JOINT EDUCATION AND RESEARCH LABORATORY OF WELDING AND RELATED PROCESSES

Main building of NTUU Igor Sikorsky KPI

Modern conditions for the development of progressive technologies require the integration of certain processes to obtain a new quality of products. The basic condition for such integration processes is the combination of a scientific experience of researchers working over related problems in different scientific divisions. This approach provides a more full analysis and solution to the problems that researchers have to do with when scientific and technological progress is constantly marching on.

Combining efforts of scientists in solving problems of plasma and hybrid welding and additive arc technologies has already become necessary a long time ago. Several decades ago, this need has led to an intensive development and branching of the E.O. Paton Electric Welding Institute of the NAS of Ukraine. However, modern realities require finding new approaches. In 2017, the basis for their creation was found. At the initiative of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" and with the support of Academician B.E. Paton, five scientific and technical organizations took part in the foundation of the Joint Education and Research Laboratory of Welding and Related Processes. Among the founders there were:

- PWI;
- Foreign Economic Representation of the E.O. Paton Chinese-Ukrainian Institute of Welding;
- National Technical University of Ukraine "Igor Sikorsky KPI";
- "Scientific and Production Center "PLAZER" Ltd;
- "Ukrspetstekhnologiyi" Corporation.

The foundation of the Joint Research Laboratory with the support of Academician B.E. Paton was legally settled by an agreement on cooperation No.2500/17-0 dated 13.06.2019.

The aim of the Laboratory foundation is building of a scientific and technological experimental base of a collective use with the attraction of the most advanced equipment for research works in plasma, laser and hybrid welding technologies and related processes, additive technologies, diffusion welding and brazing.

To achieve this aim it is planned to solve the following tasks:

1. Creation of new forms of scientific and technical cooperation by combining the creation of a scientific experimental base of a collective use with the involvement of modern equipment for conducting research works in the fields of advanced welding technologies and related processes using the material and technical base of research, educational and scientific-production organizations.

2. Attraction of investments, including from foreign partners.

3. Expansion of international scientific and technical cooperation and cooperation between research institutions and industrial enterprises in Ukraine, attraction of leading Ukrainian and international scientists and specialists to participation in scientific and technological developments.

Main building of E.O. Paton Electric Welding Institute

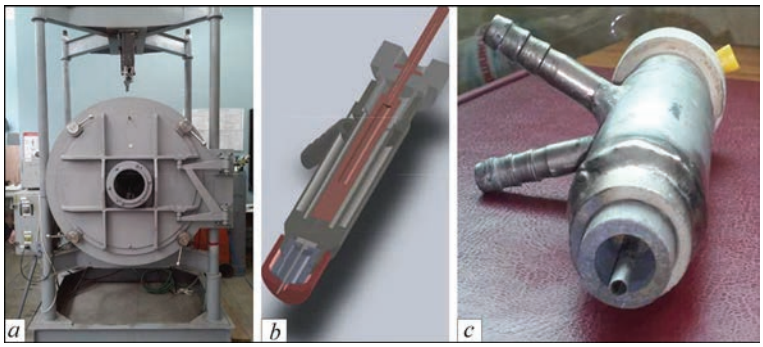

Figure 1. Appearance of vacuum chamber (*a*) and plasmatron (model (*b*) and a specimen made on its base (*c*)) for vacuum plasma-emission discharge welding

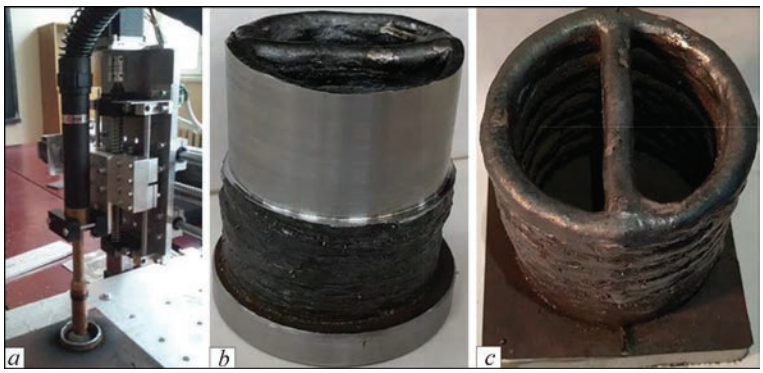

Figure 2. Head (*a*) with a consumable electrode for additive growing of parts with inner stiffeners (*b*, *c*)

4. Education of scientific personnel, involvement of students of higher education institutions of Ukraine with bachelor, master and Ph-D levels of education to participate in real scientific, technical and production projects.

