

# EQUIPMENT AND TECHNOLOGY OF ANTICORROSION ELECTROSLAG SURFACING APPLYING TWO STRIPS

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The E.O. Paton Electric Welding Institute together with the E.O. Paton Chinese-Ukrainian Institute of Welding and the SPC «PLAZER» developed the equipment and technology for anticorrosion electroslag surfacing applying strips. The effect of current, voltage and surfacing speed as well as the gap between the strips on the stability of electroslag process, geometric dimensions of deposited beads and volume of base metal in the deposited one were investigated. In the experiments the stainless strips ESAB 309LNb ESW with the cross-section of 0.5×60 mm and the flux ESAB OK 10.10 were used. The range of surfacing modes applying two strips was determined, providing a high efficiency and a stable electroslag process with a good formation of deposited metal and a minimal penetration of the base one in the ranges of 7–9 %:  $I_s = 1400–1500$  A;  $U_s = 32–33$  V;  $v_s = 14–17$  m/h; the gap between the strips is 16 mm. The mechanical properties of the metal deposited at these modes applying the strips ESAB 309LNb ESW under the flux ESAB OK 10.10 are at the level of mechanical properties of steel 309LNb. The obtained results can be used in selection or development of materials and technologies for anticorrosion surfacing of parts of power and chemical equipment. 7 Ref., 1 Table, 6 Figures.

**Keywords:** *electroslag surfacing applying strips, surfacing technology, surfacing equipment, penetration, efficiency of surfacing*

To protect the parts of power and chemical equipment from corrosion, the electric arc surfacing under the layer of flux of a high-alloyed corrosion-resistant metal on low-carbon steel is widely used [1, 2]. The surfacing is mainly carried out applying one electrode strip with a thickness of 0.5–0.8 mm and a width of 50–70 mm, which, depending on the modes, provides the efficiency of 10–35 kg/h [2]. In this case, the volume of base metal (VBM) in the deposited metal is 15–25 % and to provide the necessary chemical composition of the corrosion-resistant deposited metal, the surfacing should be performed at least in two layers.

This reduces the efficiency of surfacing and can lead to accumulation of microdefects in the deposited metal, growing residual stresses in it, increasing chemical and structural heterogeneity [3]. Under service conditions, these factors can negatively affect the resistance of deposited metal against crack and corrosion formation [4].

One of the ways for solving this problem is the use of surfacing materials and methods which could provide a minimum penetration of base metal, in particular, electroslag surfacing applying two strips (ESSS). According to some data [5–7], this method provides obtaining the necessary chemical composition of the

deposited metal already in the first layer, which is especially important for surfacing of high-alloy austenite steels on structural steel.

The scheme of electroslag surfacing process applying two strips is shown in Figure 1. The current supply, as a rule, is carried out through the copper insert located between the strips and providing a preset gap between them. The protection of surfacing zone from atmosphere is carried out by flux. During surfacing at the first moment of time an arc is occurred between the electrode strips and the product, which fuses the edges of the strip, facilitates the flux melting and the formation of a slag pool, shunting the arc. Further, the arc process is transferred into the slag one, since the current begins to pass through the molten electroconductive slag. The heating and melting of the strip, as well as fusion of the base metal, occur due to the heat transfer from the molten slag. Thus, the welding arc has no direct effect on the base metal, which leads to decrease in its penetration.

The E.O. Paton Electric Welding Institute together with the E.O. Paton Chinese-Ukrainian Institute of Welding (CUIW, Guangzhou, China) carried out works on implementation of the ESSS method in China.

