ELECTROSLAG CLADDING OF STAINLESS AUSTENITIC LAYER BY STRIP ELECTRODE

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Abstract

Paper deals with quality and properties of deposit layer made by method electroslag cladding with strip electrode. Parent material was not-alloyed structure steel S355J2. Filler metal was stainless austenitic steel - strip electrode OK Band 309Nb, with agglomerated flux OK Flux 10.10. Samples were made with 1 to 3-layers pass. Samples were examined in terms of chemical composition and dilution of parent metal and filler metal. Next, changes of structure, courses of hardness and heat affection of parent metal were mapped. Comparison of characteristics of particular layer, comparisons between results electroslag cladding and submerged arc cladding was the aim.

Keywords: Electroslag cladding, strip electrode, microstructure, hardness

1. INTRODUCTION

Present trends in industry are: reducing of production costs, improve product properties and increasing demands for labor safety and environmental protection. It is possible for example by cladding of stainless layer to not-alloyed structure steel. To economic achieve the best properties it is required minimized dilution between parent material (PM) and deposit layer and also the smallest number of passes [1]. This can be achieved by progressive high-efficiency technologies [2]. Large area weld deposits a special composition is possible create for example by plasma [3] or laser [4] [5]. In field of conventional cladding it is strip electrodes (methods: Submerged Arc Welding (SAW) [6] and Electroslag Welding (ESW) [7]). Electroslag Cladding (ESC) is used very often for creating of layer with different properties than PM has. This method has many applications for example functional surfaces in automotive and aviation industry, the lining of components for important parts in nuclear energy, etc. [8] [10].

1.1. Electroslag cladding - principle

Method ESC is very useful, flexible and economic alternative of application of surface layers with different chemical composition and properties. The most often required are corrosion resistance, hardness and wear resistance of deposit layer [8] [9]. Principle of this method is similar as submerged arc welding (and cladding) - SAW. The main difference between ESC and ESW is in welding position. ESC is made in flat position (PA according to EN ISO 6947) and without copper backing (**Figure 1**), while standard welding method using ESW runs only in position PF. [8] [9] Weld pool is formed by burning-of in full width of strip. During submerged arc cladding process the flux is supplied from both sides of the weld, during electroslag cladding the flux is supplied only from one side (**Figure 1**).

1.2. Process parameters

Welding parameters of method ESC are different (and preferable in many cases) than parameters, which SAW method allows. One of main criteria at cladding technology choosing is dilution degree of deposit metal and PM (required as small as possible). For ESC method the dilution degree can be less half than the SAW method. Deposition rate for ESC is higher (up to 80 %). Deposition rate depending upon the dimensions of used strip and amperage is in **Figure 2**. Lower welding voltage reduces the flux consumption to 0.4 - 0.5 kg per 1 kg of strip [9]. However, the much higher welding current is used therefore it is necessary to have more powerful sources.

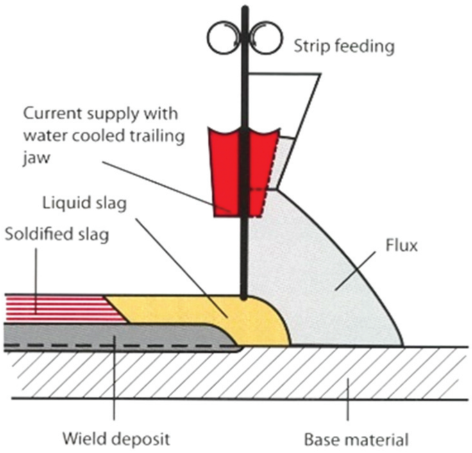

Figure 1 The principle electroslag cladding [9]