At present, the structure of the Joint Laboratory includes two experimental and technological platforms: "Plasma and hybrid welding and additive arc technologies" (E.O. Paton Educational and Research Institute of Materials Science and Welding of the Igor Sikorsky KPI) and "Demonstration and technological platform of plasma, hybrid and additive technologies" (PWI, LLC "Scientific and Production center "PLAZER", Foreign Economic Representation of the E.O. Paton Chinese-Ukrainian Institute of Welding). Scientific supervisor of the Joint Laboratory is Dr. of Techn. Sci., Prof. V.M. Korzhyk, the correspondent member of the NASU.

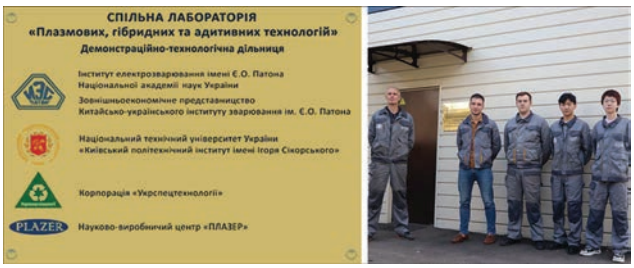

Figure 3. Mock-up of the title board of the Demonstration and technological platform and its opening by the international research team

Within the frames of Cooperation Agreements, concluded with the PWI, the mentioned Joint Laboratory is the base for international scientific and technical cooperation with the Welding Technologies Research Institute in Zhejiang Province (PRC) and Zhejiang Special Equipment Research Institute (PRC).

In the Laboratory of plasma and hybrid welding and additive arc technologies, research works are carried out on the development and further advancing of such progressive processes as:

- hollow cathode vacuum welding with a plasma-emission direct current discharge of straight polarity;
- vacuum diffusion welding;
- vacuum brazing;

Figure 4. One of the laboratory facilities of the Demonstration and technological platform

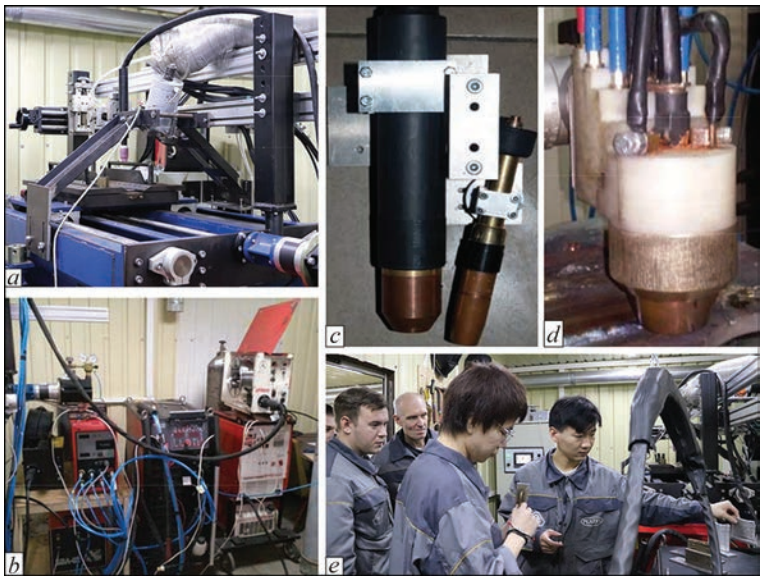

Figure 5. Universal technological complex of plasma-arc and hybrid technologies, automatic combined and hybrid welding "plasma + arc of a consumable electrode": *a* — manipulator for welding in different spatial positions; *b* — welding equipment; *c* — monoblock of combined plasma + MIG/MAG welding; *d* — plasmatron for hybrid plasma-MIG/MAG welding; *e* — familiarization of foreign partners with the equipment and technology within the framework of international scientific and technical cooperation

● additive growing of parts by means of a consumable electrode.