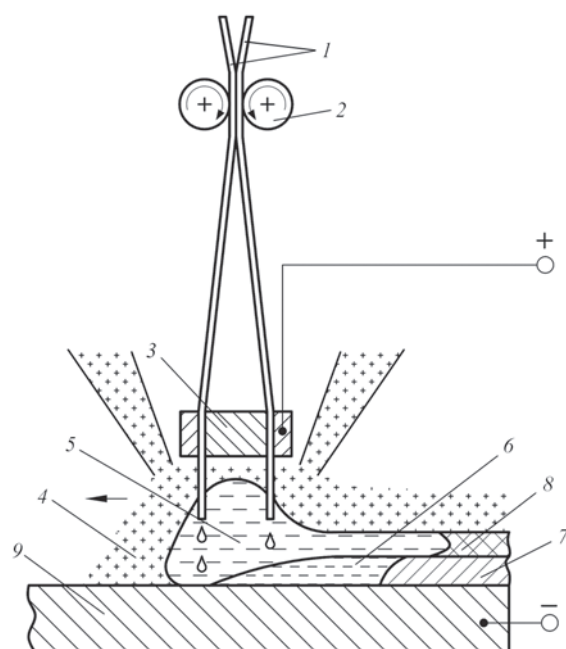
The installation for ESSS includes: welding manipulator KM 2530, on the transverse beam of which a surfacing machine is mounted with a feeding mechanism for surfacing applying two strips and a device for supply and remove of flux after surfacing; a roller stand, on which the cylindrical parts, being surfaced, are installed; an inverter power source KAIYUAN ZD5-2000 and a computer control unit.

The manipulator KM 2530 consists of a column (including lifting mechanism, device for protection against falling and device for weight balancing), transverse beam with its drive of longitudinal movement and basement on which a column with a transverse beam is fixed. The basement, in its turn, is bolted to the floor in the surfacing workshop with the help of anchor bolts. The column, transverse beam and basement represent welded structures.

The lifting mechanism raises or lowers the traverse, which provides adjustment of the surfacing machine in a position convenient for surfacing. The drive moves the traverse with the surfacing machine in the longitudinal direction at the travel or surfacing speed. During surfacing of cylindrical parts, the traverse drive also produces a displacement of the welding machine per a surfacing step. The high accuracy of manufacturing the parts of the lifting mechanism and the traverse drive provides a stable and high-quality operation of the installation.

The installation is equipped with an inverter power source ZD5-2000 manufactured by the company Tangshan Kaiyuan Specific Welding Equipment Co., Ltd (China). When using this source, the rated surfacing current is 1650 A (DC = 100 %).

For ESSS of cylindrical parts an adjustable roller stand KT5000 is used, which consists of a block of



**Figure 1.** Scheme of electroslag surfacing by two strips [4]: 1 — electrode strips; 2 — feeding rollers; 3 — copper insert-current conductor; 4 — flux; 5 — slag pool; 6 — metal pool; 7 — deposited metal; 8 — slag crust; 9 — workpiece being deposited

driving rollers and a block of auxiliary ones. A block of two pairs of driving rollers is mounted on a driving platform and has a drive system which sets a part deposited into rotation. A block of two pairs of auxiliary rollers is mounted on an auxiliary platform and does not have a drive system. The distance between the rollers of driving and the auxiliary blocks can be adjusted depending on different diameters of parts being deposited. The maximum load-carrying capacity of the stand KT5000 is 5000 kg, the diameter of the deposited parts is 500–3500 mm, the range of rotation speeds is 134–1340 mm/min. The current supply to



**Figure 2.** ESSS process of cylindrical specimen of 1000 mm diameter

the part deposited is carried out through the driving rollers with the help of sliding contacts.

The main technical characteristics of the installation for ESSS are given below, and the general appearance of the installation in the process of practicing modes of electroslag surfacing of a cylindrical specimen applying two strips are given in Figure 2.

**Technical characteristics of the ESSS installation**

Rated mains voltage, V	380
Frequency of supply mains current, Hz	50
Rated welding current of surfacing, A	1650 at DC = 100 %
Range of surfacing current adjustment, A	400–2000
Number of electrode strips, pcs	2
Thickness of cold-rolled strip, mm	0.5–1.0
Width of cold-rolled strip, mm	60
Ranges of smooth adjustment of strips feed speed, m/h:	
1 range	5–50
2 range	23–230
Surfacing speed regulation ranges, m/h	6–61
Vertical movement of surfacing machine:	
Travel, mm	400
Speed, m/h	24
Correction of electrode strips feed mechanism, mm:	
Along the deposited bead	90
Across the surfacing bead (by hand)	200
Adjustment of inclination angle of nozzlers, deg	±30
Travel speed of surfacing machine, m/h	800
Range of transverse oscillation speeds, m/h	29–118
Device for flux:	
Volume, dm <sup>3</sup>	55
Air consumption, m <sup>3</sup> /h	30
Height of flux suction, m	2

