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SAW surfacing of low-alloyed steel with super-ferrite additional material

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ABSTRACT

Purpose: of these researches was to investigate influence of heat input in SAW surfacing of low-alloyed steel with super-ferrite filler material on quality of deposits.
Design/methodology/approach: the quality of single and multilayer, stringer beads was assessed by metallographic examinations, stresses measurements and hardness tests.
Findings: due to the fact that it was used at automated surfacing stand, the analysis of properties of the deposits was performed for single and multilayer, stringer beads.
Research limitations/implications: for complete information about tested deposits it is needed to compare deposits properties with other technologies of super-ferrite deposits surfacing.
Practical implications: results of this paper is an optimal range of parameters for surfacing of single and multilayer, stringer beads of super-ferrite layers.
Originality/value: the researches (macro- and micro-observations, hardness tests, stresses distribution tests) were provided for surfacing of single and multilayer, stringer beads, and the results were compared. The influence of heat input on layers properties and theirs structure was defined.
Keywords: Welding; SAW; Surfacing; Super-ferrite

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1. Introduction

Structural components surface condition is a main problem of modern engineering because of operating parameters growth results in accelerated wear of these parts. Elements wear occurring in all industry branches starting from mining, cement, coal power plant, building engineering, recycling, environment protection to chemical industry and the others similar ones. Some of these elements stop working because of small defects. Using surfacing technologies, it is possible to regenerate machine parts (rebuilding) or improve surface properties such as wear and corrosion resistance, ageing resistance or heat and high temperature creep resistance (productive surfacing) [1-11].

High requirements, for industry equipment results use modern engineering materials while manufacturing and regeneration processes of those parts. Super-ferrite steels are used in chemical industry on nitric acid production facilities. Especially water cooling heat exchangers with chloride ions, evaporators, reactors, pipelines, on exchangers working with strongly saline water in water softening plants. Super-ferrite steels are used also on reactors for petroleum products included hydrogen sulphide, sulphur-recovery plants, for thickeners in food industry, for containers and chutes in mines and for exhaust systems and catalysts [11-15].

2. Researches

Aim of this work was to define an influence of SAW surfacing with super-ferrite 00H18M2Nb filler material of S355NL steel plates

15.0 [mm] thick on quality, dimensions, structural changes and stresses distribution on single and multilayer stringer beads deposits, Tables 1 and 2. All deposits were surfaced on automated stand equipped with A2TFH1 SAW tractor welder with ESAB LAF 635DC power source on S355NL steel plates 15.0 mm thick using 00H18M2Nb 3.2 mm dia. wire and OK. Flux 10.71 agglomerated flux, Fig 1.

To define influence of SAW surfacing parameters on deposits geometry and dilution of stringer bead deposits, surfacing tests were provided with wide range of basic parameters change, Tables 3 and 4, Figs. 2 and 3.

Parameters of single-, double and triple layer deposits surfacing with heat input: 11 and 24 [kJ/cm] were specified based on surfacing stringer beads deposits results, Table 5. Quality of deposits was assessed by visual and PT (wet fluorescent method) examinations on single-, double and triple layer deposits face, Figs. 4 to 8. Main purpose of microstructure investigation was visualization of structural changes in base material and HAZ as a result of heat input influence during surfacing, Figs. 9 and 10.

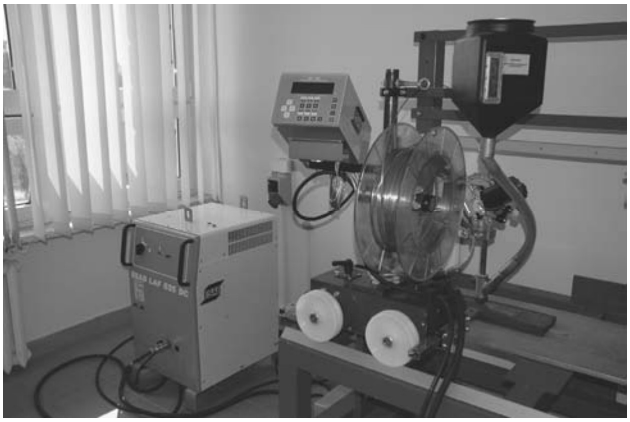

Fig. 1. A view of SAW (Submerged Arc Welding) stand

Table 1.
Chemical composition and mechanical properties of 00H18M2Nb filler material

