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DEVELOPMENTS IN THE FIELD OF LASER WEDLING EQUIPMENT AND TECHNOLOGIES PERFORMED AT E.O. PATON ELECTRIC WELDING INSTITUTE (Review)*

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The paper provides a review of a series of developments of E.O. Paton Electric Welding Institute performed in course of the latest years in the field of laser welding equipment and technologies. These developments were tested or implemented in commercial production at the enterprises of People's Republic of China in Changchun and Harbin and in Ukraine in Kiev, Chernovtsy and Dnipro. The spheres of application and factors limiting the tendency of fast development and implementation of laser welding technology at Ukrainian enterprises have been outlined. 11 Ref., 12 Figures.

Keywords: *laser welding, technology development, development of apparatus and fixture, laser technological complexes, welded joints, mechanical properties*

Global tendency of the world's progress in the economy of the most developed countries is widespread application and improvement of new science-based perspective technologies, for example, such as laser ones [1–5]. Application of laser technologies is critical for rising a labor productivity and competitiveness of economy. Distinguishing features of laser application in production is high quality of received products, high productivity of the processes, saving of human and labor resources, ecological cleanness.

The lasers with such unique properties as high concentration of radiation power, coherence and monochromaticity have found wide application in aircraft-, rocket-, shipbuilding [5–8] and car construction [8] etc. branches of industry, science, engineering, communication, medicine, biology and other fields. Figure 1 shows an analysis of the world's market volumes of realization of laser radiation sources (without consideration of accompanying components, technological and other fixture) in 2013–2016 and prediction for 2017 [4]. According to data of reputable core publication «Laserfocusworld» the laser engineering market shows steady growth in the last five years and its annual volume has already exceeded 10 bln of USD. At that portion of laser radiation sources, used for material processing, makes around 30 %. (Figure 2) [2]. In turn, the main technological operations of material processing, in which laser radiation is used, are cutting (35 %), welding (25 %), microprocessing (20 %) and engraving (15 %) [3].

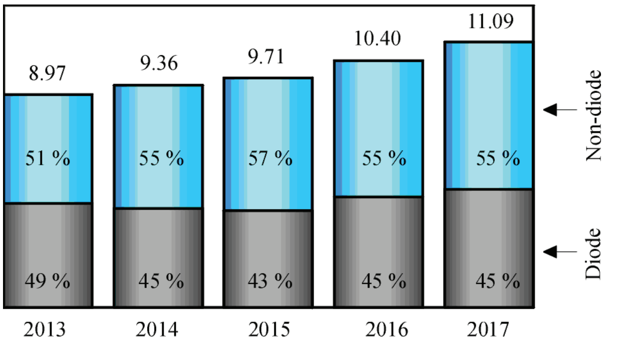

Figure 1. Sales indices (in bln of USD) of world market of laser units in 2013–2016 (without consideration of manipulators and fixture) and prediction for 2017 [4]

Analysis of the international market of laser technologies [1] allows detecting the main tendencies of its development. Among them are:

- high portion of equipment input costs in total volume of market of laser technologies;
- maintenance of laser technologies business in the countries of Western Europe, USA and others market-economy countries that reflects the need in high-qualified personnel;
- high cost of laser technological equipment resulting in reduction of consumer demand in equipment with improved process characteristics;
- increase of portion of services due to rise of complexity of laser technological systems that re-

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quires high efforts and expenses for their installation, development and maintenance as well as presence of high-qualified service staff;

● recruiting mainly outside organizations for performance of functions related with application of laser technologies.

All mentioned above tendencies are typical for the market of laser technologies used in material processing in Ukraine. Besides, it should be noted that the most typical additional factors limiting development of laser technologies market in Ukraine, are:

● absence of domestic producers of modern powerful laser units for material processing;

● loss of technologies for consumables manufacture (optical; power; electron and other elements), which were developed and implemented into industry 30 years ago as well as impossibility of the remaining domestic manufacturers to reoriente to the needs of rapidly developing market of components for laser technologies;

● difference in portion of distribution of laser material processing technologies (cutting, welding, heat treatment, engraving etc.) at Ukrainian enterprises from data of work [1].

Today, according to our data, application of laser cutting (estimated value around 65 % of total market of processing complexes) is dominant in the market of laser processing technologies in comparison with other technologies. Among the other laser processing technologies the most essential are laser marking (estimated value around 15 % of total market of processing complexes) and rapidly developing in the recent years technology of 3D-printing (estimated value around 10 % of total market of processing complexes). The market of technological complexes for processes of laser welding, heat treatment, piercing and other technologies, on our data, does not exceed 10 % of total market of the laser processing complexes. Change of the current situation with «shift» of demands of domestic market of the laser processing complexes to cutting and bringing it to the level of world standards, typical for market-economy countries, is possible by solving a series of the problems, one of which is development of domestic technologies and equipment for laser welding of different materials competitive in the world market.