For realization of research works, complexes of the corresponding vacuum equipment were created (Figure 1). The study of a plasma-emission discharge (plasma-arc discharge with a hollow cathode) in vacuum proved the possibility of its successful use in welding of titanium alloys with a thickness of up to 16 mm without edge preparation. At the same time, in terms of quality and service characteristics, the produced welds are approaching the results obtained by electron beam welding at a significantly lower cost.

Also, in this division of the Joint Laboratory, additive growing of parts by means of a consumable electrode is investigated. In particular, technologies for manufacture of metal parts of a complex spatial shape with inner stiffeners are developed (Figure 2).

On the "Demonstration and technological platform of plasma, hybrid and additive technologies" (Figure 3), the development of such technologies is carried out as:

● robotic seam and spot plasma welding by a direct current of straight polarity;

● robotic seam and spot plasma welding of aluminium and magnesium alloys by a bipolar asymmetric current;

● robotic (automated) plasma-powder cladding by a direct current of straight polarity and by a bipolar asymmetric current (for aluminium and magnesium alloys);

● robotic (automated) welding in the mode of "mild plasma" by a direct current of straight polarity and by a bipolar asymmetric current (for aluminium and magnesium alloys);

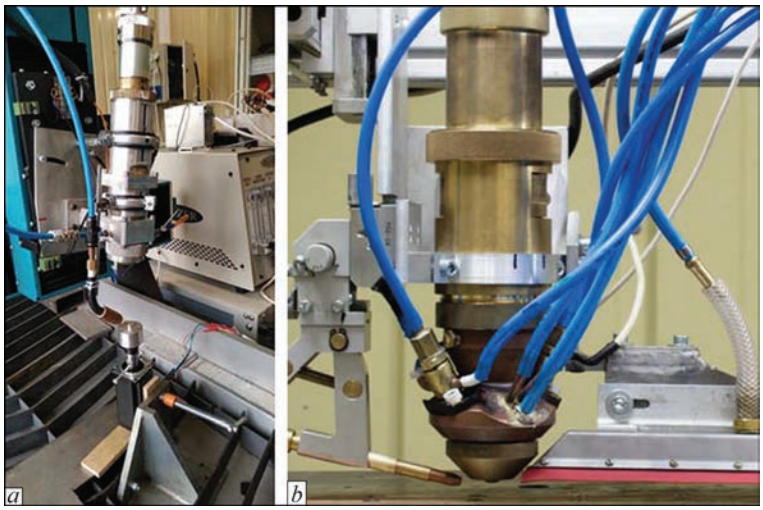

Figure 6. Heads for laser (*a*) and hybrid laser-plasma welding (*b*) created in the Joint Laboratory

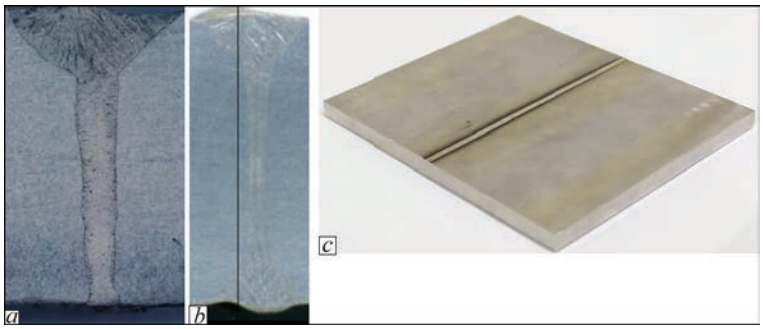

Figure 7. Macrostructures of joints of 6 (*a*) and 10 mm (*b*) thickness produced by laser-plasma welding in one and two passes, respectively, and the appearance of butt joints of 10 mm thickness (*c*). Material — stainless AISI304 steel

● robotic (automated) welding and surfacing applying the process of welding by a consumable electrode with short circuits (CMT — Cold Metal Transfer);

● robotic (automated) argon-arc welding by a direct current of straight polarity and by a bipolar asymmetric current (for aluminium and magnesium alloys);