Chemical composition, wt%								
Cr	C	N	Mo	P	S	Nb	Si	Mn
18.5	0.0012	0.0023	1.9	0.028	0.002	0.25	0.2	0.3
Mechanical properties								
Tensile strength R_m [MPa]			Yield point R_e [MPa]			Elongation A_5 [%]		
560			430			38		

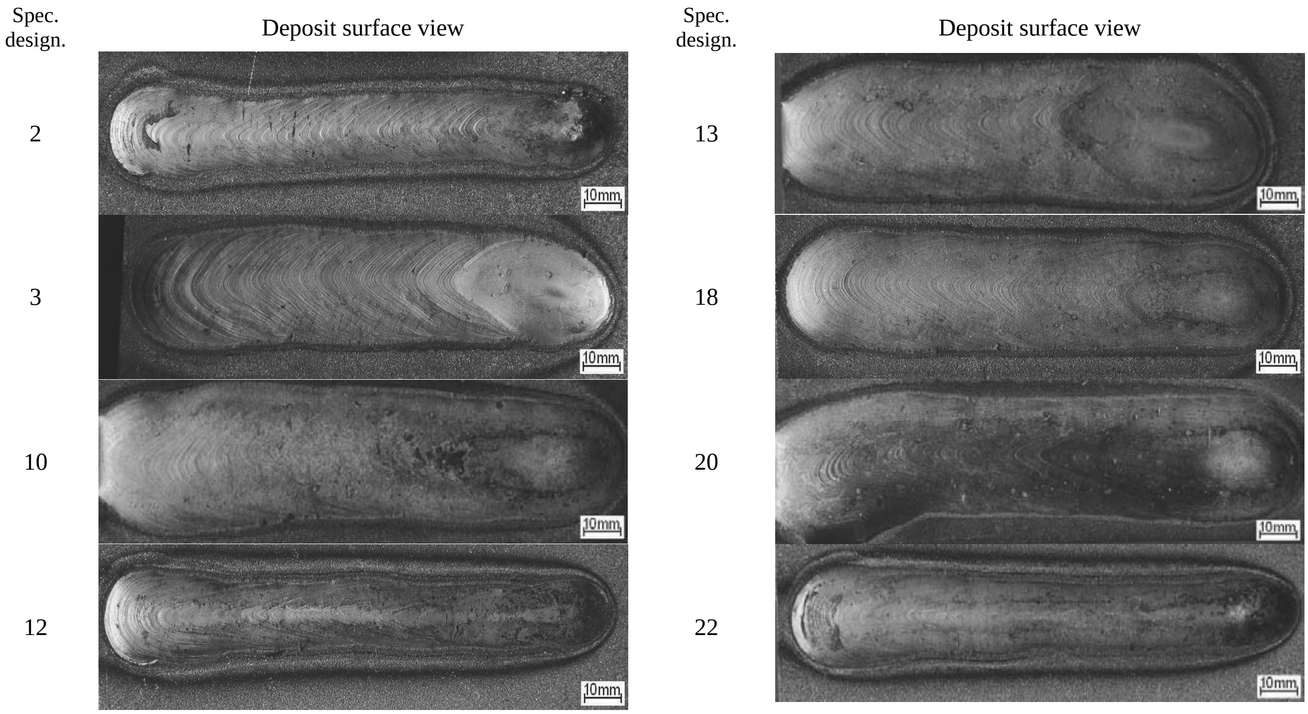

Fig. 2. SAW deposits face view surfaced with 00H18M2Nb wire on S355NL steel plates, Table 3

Table 2.
Chemical composition and mechanical properties of S355 NL steel

Chemical composition, wt%								
C	Mn	Si	P	S	N	Cr	Cu	Ni
0.16	1.50	0.50	0.035	0.035	-	0.50	0.30	0.50

Mechanical properties		
Tensile strength R_m [MPa]	Yield point R_e [MPa]	Elongation A_5 [%]
490	420	21

Table 3.
SAW S355 NL steel plates surfacing parameters with 00H18M2Nb 3.2 mm dia. wire, Figs. 2 and 3