The computer control system of the installation allows monitoring the process of surfacing applying two strips with a high degree of automation. For example, during surfacing of cylindrical parts, the operator sets the surfacing modes and diameter of workpiece being deposited on the computer screen and presses the «Start» button. The control system, coming from the workpiece diameter, selects the rotation speed, displacement moment and value per step during closing of each circular bead. The control system of the installation is integrated with the power source control system, which allows conducting the process of surfacing in automatic mode and provides a high quality of surfacing. If necessary, the operator can interfere with the surfacing process and correct its modes.

In the installation the modes of electroslag surfacing by two strips were practiced on flat and cylindrical parts and the investigations of effect of current, voltage and surfacing speed, as well as the gap between the electrode strips on the stability of the electroslag process, the geometrical dimensions of the deposited beads and VBM in the deposited metal were carried out.

In the experiments the strip ESAB OK Band 309LNb ESW with cross-section of 0.5×60 mm and flux ESAB OK Flux 10.10 were used. The surfacing was performed on plates of steel St3 of 350×200×(30–40) mm, the current and voltage values varied within 1200–1600 A and 25–38 V, respectively. The speed of surfacing varied between 10–30 m/h, and the gap between the strips was 8–20 mm, the strips stickout remained unchanged and was 35–40 mm.

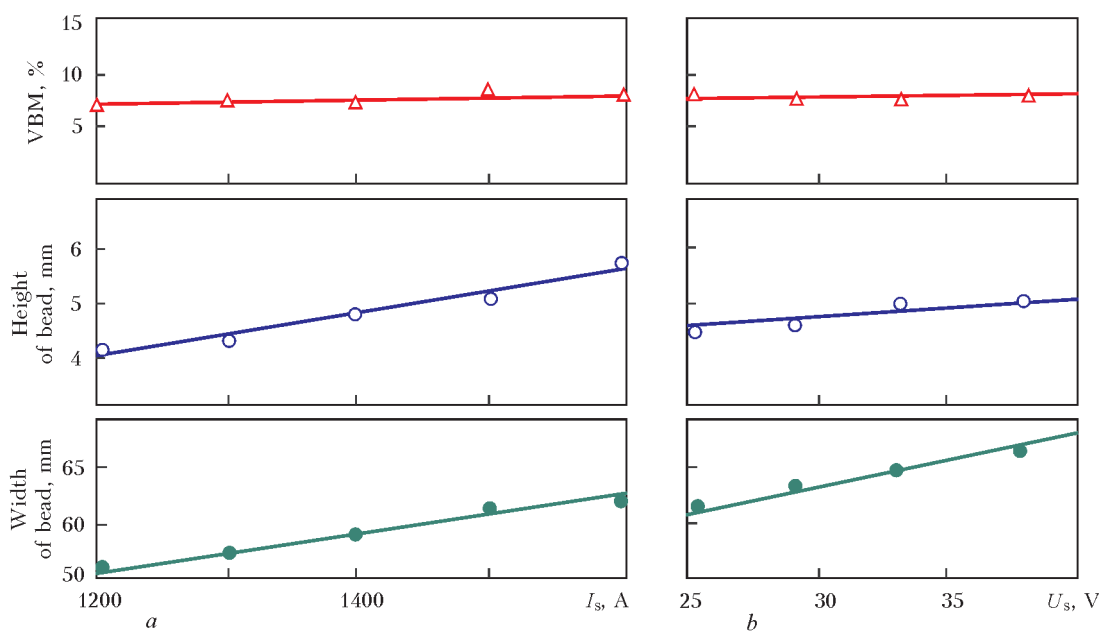
After surfacing, a layer-by-layer spectral analysis of chemical composition of the deposited metal was carried out, the results of which are given in the Table. The analysis of these data shows that in ESSS the pre-set chemical composition is achieved already in the first deposited layer.

