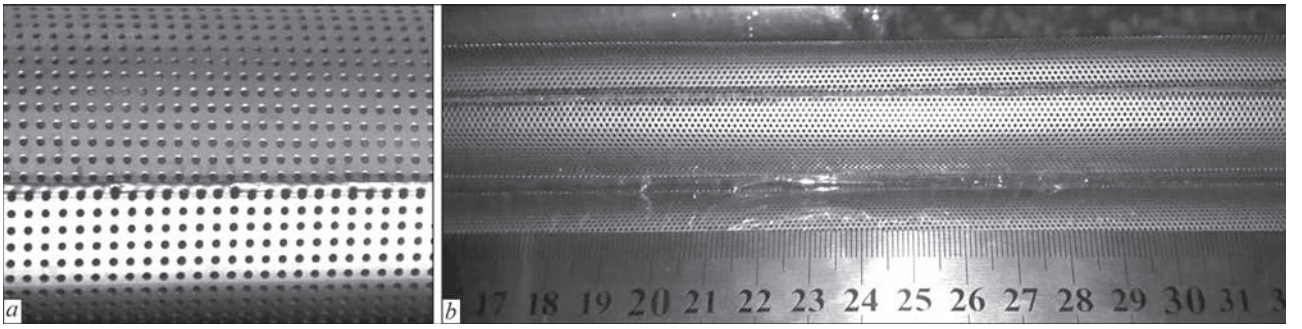

Figure 2. View of welded joint (*a*) and specimen (*b*) of filter element of stainless steel 08Kh18N10T (δ = 0.5 mm), produced by laser welding with powder filler PG-10N-04

for further development of industrial technology with next implementation.

Further development of the industrial technology of laser welding of cone filter elements for chemical industry was carried out on pilot specimens, which were produced in four steps:

● manufacture of perforated sheet of stainless steel 08Kh18N10T of 2000×1000×δ mm (δ = 0.5–0.6 mm) with filter holes of 0.8–1.0 mm diameter and step close to their diameter, using mechanical punching method or spark erosion;

● guillotine flat blanking of filter elements from perforated sheets of 2000×1000×δ mm;

● rolling of flat billets of filter elements for obtaining cone tubes of Ø26×Ø20×328 mm;

● laser welding of edges of rolled billets for obtaining straight seam cone tubes with filter holes.

In flat blanking of the filter elements the filter holes are cut up from a perforated sheet. There is a problem of such edges tight mating without gap for further welding. The reference [6] indicates that a gap between the edges in laser welding should not exceed 10 % of their thickness. Process scheme, shown in Figure 3, was used for this problem solving according to work [7] recommendations. Following the scheme the welded edges *1* are brought together with a gap close on size to their thickness, and tightly pressed to copper technological substrate *6*. During welding the gap is filled with filler powder material *2* and is melted using defocused laser radiation *4*. The next technological fixture was designed and manufactured for realization of proposed scheme: screw clamp for fixing cone tubular specimens; copper substrate inserted in the specimen; welding head with focusing system and dosing unit for feeding of filler materials in form of powder of 20–150 μm fraction. Prototype of developed at the PWI welding bench was used for welding of separate specimens for performance of mechanical and corrosion tests as well as pilot-commercial batch of filter elements for performance of service tests.

A range of specimens was welded using the selected technological modes with alternating and pulse laser radiation for determination of mechanical properties of produced joints. Static tension samples, type XXIV (three samples for each value) were cut out from produced specimens on GOST 6996–66. The tests were carried out using tensile testing machine MTS 318.25 at 20–25 °C temperature and loading rate 4 mm/min. Received results were used for determination of the average values of ultimate strength σ_t (MPa) for application of continuous laser radiation as well as pulse radiation of low (12 Hz) and comparatively high (200 Hz) frequency. Welding heat inputs in all cases were the same. Figure 4 shows a diagram with test results. As can be seen from the Figure, laser welding of loose edges with powder filler material in the case of application of continuous as well as pulse with low frequency radiation provides 90 % level strength of the base metal. It can be explained by usage of defocused radiation, effect of which on weld grain refinement, and, respectively, rise of joint strength, is not so obvious as effect of focused one. Nevertheless, obtained index is acceptable for the problem being solved.

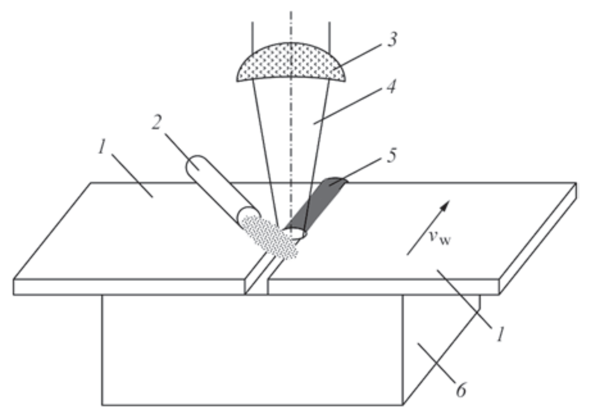

Figure 3. Technological scheme of laser welding process of edges of pilot specimens of cone filter elements with loose edges: *1* — welded edges; *2* — feeding of filler powder; *3* — focusing lens; *4* — laser radiation; *5* — weld; *6* — substrate (arrow shows direction of welded specimen movement)

Determination of corrosion resistance of butt joints of steel 08Kh18N10T (δ = 0.5 and 0.6 mm) was carried out on a weight procedure. According to this procedure the templates close on width to weld width with HAZ were cut out from the welded specimens. The templates length made 5–10 mm. Also, the templates of similar size were cut out from base metal (so called reference specimens). Prepared templates were weighed on analytical balance with up to 0.001 g accuracy after what they were immersed in a mixture of HNO_3 + HCl acids with 1:2 relationship. Within a given period (as a rule in 1–2 h) the specimens were taken out, thoroughly rinsed, dried and weighed one more time. Corrosion resistance was determined on a weight loss difference between the reference specimen of base metal and welded specimen.