Laser welding of metallic materials is used in development of structures for aircraft and marine ships, parts of medical equipment and assemblies of instrument-making as well as many other branches of industry. The scientific groups from E.O. Paton Electric Welding Institute, NTUU «Igor Sikorsky KPI» and other institutes of higher education as well as research laboratories of a range of large industrial enterprises successfully deal with the developments in the field of laser welding in Ukraine.

This work provides a review of a series of developments in the field of equipment and technology of laser welding, which have been performed at the E.O. Paton Electric Welding Institute in the recent years, tested or implemented into industry.

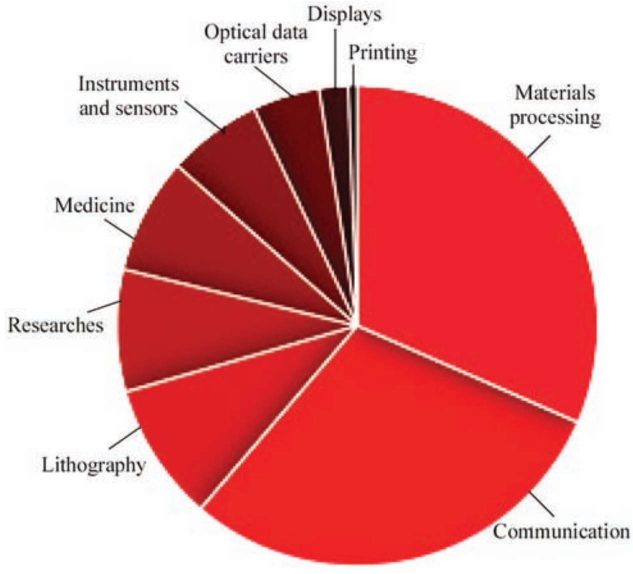

Figure 2. Distribution of application of laser units in the world for different branches of industry [2]

E.O. Paton Electric Welding Institute in course of performance of scientific tasks has solved a problem on determination of the dependencies of effect of technological parameters of laser welding of thin-wall tubes on geometry and mechanical characteristics of received cold-rolled strip butt joints of δ = 0.15–0.2 mm thickness from high-alloy corrosion-resistant steels 12Kh18N10T (GOST 4986–79) and 1.4541 (DIN EN 10028-7:2000), taking into account the requirements of the next production of multilayer bellows from them [10]. It is determined based on the results of comparison of geometry, structure and mechanical properties of the produced joints that a determining parameter effecting the quality of this welded joint is a heat input, optimum range of variation of which lies in 3–5 J/mm limits. The results, obtained in course of work, made a basis for development of commercial technology of manufacture of straight thin-wall welded tubes of different diameter from stainless steels, applied for production of multilayer bellows on GOST 21744–83 (Figure 3). Such bellows are designed for operation as compensation elements, phase separators, sealing devices as well as elements of power assembly in the media promoting material corrosion at temperature from –260 to 550 °C.

Designed three-coordinate complexes of «ARMA-100M» type (Figure 4) for laser welding of straight thin-wall tubes of stainless steel are implemented at PJSC «KTsKBA» (Kiev) and «SRC»Armatom» LLC (Kiev). Application of developed technological recommendations and original technological fixture allowed providing productivity of one such complex up to 5 thou pcs of bellows billets per month. Finished products have been already used in different stop

Figure 3. Appearance of billet of multilayer bellows after hydroforming

valves operating in high-pressure pipelines at constant high-frequency and low-frequency vibration as well as stop assemblies requiring accurate positioning of a stop body. The multilayer bellows produced using laser welding are certified in accordance with the requirements of norms and rules as well as other reference documents in the field of nuclear power engineering.