Specimen designation	Surfacing current [A]	Arc voltage [V]	Surfacing speed [cm/min]	Heat input [kJ/cm]
1	300	30	25	22
2	400	30	25	29
3	500	30	25	36
4	300	35	25	25
5	400	35	25	34
6	500	35	25	42
7	300	40	25	29
8	400	40	25	38
9	500	40	25	48
10	300	30	50	11
11	400	30	50	14
12	500	30	50	18
13	300	35	50	13
14	400	35	50	17
15	500	35	50	21
16	300	40	50	14
17	400	40	50	19
18	500	40	50	24
19	300	30	75	7
20	400	30	75	10
21	500	30	75	12
22	300	35	75	8
23	400	35	75	11
24	500	35	75	14
25	300	40	75	10
26	400	40	75	14
27	500	40	75	16

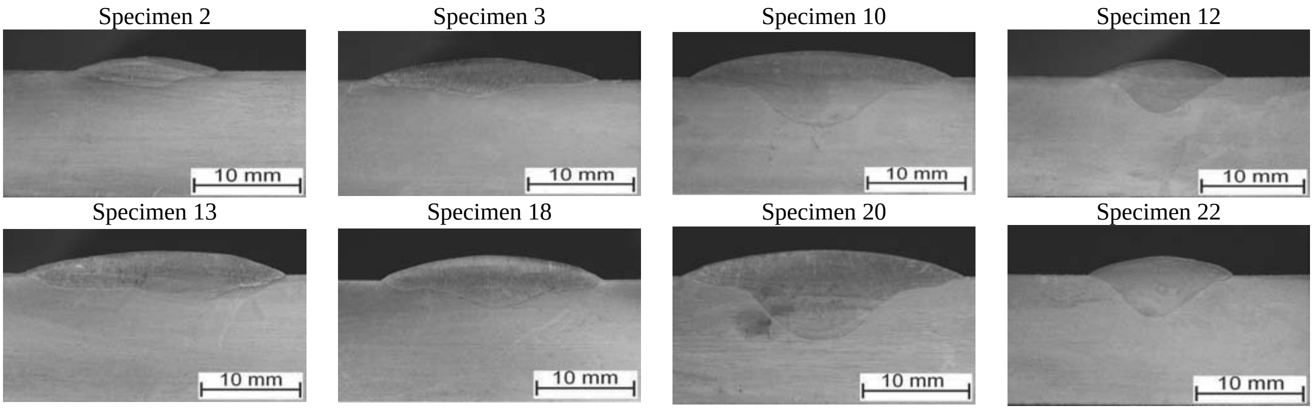

Fig. 3. Macrostructure of SAW deposits surfaced with 00H18M2Nb wire on S355NL steel plates. Surfacing parameters – Table 4

Table 4.
Influence of SAW S355 NL steel plates surfacing parameters with 00H18M2Nb 3,2 mm dia. wire on dimensions and dilution of deposits, Table 3, Figs. 2 and 3

Specimen number	b [mm]	h_w [mm]	h_n [mm]	Fn [mm^2]	Fw [mm^2]	$\Phi = b/h_w$	U_p [%]
1	24.02	1.41	2.76	41.02	22.21	17.03	35.1
2	13.96	1.98	1.82	15.43	12.65	7.05	45.0
3	22.52	2.26	2.73	39.04	23.22	9.96	37.3
4	19.5	6.2	2.25	27.75	54.34	3.14	66.2
5	14.8	2.34	1.67	14.85	17.04	6.32	53.4
6	12.68	2.1	1.43	12.36	14.41	6.03	54.0
7	11.3	1.5	1.54	11.77	8.55	7.38	42.3
8	16.5	3.94	2.02	20.48	29.26	4.06	58.9
9	19.3	3.40	2.74	34.35	30.19	5.67	46.8
10	27.3	6.28	3.45	64.45	79.54	4.34	55.3
11	17.55	3.51	1.96	23.95	30.66	5.00	56.1
12	13.3	4.53	2.21	19.33	31.62	2.93	62.1
13	27.52	3.44	2.72	50.52	54.16	8.00	51.7
14	18.42	4.77	2.96	34.83	42.45	3.86	54.9
15	14.1	2.70	1.75	15.20	19.98	5.22	56.8
16	15.9	5.42	1.62	16.53	41.90	2.93	71.7
17	17.87	5.88	2.51	29.09	49.61	3.03	63.0
18	23.45	3.41	3.2	49.48	39.48	6.87	44.4
19	27.98	2.82	2.72	48.53	39.31	9.92	44.8
20	27.38	6.95	2.88	54.41	80.31	3.93	59.6
21	11.2	3.00	1.4	10.19	18.54	3.73	64.5
22	13.89	4.80	2.15	19.94	34.17	2.89	63.2
23	14.06	2.89	2.34	21.43	19.64	4.86	47.8
24	14.1	3.61	2.37	20.47	25.09	3.90	55.1
25	13.9	3.02	1.82	15.30	21.81	4.60	58.8
26	18.9	4.00	1.72	21.02	36.04	4.72	63.2
27	26.63	6.70	4.0	65.98	78.69	3.97	54.4