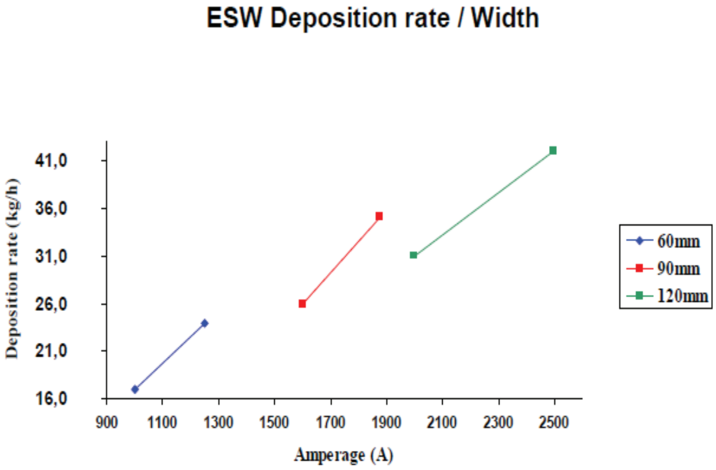

Figure 2 The deposition rate dependence on strip width and amperage [10]

2. EXPERIMENT

Microstructure and mechanical properties of stainless austenitic cladding deposit were verified. As parent metal was used not-alloyed structure steel S355J2 with thickness 60 mm. Base characteristics are in **Table 1**.

Table 1 PM specification - contents of main alloy elements, base mechanical properties [11]

Designation	Chemical composition (wt. %)						
S355J2	C	Si	Mn	P	S	N	Cu
	max 0.2	max 0.55	max 1.6	max 0.025	max 0.025	-	max 0.55

Minimal ductility (in the cross direction) $A_{5.65}$	Minimal upper yield strength R_{eH}	Tensile strength R_m	Impact strength KV
25 %	335 MPa	470 - 630 MPa	27 J at -20 °C

Filler metal (FM) was strip electrode from stainless steel - OK Band 309LNb ESW with dimensions 60 x 0.5 mm. Chemical composition is in **Table 2**. The flux with designation OK Flux 10.10 was used. Characteristics are in **Table 3**. It is a highly basic agglomerated flux (basicity index = 4). The flus has particle size 0.15 - 1 mm, density =1 kg / dm^3.

Table 2 Designation and chemical composition of use strip electrode (FM) [9]

FM designation (strip)		Chemical composition (wt. %)							
Firm designation	EN ISO 14343-A	C	Si	Mn	Cr	Ni	Mo	N	others
309LNb ESW	B 22 12 L Nb	0.015	0.2	1.8	21	11	-	0.06	Nb 0.6

Deposit was made with 1 - 3 layers (samples V1 to V3). Welding source ESAB LAF 1250 DC was used (polarity was DC+ and way of regulation CA). Flux layer thickness was 30 mm. Welding parameters were: first pass - current 1250 A, voltage 25 V, speed 18 cm·min^{-1}.

Table 3 Designation and chemical composition of flux [9]

FM designation (strip)		Chemical composition (wt. %)					
Firm designation	EN ISO 14174	C	Si	Cr	Ni	Mo	N
OK Flux 10.10	ES A FB 2B 56 44 DC	0.03	0.4	1.2	19	10	0.25

The flux was filled manually from one side of cladding. The same parameters was used for other layers was (only cladding speed was increase to 20 cm·min^{-1}). Generally for ES claddings are used maximally 2 layers, for this experiment the samples with also 3 layers were created. Every pass was made when previous pass has cooled.

3. RESULTS

3.1. Macro and microstructural analysis

On **Figure 5** is macrostructure (A) of 3-layer deposit - sample V3 (microstructures of 1 and 2-layers cladding was almost the same) with details in areas: not affected parent material S355J2 with pearlite-ferritic structure (B), heat affected zone - HAZ (C), normalized annealed area (D), transition area between PM and austenitic deposit (E) - where is seen diffusion layer with thickness about 20 µm, transition area between 1st and 2nd layer of austenitic deposit (F) and transition area between 2nd and 3rd layer of austenitic deposit (G). Microstructures are in magnification 100x, in etched state (nital 2%). Thicknesses of particular deposit layers are 4.2 mm for 1st layer, 3.6 mm for 2nd layer and 4.5 mm for 3rd layer, HAZ size is about 9.5 mm (for 3-layers deposit).The size of area, where comes to dilution of chemical composition, are 30 µm.

3.2. Electron microanalysis

Chemical analysis was made on electron microanalyzer CAMEBAX MICRO (firm CAMECA) and energy dispersive analyzer (firm KAVEX) - control microcomputer PDP 11/23 was used (firm DEC). It was used wave dispersive system (WDS). The diameter of analyzed area is between 2 and 4 µm, the depth is 0.5 to 2 µm.