The continuation of work mentioned above was development of a technology and fixture for laser welding of expansion bellows. They join parts and units, which in process of operation perform relative displacement or work under vibration conditions. The main operating element of these products is a bellows, that is flexible corrugated metallic tube of thin-wall stainless steel. The expansion bellows are produced by welding of a corrugated tube with a massive fixture (flanges, tubes, bushes etc.). Carried investigations showed that welding with pulse modulation of laser radiation is reasonable for manufacture of expansion bellows from stainless austenite steels. Techniques and equipment (Figure 5) were developed for laser welding of the expansion bellows. They allow getting fine grain structures, having increased mechanical characteristics level, in a cast weld metal and HAZ metal. This development was implemented at PJSC

Figure 4. Appearance of three-coordinate complex «ARMA-100M» for laser welding

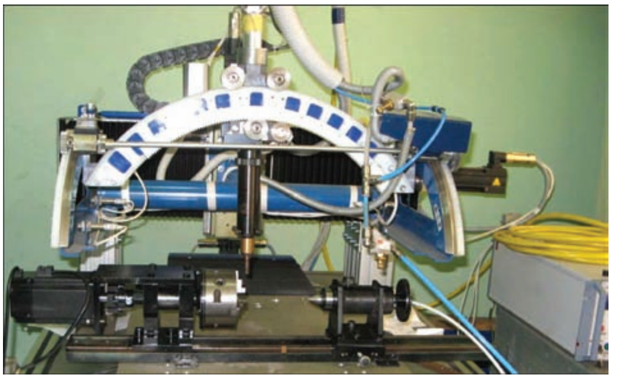

Figure 5. Technological complex for laser welding of expansion bellows

«Kiev plant «Analitpribor» and «SRC»Armatom» LLC for laser welding of probe housing (Figure 6).

S.M. Konyukhov Institute for strategic technologies (Dnepr) in a course of last years has been dealing with the problems of development of fundamentally new power unit of plasma engine PD140, which is used in a complex of cruise or adjustment-propulsion systems of rocket-space equipment. Manufacture of separate assembly elements of this power unit stipulates extremely rigid requirements on tailoring and quality of welding of its constituents. Together with PWI the works were carried out on approbation of laser tailoring technology and further laser welding without mechanical treatment of welded edges (250 pcs), parts of spiral heater of 0.25 mm thickness (produced from titanium alloy VT6). The results of work allow stating significant simplification of part edge mating and improvement of quality of welded joints. Researched level of mechanical characteristics indicates high reliability of the welded joints and perspective of application of these technologies in a rocket-space branch.

Different methods of arc fusion welding often apply a technique lying in filling of a gap between the edges being joined with molten filler metal [11]. The similar technique is rarely used for laser welding. There are usually concerns about minimizing a gap between the edges being welded and not using filler materials (to reduce energy consumption). We have proposed the method for joining the edges, which can not be tightly mated (for example, in the case of perforation). It is based on laser powder surfacing. The

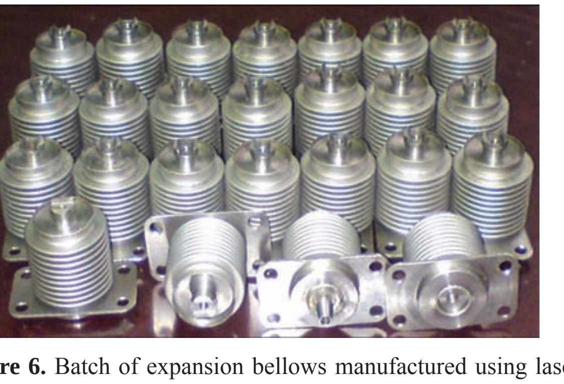

Figure 6. Batch of expansion bellows manufactured using laser welding

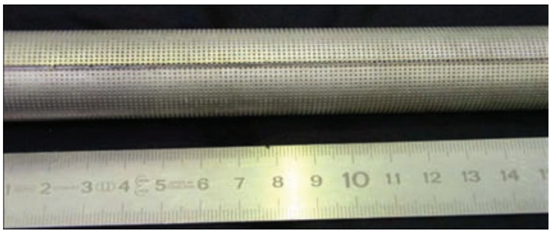

Figure 7. Housing of thin-wall tubular filter element manufactured on developed technology by laser welding with flux-cored wire

edges being welded are matched with small (up to one diameter of perforation hole) gap and tightly pressed to copper technological substrate. A proportioning feeder for supplying the filler powder of 60–100 μm granulation is used as auxiliary equipment. The filler material is selected depending on metal of edges being welded. In the process the gap is filled with powder, which is melted by laser radiation. Such an approach allows 10–30 % increase of coefficient of laser radiation absorption in comparison with simple welding. Laser welding of housings of tubular filter elements of δ = 0.5–0.6 mm wall thickness (steel Kh18N10T) (Figure 7) was carried out in accordance with the developed technology. Pilot batches of housings of the tubular filter elements, produced at PWI on the developed technology using laser welding with filler wire, were successfully tested and used in manufacture of elements for liquid filtering at «Chernovitskii chimzavod» ALC (Chernovtsy).