The influence of current, voltage and speed of surfacing, as well as the gap between the strips on the stability of the electroslag process, the geometric dimensions and VBM were investigated. It was found that geometric dimensions of the deposited bead are almost directly proportional to the value of surfacing current and voltage, however, the value of VBM remains almost unchanged (Figure 3). This is explained by the fact that in electroslag process there is no direct effect of arc on the base metal, therefore the increase in electrical power mainly affects only the increase in the amount of deposited metal.

A greater influence on VBM is provided by surfacing speed as well as by gap between the strips (Figure 4). The surfacing speed determines the duration of thermal action of slag pool on the base metal, and the size of a gap significantly affects the stability *N* of running the electroslag process itself. The stability was determined according to oscillograms as a ratio of duration of periods of electroslag and arc processes for a certain time. At a small size of gap the slag pool

Chemical composition of strip of grade ESAB OK Band 309LNb ESW and metal deposited by electroslag method applying two strips of this grade

Material investigated	Mass fraction of elements, %							
	C	Mn	Si	Cr	Ni	Nb	S	P
Strip								
ESAB OK Band 309LNb ESW	0.015	1–2.5	≤0.4	20.0–22.0	11.0–13.0	0.4–0.8	≤0.03	≤0.03
Deposited metal								
1 layer	0.014	1.43	0.67	21.7	12.5	0.59	0.005	0.017
2 layer	0.017	1.47	0.65	21.4	12.4	0.63	0.005	0.017
3 layer	0.017	1.42	0.70	22.1	12.8	0.58	0.007	0.019

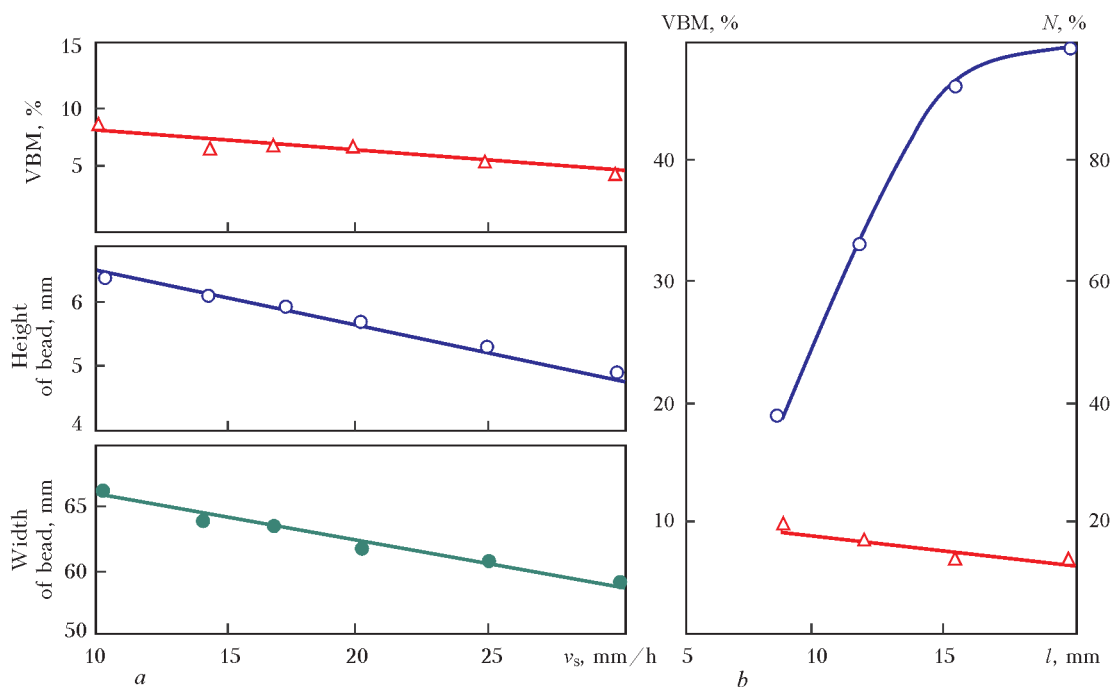


**Figure 3.** Influence of current  $I_s$  (a) and voltage  $U_s$  (b) of surfacing on geometric dimensions of deposited bead and VBM in the deposited metal

overheats between the strips, an unstable slag-arc process is observed, as a result, the penetration of base metal increases and its formation is deteriorated. As the gap increases, the area of the slag pool mirror increases, the pool temperature decreases and the electroslag process becomes more stable. At a width of 16 mm, the deposited bead has even edges and a smooth surface, i.e. the better formation (Figure 5, a) than the bead deposited at the same mode, but with a gap of 8 mm (Figure 5, b).