h_n – reinforcement height, h_w – penetration depth, [mm], b – deposit width, F_w – base material fusion zone area, F_n – reinforcement area, Φ - shape factor, U_p – dilution

Spec. design.	View of deposits faces	Spec. design.	View of deposits faces
Z1		Z2	

Fig. 4. A view of multilayer overlapped deposits faces

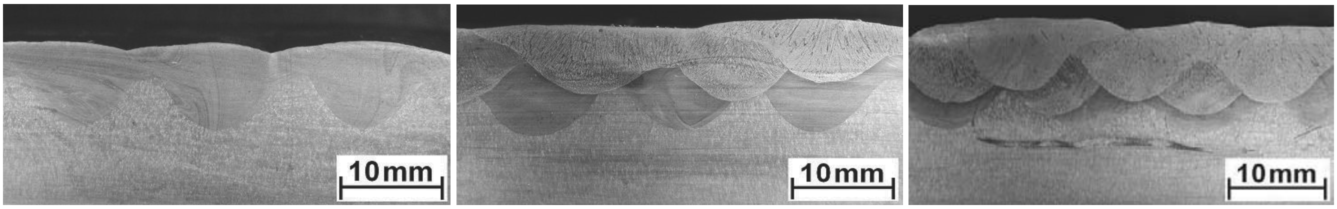

Fig. 5. Macrostructure of single-, double- and triple layer SAW deposits surfaced with 00H18M2Nb wire on S355NL steel plates. Surfacing parameters: I = 500 [A], U = 40 [V], V = 50 [cm/min]

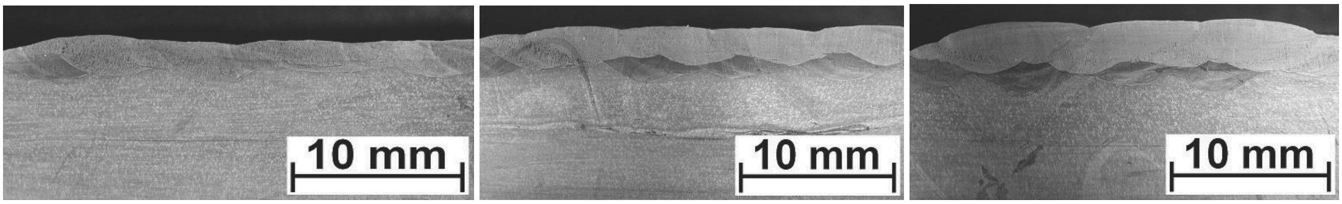

Fig. 6. Macrostructure of single-, double- and triple layer SAW deposits surfaced with 00H18M2Nb wire on S355NL steel plates. Surfacing parameters: I = 300 [A], U = 30 [V], V = 50 [cm/min]