3.2.1. Qualitative spectral analysis

For spectrogram was used crystals LiF, ODPb, TAP and PET. Elements C, Fe, Mn, Si were identified for PM (**Figure 3**) and elements: C, Mn, Si, Cr, Ni, Fe were identified for cladding (**Figure 4**).

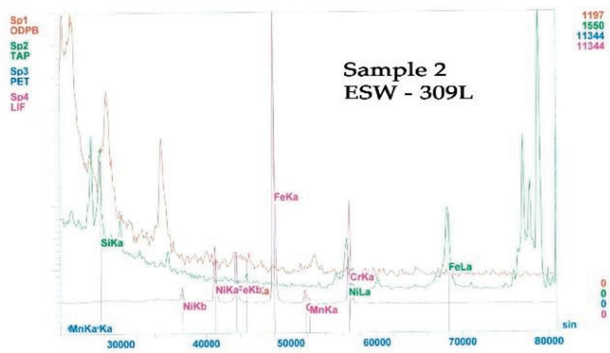

Figure 3 Spectrograms for PM

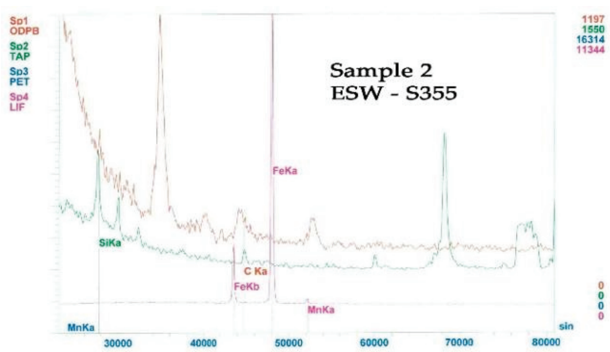

Figure 4 Spectrograms for cladding deposit

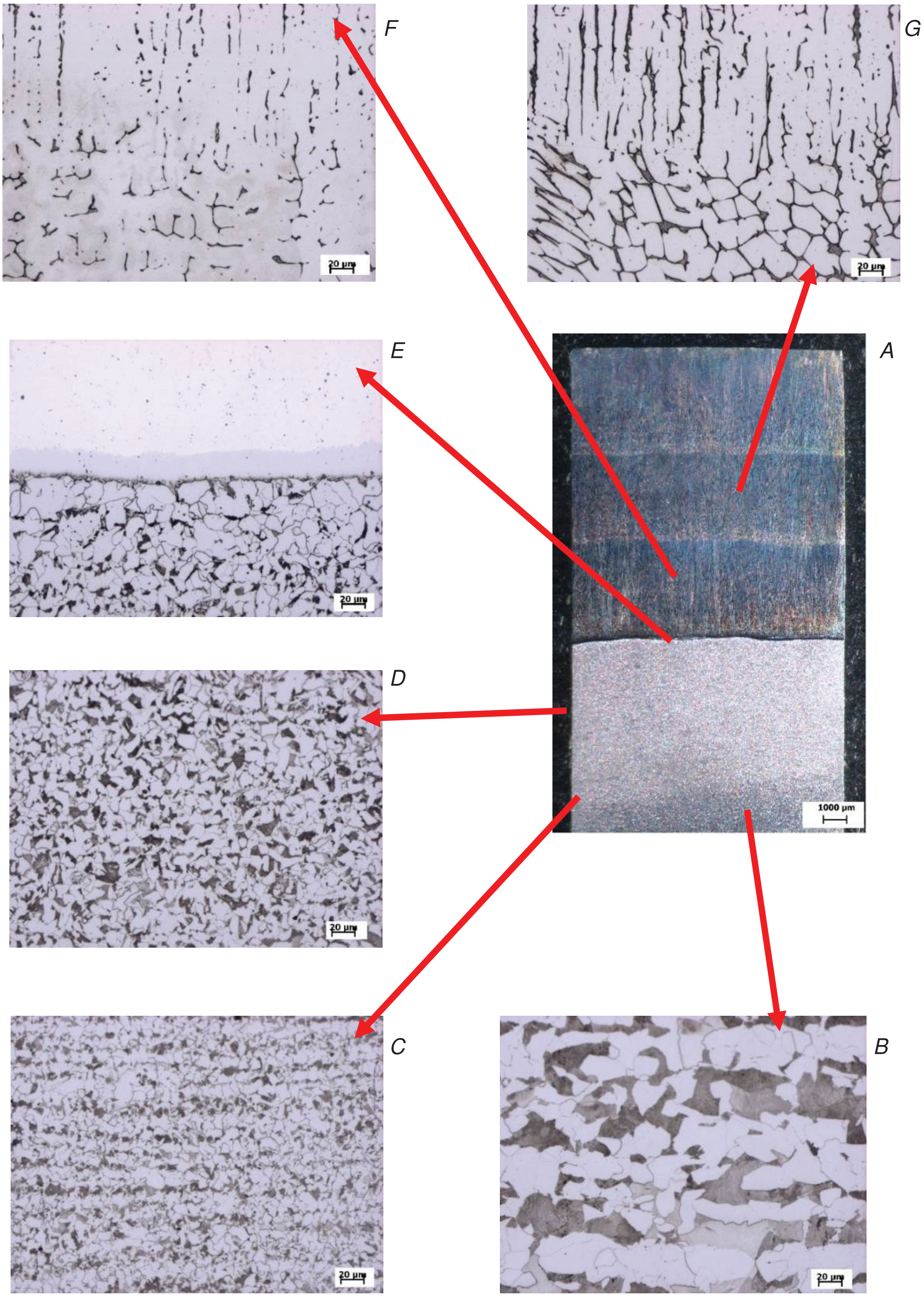

Figure 5 Macro and microstructure of 3-layers cladding deposit (sample V3)

3.2.2. Spot quantitative analysis

Content elements found by qualitative spectral analysis were measured. On sample V3 transition areas between parent material and deposit, transition areas between particular layers of cladding were mapped. Results of quantitative analysis are on **Figures 6, 7** and **9**.