As a result of investigations it was found that a stable electroslag process applying strips of 0.5×60 mm

section is reached at the following surfacing parameters:  $I_s = 1400\text{--}1500$  A;  $U_s = 32\text{--}33$  V;  $v_s = 14\text{--}17$  m/h; feeding speed of the strip is 65–70 m/h; the gap between the strips is 16 mm. The metallographic examinations showed that specimens deposited at these modes are characterized by a good formation of deposited metal and minimal penetration of base metal within the range of 7–9 % (Figure 6, a, b). At the same time, the fusion boundary of the deposited and base metal is quite even, which positively affects the strength properties of the produced joint.



**Figure 4.** Influence of speed of surfacing  $v_s$  (a) and gap between the strips  $l$  (b) on geometric dimensions of deposited bead, stability of the process  $N$  and VBM in the deposited metal

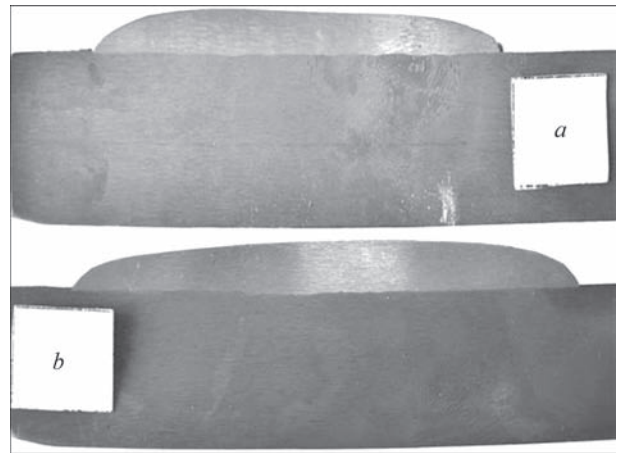


**Figure 5.** Influence of gap between the strips  $l$  on formation of deposited metal:  $a$  —  $l = 8$  mm;  $b$  — 16 mm. Surfacing mode:  $I_s = 1200$ – $1300$  A;  $U_s = 32$ – $33$  V;  $v_s = 14$  m/h

To determine mechanical properties of the deposited metal, a multilayer surfacing was carried out according to the abovementioned mode. The total thickness of the deposited metal was  $\approx 20$  mm, width was 62–65 mm. The specimens for mechanical testing were cut from the deposited billet. The mechanical properties of deposited metal of steel 309LNb at 20 °C are the following:  $\sigma_t = 504$ – $506$  MPa ( $\geq 510$ );  $\sigma_y = 286$ – $297$  MPa ( $\geq 205$ );  $\delta = 44$ – $49$  % ( $\geq 25$ );  $\psi = 64.0$ – $69.7$  % ( $\geq 60$ ) (in brackets the data on mechanical properties of steel 309LNb are given).

The test results show that strength characteristics of the metal deposited applying strips ESAB 309LNb ESW are at a sufficiently high level and meet the requirements specified to them. The obtained results can be used to select or develop materials and technologies for anticorrosion surfacing of the parts of power and chemical equipment.

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**Figure 6.** Macrosections of cross-section of specimens deposited at the modes  $U_s = 32$ – $33$  V;  $v_s = 12$  m/h;  $l = 16$  mm:  $a$  —  $I_s = 1400$  A (VBM = 7 %);  $b$  —  $I_s = 1500$  A (VBM = 9 %)

*tion research team of Guangdong province (China) No. 201101C0104901263, as well as research projects of China: No.2013B050800032 «Investigation and application of high-efficient welding equipment for arc welding» and No. 201508030023 «Development of submerged arc welding technology».*

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