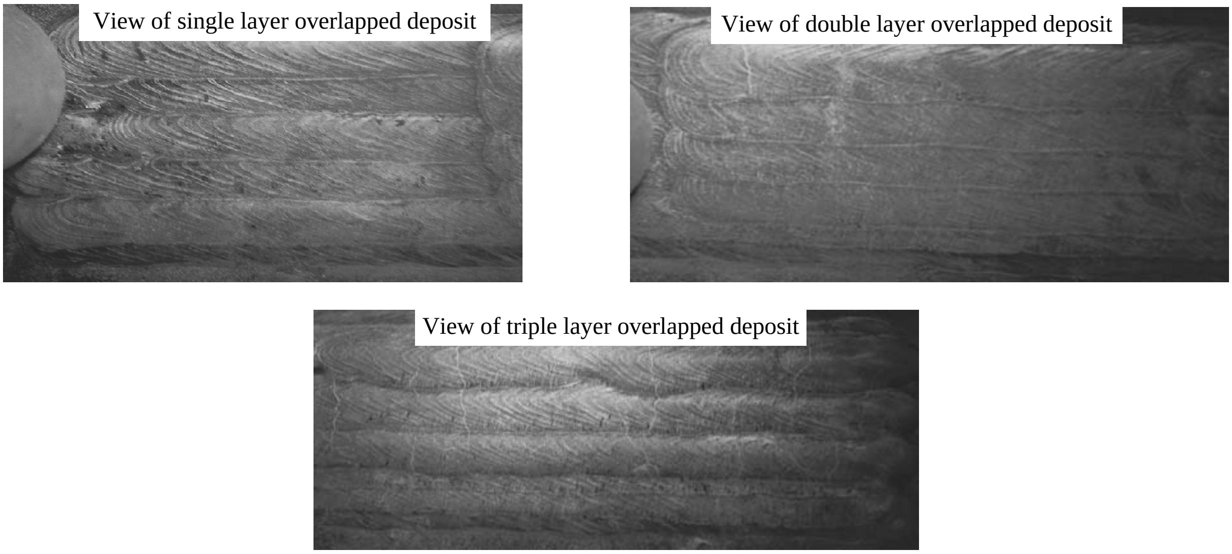

Fig. 7. A view of multilayer overlapped deposits face during PT examinations (wet fluorescent method). Surfacing parameters: I = 300 [A], U = 30 [V], V = 50 [cm/min]

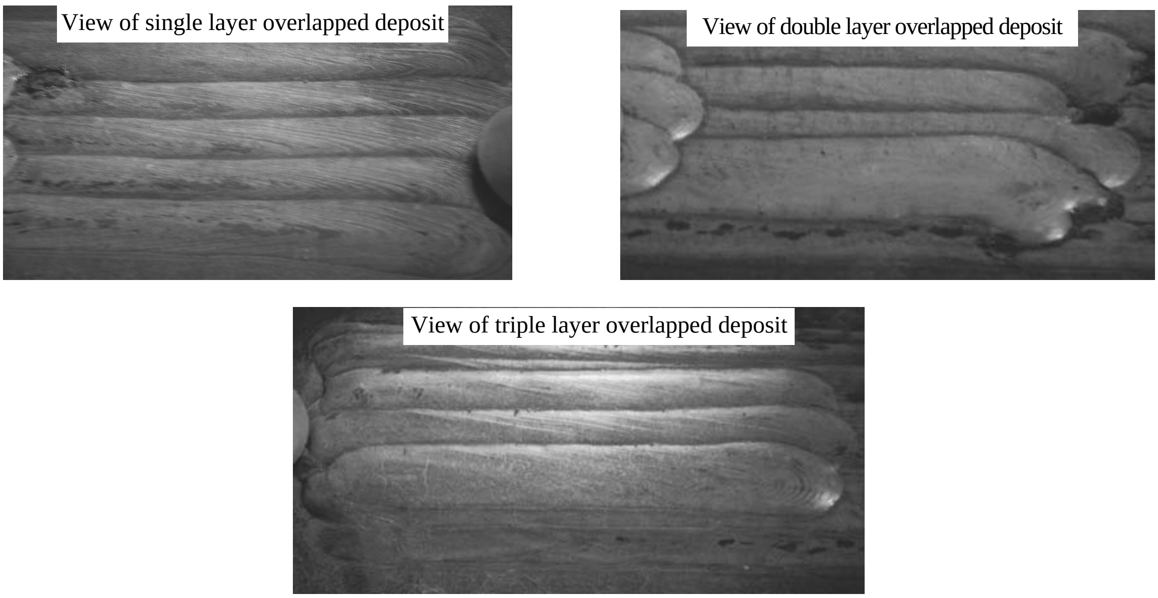

Fig. 8. A view of multilayer overlapped deposit face during PT examinations (wet fluorescent method). Surfacing parameters: I = 500 [A], U = 40 [V], V = 50 [cm/min]

