MODERNISATION OF ELECTRON BEAM WELDING INSTALLATION ELU-20

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The electron beam welding installation of the universal type ELU-20, designed by National Institute of Aviation Technologies (NIAT, Russia), in most cases does not provide meeting the modern requirements, specified to the technology and equipment. On order of users the E.O. Paton Electric Welding Institute developed and created specialized complex for EBW with automatic systems of control and application of distributed computer systems on the base of the installation ELU-20. Such approach allowed realization of a number of technological capabilities on automatic control of parameters of welding electron beam, programmable movement and inclination of electron beam gun, visual programming of trajectory of a butt in the real time mode, during the operation of vacuum system of pumping-out. «Windows» as the oriented interface of the user provided graphical plotting and editing of programs for welding, 3D display of specimens of the product and trajectories of the butt during welding process. 2 Ref., 3 Figures.

Keywords: *electron beam installation, vacuum chamber, electron beam gun, pumping-out system, coordinate axes of movement, inclination and rotation, computer control, interface, video monitoring, focusing, programming of butt trajectory, master-program, cutoff voltage*

As the experience of application of the universal installation of ELU-20 type, designed by the NIAT, showed that the necessity in its modernization arose in most cases to meet the nowadays requirements of leading branches of industry. In the first turn it concerns the vacuum pumping-out system, high-voltage power source, welding EB gun, system of control of parameters of welding electron beam, system of butt tracking and visual monitoring of welding process and also mechanism of movement and inclination of a gun, loading carriage and rotators of a product.

On order of the user (OJSC «Motor Sich», Zaporozhie) at the E.O. Paton Electric Welding Institute a specialized complex on the base of installation ELU-20 was designed and manufactured for EBW with automatic control system (ACS) and using the distributed computer systems [1]. Such approach provided the realization of the following technological capabilities:

- movement along the five axes (three coordinates X, Y, Z for movement of EB gun, coordinate VG of inclination of a gun, axis of rotation of rotator);
- simultaneous synchronous movement along any three coordinate axes with linear interpolation;
- synchronous movement with control of parameters of welding electron beam;
- conductance of welding in both modes: automatic and manual welding;
- «Windows» is the oriented interface of the user providing graphical designing and editing of programs for welding, 3D display of specimens and trajectories of butt in the welding process;
- combining of several subprograms into one program;
- visual programming of a butt trajectory in manual, semi-automatic and automatic modes;
- automatic control of vacuum system and high-voltage power source;
- logging of all the commands of control and parameters of welding process in graphical and tabulated form;
- diagnostics of single subsystems (vacuum system, high-voltage power source, movement system, parameters of welding process).

Vacuum chamber of rectangular shape with inner sizes of 3000 × 2000 × 2000 mm (length × × width × height) and volume of 12 m^3 is equipped with one door, hinge-hanged up on the door suspension beam (Figure 1). The door can move along the beam using electric drive, opening the space for delivery of loading carriage to the position of welding. The front wall of vacuum chamber (on the side of welding operator) is equipped with inspection windows and also lighting and monitoring camera. On the rear wall the mechanisms of movement of welding EB gun along the coordinates X, Y, Z and gun inclination VG and also vacuum pumping-out system are located.

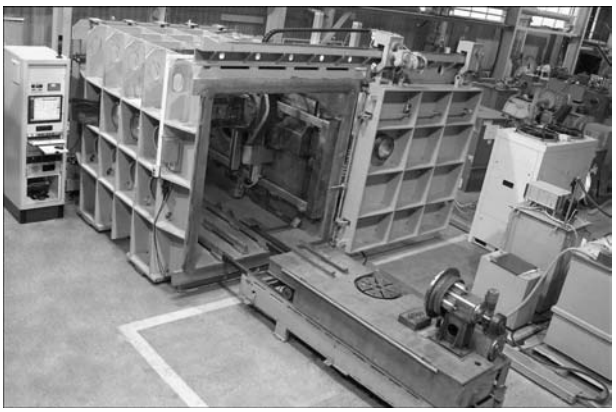

Figure 1. Appearance of EB installation ELU-20 after modernization

The unit of updated EB gun from the components of the equipment ELA-60B with a collector of secondary-emission signal of the video monitoring system RASTR [1, 2], turbomolecular pump, vacuum sensors and screen of thermal protection of a gun is mounted on the rotary beam for the gun inclination in the plane XZ (coordinate VG) (Figure 2). The movement of EB gun along the coordinates X, Y, Z is performed using linear modules. The control of movements is performed from the Siemens drive SINAMICS S210, providing the accuracy of positioning of not worse than ±0.05 mm. The application of ceramic high-voltage isolator and metallic tungsten cathode of 3 mm diameter in EB gun allowed obtaining the current of electron beam in the range 0–500 mA and life of cathode of not less than 40 h at accelerating voltage 60 kV.