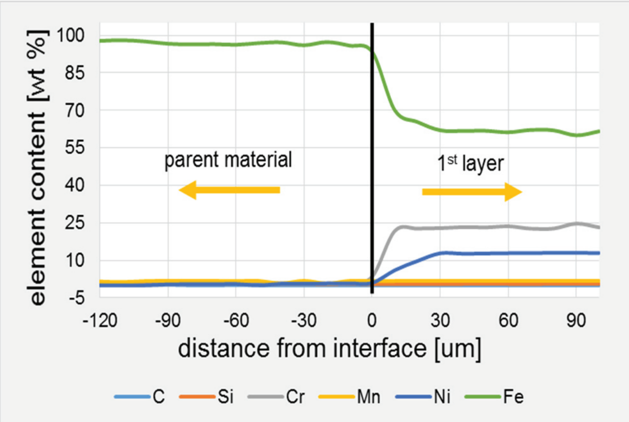

Figure 6 Chemical composition on transition area between PM (HAZ) and deposit

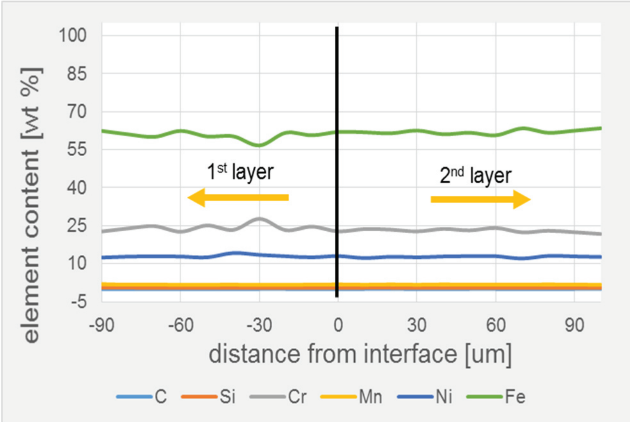

Figure 7 Chemical composition on transition area between 1st and 2nd deposit layer

3.3. Micro-hardness measurement

Due to the nature and character of the deposits, from mechanical properties the hardness course across the created interface of weld was evaluated (measurement was made according to standard EN ISO 6507 and in accordance with standard EN ISO 9015-2 = basically micro-hardness measurement was performed - HV1). Average hardness of PM (steel S355J2) was 176 HV1. Measured hardness values (perpendicularly to the transition interface between the PM and FM) are on **Figure 8** - example is sample V3.