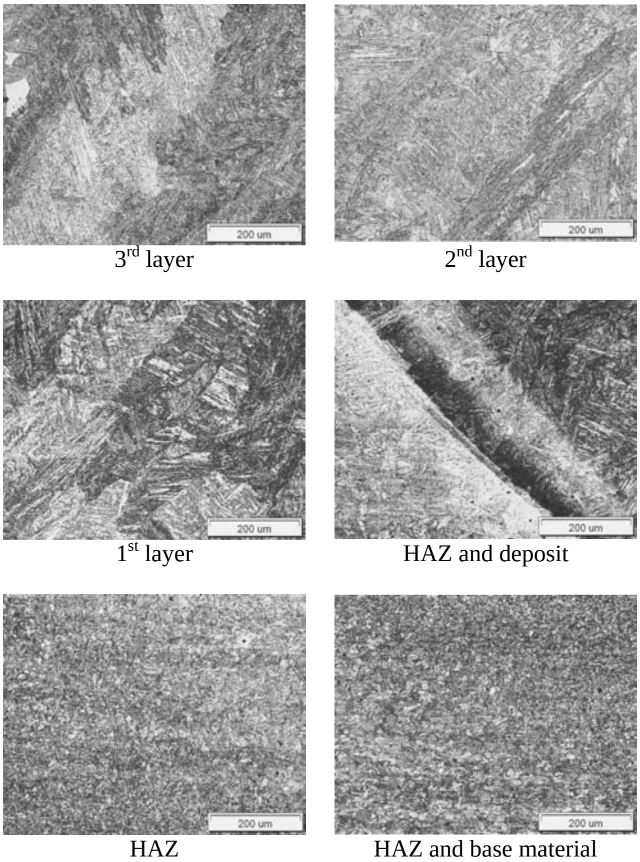

Fig. 9. View of microstructure of three-layers overlapped deposit. Etching: Adler. Surfacing parameters: surfacing current: I = 500 [A], arc voltage: U = 40 [V], surfacing speed: v = 50 [cm/min]

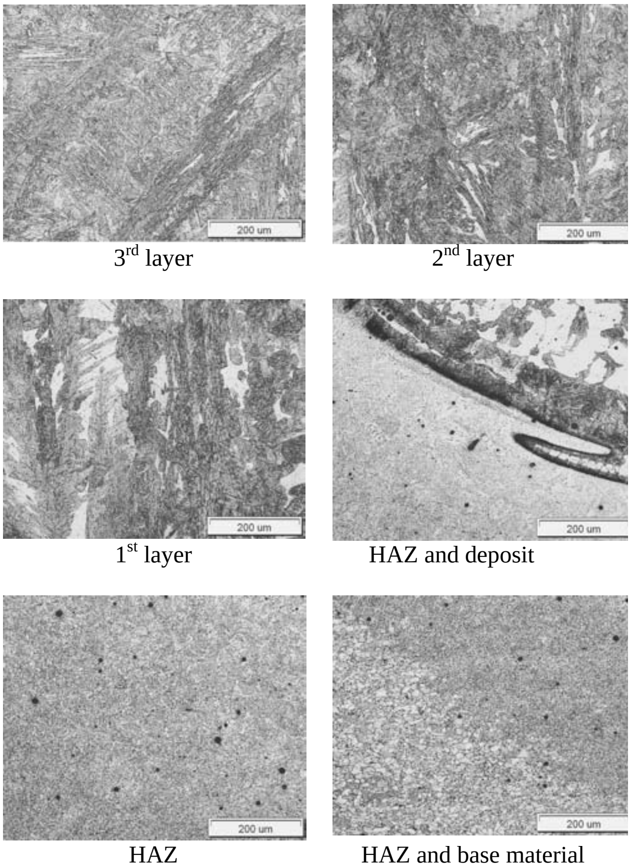

Fig. 10. View of microstructure of three-layers overlapped deposit. Etching: Adler. Surfacing parameters: surfacing current: I = 300 [A], arc voltage: U = 30 [V], surfacing speed: v = 50 [cm/min]