● laser welding in a controlled atmosphere and in a dynamic vacuum;

● robotic (automated) laser cutting and welding;

● hybrid welding processes (plasma-MIG/MAG, plasma-TIG, laser-plasma, laser-MIG/MAG, laser-TIG);

● hybrid laser-plasma cutting;

● plasma cutting of metal sheets of increased thicknesses on the reverse polarity;

● plasma cutting with different types of plasma-forming gases and addition of water;

● supersonic plasma powder spraying of coatings;

● high-velocity plasma-arc spraying of coatings by conductive wires;

● high-velocity electric arc two-wire spraying of coatings in the products of combustion of hydrocarbon gases;

● hybrid supersonic electric arc oxy-fuel two-wire spraying of coatings;

● supersonic high-velocity oxy-fuel spraying of coatings by powders and wires (HVOF);

● plasma technologies of powder spheroidization;

● growing of three-dimensional products by additive layer-by-layer microplasma, plasma and arc cladding (3D-printing).

To study the mentioned technologies, there are appropriate laboratory facilities with the necessary technological equipment (Figure 4). Also office premises, a modern conference room with the possibility of online conferences, areas for mechanical treatment with milling and turning machine tools, utility and warehouse premises, etc. are provided. In particular, the Demonstration and technological platform for plasma-arc and hybrid technologies was certified by the Certificate on the quality management system ISO 9001:2015.

Specially, the innovative hybrid technologies should be noted, which are developed on the Demonstration and technological platform. Thus, the equipment and technologies of automatic and robotic combined (Plasma + MIG/MAG) and hybrid (Plasma-MIG/MAG) welding by a constricted arc of a nonconsumable electrode with an arc of a consumable electrode arc allow joining sheets of aluminium alloys with a thickness of up to 16 mm for a one pass, minimizing the tendency to inner pore formation in welds, increasing the efficiency of welding by eliminating the operations on edge preparation, increasing

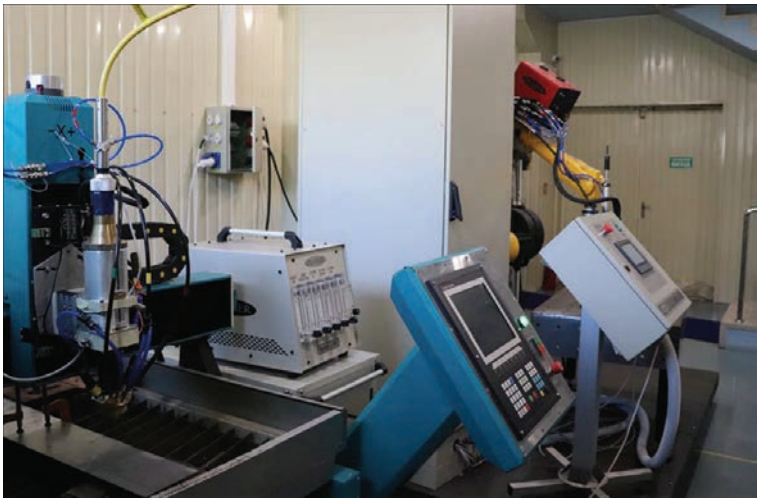

Figure 8. Universal technological complex for laser and hybrid laser-plasma cutting

Figure 9. Complex for laser, microplasma and laser-microplasma welding in a controlled atmosphere and in a dynamic vacuum

welding speed up to two times as compared to conventional MIG/MAG-welding (Figure 5).

The equipment and technologies for laser and hybrid laser-plasma welding created in the Joint Laboratory allow producing joints of steels and alloys with a high thermal locality and speed of welding. A vivid example of achievements in the field of laser-plasma welding is the production of single- and two-pass butt joints of stainless AISI304 steel of 6 and 10 mm thickness, respectively, at a speed of 60 m/h using 1.8 kW radiation power of a fiber laser (Figures 6, 7).