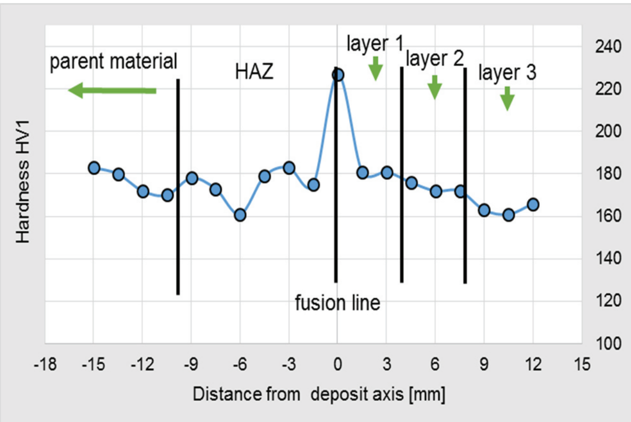

Figure 8 Hardness course perpendicular to created deposit

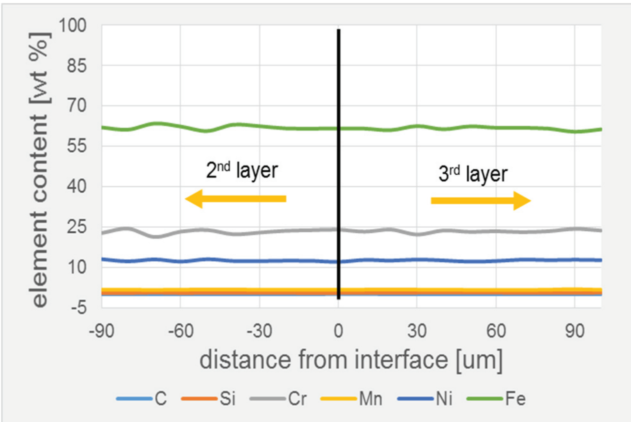

Figure 9 Chemical composition on transition area between 2nd and 3rd deposit layer

There is a significant local maximum at transition area between PM and deposit (where is seen diffusion layer in microstructure). Local hardness minimum (161 HV1) is in HAZ on transition to annealed area of HAZ. Hardness course in cladding is gently decreasing with bigger amount of deposited layers. For 2-layers deposit (sample V2) the hardness course is similar but every values are by 5-10 HV1 minor. For 1-layer deposit the hardness maximum is 238 HV1. From this view the ESC is preferable then SAC, where hardness values are bigger in all course. This shows for example the research done on CTU in Prague [8].

4. CONCLUSION

The ES cladding in combination with using of strip electrodes has many advantages [8] [10] [12]. In compare with SA cladding by rod electrode [12] the ESC has much smaller penetration and also dilution (for SA cladding with strip electrode the dilution is to 80 µm from fusion line at the same type of deposit [8]). For created samples (shown in sample V3, however it applies to other samples) the required chemical composition (the same as has FM) of deposit is achieved in the first deposit layer (it is about 30 µm from interface PM and deposit). Dilution of FM (deposit) to PM is 20 µm. In compare with SAC by strip electrode the ESC has also higher productivity (there are used higher parameters and speed - for SAC the currents and speeds are used on the level 60 % of ESC. For ECS the heat input is about 10.4 kJ / mm and for SAC it is 10.6 kJ / mm) [8] [12]. Courses of chemical composition and hardness (for 3-layers deposit) are fairly steady in HAZ. There are local hardness maximum on transition area between HAZ and deposit (227 HV1). From this view 1-layer deposit created by ESC method is satisfactory (if there is no requirement to deposit thickness greater than 5 mm). The experimental results confirm this.

ACKNOWLEDGEMENTS

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