An instrument for manual laser welding of products (Figure 8), in particular, elements of internal structures of the cars for modern high-speed trains was developed to solve the tasks in the field of welding at carriage works (Changchun, PRC). Developed manual laser instrument is included in a content of the welding unit, which is manipulated by one operator-welder. Weight-dimension characteristics of the

Figure 8. Appearance of developed instrument for manual laser welding

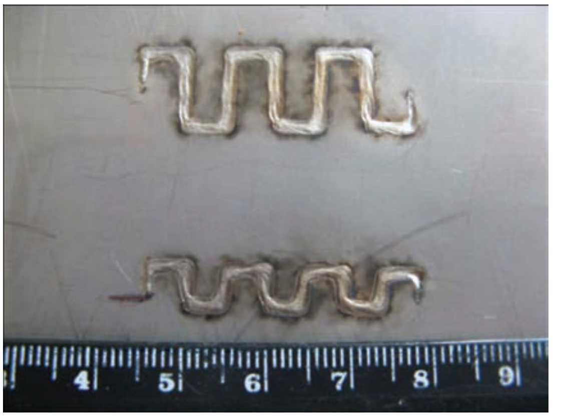

Figure 9. Appearance of welds produced on curved trajectory using instrument for manual laser welding

developed manual laser instrument allow carrying out welding in different spatial positions. Functional possibilities of the developed instrument permit to weld with movement of laser heat source at any set trajectory (Figure 9) within the limits of working field of 50×30 mm size. Carried metallographic examinations and mechanical tests of the lap welded joints of stainless steel 12Kh18N10T (plate thickness 2 mm), produced using developed manual laser instrument, showed that their mechanical characteristics are as good as the characteristics of the joints produced employing automatic laser welding.

Development and manufacture of the equipment (Figure 10) was carried out in order to perform research in the field of investigation of physics of the processes of combined impact on different metals of laser radiation with 1.07 μm wavelength and pulse arc plasma.

Figure 10. Appearance of developed working head for laser, microplasma and hybrid laser-microplasma welding

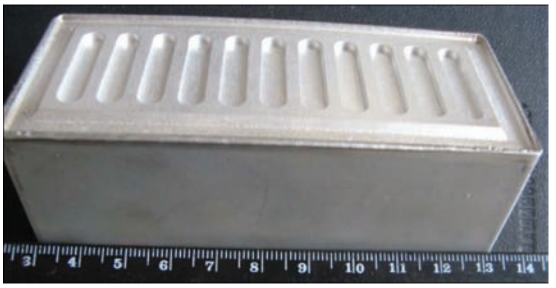

Figure 11. Appearance of fragment of accumulator housing of AMg6 (δ = 0.8 mm) alloy welded by closed weld using fiber laser radiation

Figure 12. Housing of probe from steel 08Kh18N10T welded by laser radiation

The research was ordered by Harbin Welding Institute of China Academy of Machinery Science & Technology (Figure 10). A complex of devices was developed. It is designed for performance of the technological operations by laser, microplasma and hybrid laser-microplasma welding of thin-wall (0.1–2.0 mm) metals at direct, pulsed, alternating current with the possibility of separate regulation of amplitude and duration of current flow as well as effect of continuous or pulse laser radiation.

Other scientific developments of PWI in laser welding have passed industrial tests and approbation based on as series of Ukrainian and foreign aircraft- and rocket-building enterprises. Among them are welding of dissimilar materials (titanium alloys with aluminums); carbon with high-alloy stainless steels; welding with each other different grades of corrosion-resistant high-alloy steels etc.); welding of stringer panels and other elements of structures of aircrafts of titanium alloys [12]; butt welding of complex-profile reflective plates of nickel alloys; welding of casings of aluminum alloys (Figure 11); manufacture of different probes of high-alloy steels (Figure 12) and high-strength alloys.

Conclusions

1. Today the distinctive tendencies, typical for the Ukrainian market of material processing laser technologies, in comparison with the international market, are absence of domestic manufacturers of modern high-accuracy power laser units for material processing; loss of technology of manufacture of consumable components; prevailing demands on cutting equipment in the domestic market.

2. Increase of portion of laser welding in the domestic market is possible by means of development of domestic technologies and creation of the equipment for laser welding of different materials able to compete with leading world technologies.

3. Today laser welding technologies are essential for nuclear, chemical, instrument, aircraft and rocket construction branches of Ukrainian industry.

4. High level of developments of E.O. Paton Electric Welding Institute in the field of technology and equipment for laser welding is verified by their relevance in the world's market.

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