Among the challenging technological developments, created on the basis of the Joint Laboratory, a universal technological complex of laser and hybrid laser-plasma cutting (Figure 8), laser, microplasma and laser-microplasma welding in a controlled atmosphere and in a dynamic vacuum (Figure 9), installation (3D printer) for 3D-printing by a powder

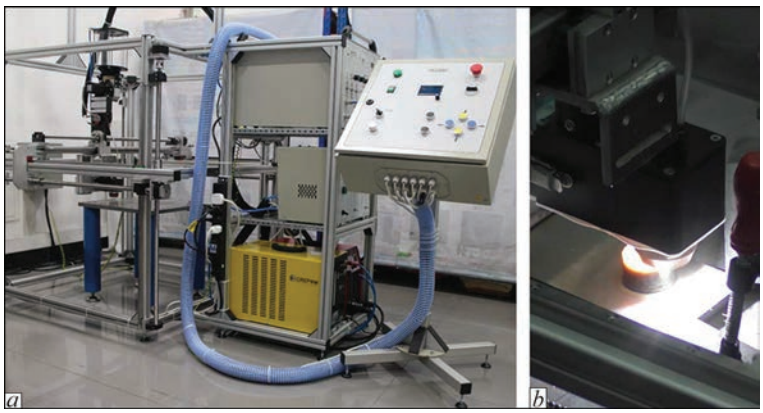

Figure 10. Appearance of installation (*a*) and process (*b*) for microplasma 3D-printing using powder materials

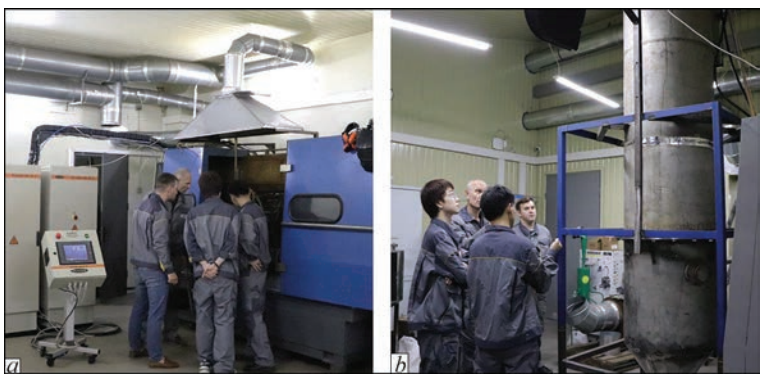

Figure 11. Equipment for realization of plasma-arc technologies for spraying of coatings and treatment of materials: *a* — universal technological complex of plasma-arc spraying and cutting; *b* — experimental installation for plasma-arc spheroidization of wire materials and rods and powders of irregular shape

Figure 12. Familiarization of the Academician of the NASU I.V. Krivtsun, Director of the PWI, with the capacities of the Joint Laboratory

microplasma layer-by-layer cladding can be attributed (Figure 10).

At present, the works on the development and industrialization of plasma-arc technologies of spraying coatings and treatment of materials, production of spherical powders by plasma-arc spraying of wires and rods, plasma-arc spheroidization of powders of irregular shape are actively continuing. With this purpose, the necessary equipment and technological base were created (Figure 11).

After opening of the Joint Laboratory, its Demonstration and technological platform was visited by leading staff scientists of the NAS of Ukraine, in particular, Academicians of the NASU I.V. Krivtsun and L.M. Lobanov (Figure 12). They approved the technical equipment of the Laboratory and highly praised the scientific and technological developments, which are currently carried out by its staff colleagues. Further, it is planned to visit the Joint Laboratory by delegations of foreign scientists and managers, which are interested in scientific cooperation and industrial implementation of developed technologies.

The management of the Joint Laboratory offers the application of the described advanced innovation equipment with all those desirable researchers, students and postgraduate students. Research works can be conducted both within the joint projects as well as on individual agreements. A separate task is teaching students and postgraduate students. The Laboratory gladly welcomes not only domestic students, but also foreign ones — all who wishes to raise their own skills within the framework of joint projects and programs. For this purpose, both specialists of the Laboratory, as well as third-party specialists may be involved. The latter may be involved on individual principles. In general, the Joint Education and Research Laboratory was built as a scientific and technological experimental base of a collective use. The accumulated advanced experience and available innovative equipment are aimed to be attracted for research works in the fields of advanced technologies of welding and related processes.

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