Three specimens were done in each case and obtained data were averaged. Welding was carried out using continuous as well as pulse (with 12 and 200 Hz) frequency radiation with filler powder of steel 08Kh18N10T and granulation 20–150 μm. The results were used for plotting the diagrams, shown in Figure 5. As can be seen from these diagrams, in all cases corrosion resistance of welded joints is satisfactory and makes from 90 to 98 % of base metal resistance. Presence or absence of radiation pulse modulation makes small effect on corrosion resistance variation.

A pilot-commercial batch (250 pcs) of cone filter elements was welded using developed commercial

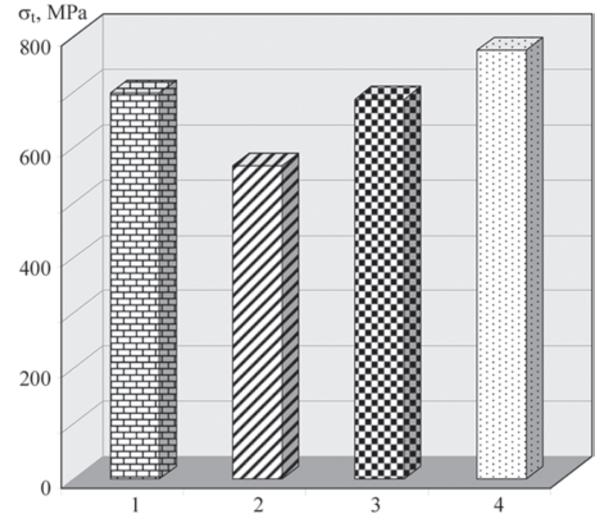

Figure 4. Comparison of strength of 08Kh18N10T steel welded joints (δ = 0.5 mm), produced by laser welding with filler powder of the same material and base metal strength: 1 — continuous radiation; 2 — pulse radiation f = 200 Hz; 3 — pulse radiation f = = 12 Hz; 4 — base metal

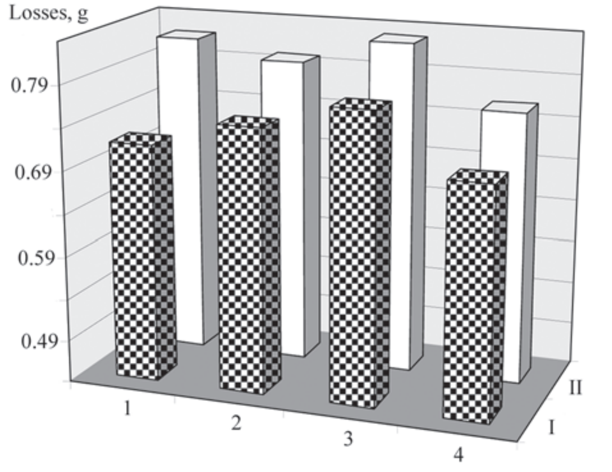

Figure 5. Values of mass loss by specimens of 08Kh18N10T steel welded joints at their etching in mixture of HNO_3 + HCl acids (description 1–4 the same as in Figure 4); I — δ = 0.6 mm; II — 0.5

technology of laser welding of thin-wall products with loose edges. The batch was delivered to relevant enterprise («Chernovitsky Khimzavod» ALC, Chernovtsy) for performance of service tests. The following was determined as a result of these investigations, namely there were no rejected products in the batch; all products correspond to structural dimensions and technical requirements; all products maintained service loads; based on data on life prediction the investigated batch of products is within the norms.

Carried work allows making the following conclusions:

● industrial technology was developed for laser welding of butt joints of perforated edges in tubular cone filter elements for chemical industry. It rises structure safety (in comparison with brazing), eliminates danger of embrittling structures in welds and HAZ, allows escaping application of expensive brazing filler materials, minimizes geometry dimensions of welded joints as well as approximates corrosion resistance and mechanical characteristics of produced welds to the base metal level;

● comparison was carried out for argon arc, electron beam and laser welding of billets of filter elements of austenite stainless steel 08Kh18N10T. Typical defects for all considered methods of welding (burning through and lack of penetrations) and methods of their elimination were determined. Laser welding differs by the highest productivity (10–15 times higher welding rate) in combination with high stability of weld formation. This makes its reasonable for application as industrial technological process;

● experiments on laser welding with powder filler materials were carried out using developed technological fixture. They determined a range of optimum, from point of view of weld formation, process modes, i.e. radiation power Nd:YAG laser 0.5–0.6 kW; welding rate 140–160 m/h; focus deepening 15–20 mm; consumption of filler powder 0.2–0.3 g/s. In this range of modes formation of defect-free welds is stable that provides insignificant percent of rejection in industrial process application.

laser welding of loose edges using powder filler material as in the case of application of continuous and pulse radiation provide 90 % strength of the base metal strength and corrosion resistance of welded joints from 90 to 98 % of the base metal relative strength. Such indices are acceptable for problem being solved.

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