The vacuum pumping-out system of the installation designed and manufactured on the base of modern vacuum equipment provides necessary rarefaction in welding chamber and EB gun in automatic mode at the computer control (Figure 3). The time of reaching the working pressure in the chamber ($1 \cdot 10^{-4}$ mm Hg) and gun ($5 \cdot 10^{-5}$ mm Hg) amounted to not more than 30 min. «Windows» as the oriented interface at the control on commands of welding operator allowed realizing the following operation modes of the vacuum system:

- «Pumping out» — the mode of pumping out of air from the vacuum chamber and gun both during preparation for welding as well as directly in the process of its fulfillment;
- «Expectation» — the guard mode allowing preserving safe state of the machine under vacuum at switched-on diffusion pumps;
- «Letting-up» — the mode of ventilation of vacuum chamber and gun before the ready state of opening the door of vacuum chamber;
- «Stop» — the mode of interruption of operation of vacuum system with switching-off of diffusion pumps;
- «Manual» — the mode of manual control of the equipment of vacuum system during search and elimination of failures;
- «Cold pumping-out» — switching-on of «Pumping» mode without switching-on of diffusion pumps.

The program of automatic control of vacuum system follows and displays the condition of the equipment on the screen of the monitor of ASC using designations of state of valves, shuttles and vacuum pumps.

To obtain the image of welding site on the ASC monitor in the real time mode the RASTR video-monitoring device was applied. The image of a surface of the item being welded is formed according to signals from the sensor of secondary-emission electrons, mounted on the EB gun in direct vicinity from the site of welding (see Figure 2). The clear image of welding process with formation of a face bead of weld is displayed on the ASC monitor and as compared to traditional optic monitoring systems it is not subjected to influence of vapors of the metal being welded. The application of additional computer which solves the problems of recognition of a butt on the image of product surface, obtained from the RASTR video monitoring device and also from human–machine interface, provided the fulfillment of functions of automatic visual designing of trajectory of a butt, correcting of butt deflection and tracking the butt.

«Windows» as the oriented interface of the user allows plotting the master-programs of welding process for different configurations of products in a form of diagrams and tables. The master-program can include up to five subprograms — «Cleaning», «Partial Tacking», «Full Tacking», «Welding», «Finishing Welding». In

Figure 2. Unit of modified welding EB gun with the mechanisms of movement along coordinates X, Y, Z and inclination on the coordinate VG

tables the values of welding current, focusing current, welding speed, value of operating distance from the end of EB gun to the product, type and amplitude of technological scanning, amplitude and direction of deflection of gun are preset. During performance of EBW process in the automatic mode the possibility of manual correction of the following parameters is foreseen: welding current in the limits of ±10 %, focusing current in the limits of ±5 % of the program mode. Welding according to the program can be performed in the mode of pulse current modulation with presetting the frequency of tracking the pulses and length of a pulse.

The subprogram «Cleaning» is applied for cleaning of surfaces of abutted edges of a product from contamination and oxides using sharp-focused low-power electron beam. The value of focusing current for location of electron beam focus on the surface of a product is determined using the video-monitoring system RASTR. The mode of cleaning using electron beam is usually performed at the speed of movement of 10 mm/s with a beam scanning around the circle of 10 mm diameter and welding current of 15 mA.

The interface of welding operator provides the possibility of presetting the two types of rotators: horizontal rotator W_x (horizontal axis of rotation) and vertical rotator W_z (vertical axis of rotation). During compiling and correcting of welding programs using rotators the speed of rotation and direction of rotation are indicated in the table.

The transition to software conductance of the process of EBW under shop conditions sets forth the more severe requirements both to equipment as well as to technological process. To provide the reproduction of geometry of welds the following procedure of testing the welding EB gun can be applied. Except of information about parameters of electron-optical system (accelerating voltage, beam current, focusing current, bombardment current, filament current) the monitor of ASC gives the value of cutoff voltage on the gun controlling electrode. On following the change in cutoff voltage for a definite value at a rated beam current, the welding operator can predict the working efficiency of tungsten thermal cathode and timely determine the need in its change.

Technical characteristics of electron beam installation ELU-20 after modernization

Dimensions of the installation, mm:	
length	9000
width	7700
height	3100
Inner sizes of vacuum chamber, mm:	
length	3000
width	2000
height	2000
Working pressure in vacuum chamber, mm Hg	not more than $1 \cdot 10^{-4}$
Working pressure in EBG, mm Hg	not more than $1 \cdot 10^{-5}$
Time of reacheng the of working pressure in vacuum chamber and EBG, min	not more than 30
Time of letting the air into vacuum chamber, min	2
Movement of EBG along the coordinates, mm, not less than:	
X–X	2000
Y–Y	900
Z–Z	800
Time of movement of EBG along coordinates X–X, Y–Y, Z–Z, mm/s	1.66–25
Accuracy of EBG positioning along coordinates X–X, Y–Y, Z–Z, mm	±0.05
Angle of EBG rotation in the plane XOZ, deg	0–90
Number of rotators for products being welded, pcs:	
with horizontal axis of rotation	1
with vertical axis of rotation	1
Speed of rotation of faceplates of rotators, rpm	0.06–12
EBG and equipment ELA-60B:	
accelerating voltage, kV	60
range of adjustment of welding current, mA	0–500
working distance of electron beam, mm	100–400
frequency of technological scannings of beam, Hz	not more than 1000
angle of beam deflection, deg	±3.5
operation life of cathode, h	40
welding in pulse mode at frequency, Hz	5–600
RASTR system of monitoring and tracking of butt:	
accuracy of alignment of electron beam with butt, mm	±0.1
magnification of the object being monitored	×5

Figure 3. Vacuum system of pumping out of installation ELU-20 with off-line water cooling of vacuum pumps, EB gun and power source («Lahntechnik» chiller of the type BL-365-16, Germany)

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