Table 5.
Single, double and triple layer overlapped deposit hardness. Surfacing parameters: surfacing current: I = 500 [A], arc voltage: U = 40 [V], surfacing speed: v = 50 [cm/min], Figs. 4 to 8

Measurement place	Deposit			HAZ (Heat Affected Zone)			Base material		
Layer number	Hardness HV 1								
				Triple layer deposit					
3rd layer	337	329	343	-	-	-	-	-	-
2nd layer	333	334	361	-	-	-	-	-	-
1st layer	340	336	328	261	245	222	192	188	185
				Double layer deposit					
-	-	-	-	-	-	-	-	-	-
2nd layer	357	350	328	-	-	-	-	-	-
1st layer	367	348	330	288	285	287	189	184	186
				Single layer deposit					
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
1st layer	347	338	326	286	255	235	182	188	185

Table 6.
Single, double and triple layer overlapped deposit hardness. Surfacing parameters: surfacing current: I = 300 [A], arc voltage: U = 30 [V], surfacing speed: v = 50 [cm/min]

Measurement place			Deposit			HAZ (Heat Affected Zone)		Base material	
Layer number	Hardness HV 1								
Triple layer deposit									
3rd layer	346	320	357	-	-	-	-	-	-
2nd layer	340	323	320	-	-	-	-	-	-
1st layer	332	336	320	280	245	213	183	188	179
Double layer deposit									
-	-	-	-	-	-	-	-	-	-
2nd layer	343	331	327	-	-	-	-	-	-
1st layer	339	332	362	325	292	260	193	184	177
Single layer deposit									
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
1st layer	356	343	330	264	245	214	197	188	180

Table 7.
Results of stress level measurements in overlapped deposit. Surfacing parameters: Surfacing current: I = 500 [A], arc voltage: U = 40, surfacing speed: v = 50 [cm/min]

Measurement place	Direction of measurement	Stress level [MPa]
Three layer deposit	perpendicular to surfacing direction	82
	in direction of surfacing	484
Single layer deposit	perpendicular to surfacing direction	38
	in direction of surfacing	303

To determine influence of heat input on deposits hardness, measurements were provided on Wilson Wolpert 401 MVD Rockwell hardness tester with testing load: 1.0 [kg] and loads applying time: 15 seconds. Hardness was measured on the cross section of stringer and overlapped multilayer deposits in deposit, HAZ and base material, Tables 5 and 6. To determine the stress level in following layer of overlapped stringer beads of single, double and triple layer deposit, measurements were make on X-ray diffractometer. Measurement is made in surfacing direction and perpendicularly to surfacing direction, Table 7.

3. Conclusions

Aim of this work was to define the influence of basic process parameters of 00H18M2Nb super-ferrite wire SAW surfacing on quality, dimensions, structural changes and hardness distribution of deposits surfaced on S355NL plates.

At the 1st stage of investigations, stringer beads deposits surfaced with parameters in range: surfacing current: 300-500 [A], arc voltage: 30-40 [V] and surfacing speed: 25-75 [cm/min], indicate no surface defects in tested parameters field, Tables 3 and 4, Figs. 2 and 3.

Transverse cracks are present in the 3rd layer during surfacing of multilayer deposits with heat input above 11 [kJ/cm]. A cause of these cracks can be increasing of stresses level produced by multiple thermal cycle. Thermal stresses forming in heated area can be totalized and cracks can be produced, Figs. 4 to 8.

Macro-observations of stringer single beads structures allow to define the influence of basic parameters changes on deposits dimensions and dilution, Table 4, Fig. 3. Dilution changes from 35% (welding current: 300 [A], arc voltage: 30 [V], surfacing speed: 25 [cm/min] heat input: 22 [kJ/cm]) up to 72% (welding current: 300 [A], arc voltage: 40 [V], surfacing speed: 50 [cm/min], heat input:14 [kJ/cm]). Dilution depends directly on all parameters and cannot be assessed only by heat input changes. With the same heat input and different parameters dilution it can be significantly changed. Microstructures observations of deposits indicate that there are no internal defects in the deposits, Figs. 9 and 10.

Microstructure observations indicate that in the 3rd layer deposits have super ferrite structure but in the 1st and the 2nd the influence of base metal participation is visible. In HAZ zone refinement of structure because of heat input influence is visible. Base material of ferrite-pearlite structure, Figs. 9 and 10.

Hardness tests on cross section of overlapped multilayer deposits indicate growth of hardness in HAZ up to 345 HV1 (in comparison to 180HV1 in base metal). Highest hardness at about 360 HV1 was measured in the 3rd layer of deposits. Decreasing of hardness in the 2nd and the 1st layer is because of increasing dilution. Growth of hardness in HAZ is a result of heat input cycle influence, Tables 5 and 6.

Measurement indicates that stresses level increases with a number of surfaced layers. Stresses measured in surfacing direction increase from 300 [MPa] in the 1st layer up to 500 [MPa] in the 3rd layer and in perpendicular direction from 40 [MPa] up to

80 [MPa]. To keep stresses at minimal level sequence of surfacing of multilayer deposits and suitable selection of surfacing process parameters is very important, Table 7.

References

[1] A.B. Chid, Welding GAP Control Using Infrared Sensing, Report of the Materials Research and Education Centre, July 20, 2001.

[2] Y.S. Tarng, S.C. Juang, C.H. Chang, The use of grey-based Taguchi methods to determine submerged arc welding process parameters in hardfacing, Journal of Materials Processing Technology 128/1-3 (2002) 1-6.

[3] J. Grum, R. Kejžar, J.M. Slabe, Submerged arc surfacing of Ni–Co–Mo alloys similar to maraging steels on a structural steel, Journal of Materials Processing Technology 155-156 (2004) 2011-2018.

[4] Shan-Ping Lua, Oh-Yang Kwon, Tae-Bum Kima, Kwon-Hu Kima, Microstructure and wear property of Fe–Mn–Cr–Mo–V alloy cladding by submerged arc welding, Journal of Materials Processing Technology 147/2 (2004) 191-196.

[5] H.L. Tsai, Y.S. Tarng, C.M. Tseng, Optimization of submerged arc welding process parameters in hardfacing, International Journal of Advanced Manufacturing Technology 12/6 (1996) 387-462.

[6] A. Patnaik, S. Biswas, S.S. Mahapatra, An evolutionary approach to parameter optimisation of submerged arc welding in the hardfacing process, International Journal of Manufacturing Research 2/4 (2007) 462-483.

[7] N.A. Fleck, Ö. Grong, G.R. Edwards, D.K. Matlock, The role of filler metal wire and flux composition in submerged arc weld metal transformation kinetics, Welding Journal 65/5 (1986) 113-121.

[8] N. Murugan, R.S. Parmar, S.K. Sud, Effect of Submerged arc Process Variables on Dilution and Bead Geometry in Single Wire Surfacing, Journal of Materials Processing Technology 37/1-4 (1993) 767-780.

[9] R. Bendikiene, B. Petras Ambroza, C. Lina Kavaliauskiene, Formation of High Wear Resistance Surface Layers using Metals Powder, International Journal of Mechanics 17/1 (2007) 6-9.

[10] R. Paschold, Submerged-arc strip cladding of continuous casting rollers using OK Band 11.82 and OK Flux 10.07, Svetsaren 1 (2001) 17-19.

[11] J. Tusek, M. Suban, High-productivity multiple-wire submerged-arc welding and cladding with metal-powder addition, Journal of Materials Processing Technology 133/1-2 (2003) 207-213.

[12] J.T. Busby, M.C. Hash, G.S. Was, The relationship between hardness and yield stress in irradiated austenitic and ferritic steels, Journal of Nuclear Materials 336/2-3 (2005) 267-278.

[13] G.M. Reddy, T. Mohandas, Explorative studies on grain refinement of ferritic stainless steel welds, Journal of Materials Science Letters 20/8 (2001) 721-723.

[14] A.M. Kliauga, M. Pohl, C. Cordier-Robert, J. Foct, Phase transformations in a super ferritic stainless steel containing 28% Cr after nitrogen ion implantation, Journal of Materials Science 34/16 (1999) 3833-4093.

[15] N.J.E. Dowling, H. Kim, J-N. Kim, S-K. Ahn, Y-D. Lee, Corrosion and toughness of experimental and commercial super ferritic stainless steels, Corrosion 55/8 (1999) 743-755.