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The study of properties of Ni-WC wires surfaced deposits

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Abstract: In thi paper, results of investigations of the effect of welding parameters of Metal Cored Wire Arc Surfacing (MCAW) on the quality of deposits are presented. Single stringer bead deposits were MCAW surfaced on the dry and metallic clean surface of carbon steel plates S355NL - EN 10 113. The wires used were 1,6 [mm] in diameter type EnDOtec XDO*11-S1 (3,5 kg spool) produced by CASTOLIN Ireland and EnDOtec DO*11-P. Additionally following EnDOtec XDO*11-S1 wire and EnDOtec DO*11-P wire properties were tested: WC granules size [μm], linear density of wire [kg/m], density of wire [g/cm3], density of weld metal [g/cm3].

Keywords: Surfacing; MCAW

1. STUDY OF INFLUENCE OF MCAW SURFACING PARAMETERS ON THE QUALITY OF DEPOSITS

To determine the effect of welding parameters of Metal Cored Wire Arc Surfacing (MCAW) on the quality of deposits, using metal cored wires dia. 1,6 [mm] type EnDOtec XDO*11-S1 (3,5 kg spool) produced by CASTOLIN Ireland and EnDOtec DO*11-P (15 kg spool - purchased), Table 1, single stringer bead deposits were MCAW surfaced on the dry and metallic clean surface of carbon steel plates S355NL - EN 10 113, 12 [mm] thick, by 120 [mm] wide and 150 [mm] in length. Additionally following EnDOtec XDO*11-S1 wire and EnDOtec DO*11-P wire properties were tested: WC granules size [μm], linear density of wire [kg/m], density of wire [g/cm^3], density of weld metal [g/cm^3], Table 1. The ivestigated parameters of MCAW were wire feed speed, arc voltage and speed of surfacing. Results of preliminary quality assessment of stringer bead deposits MCAW EnDOtec DO*11 wires surfaced in the wide range of surfacing parameters were tested by visual inspection, ultrasonic - UT, magnetic particle - MT and liquid-penetrant - PT examinations. Surfacing arc currents were set far over the limits established by CASTOLIN (i.e. 120-160 [A]), to the limits of arc instability and intensive arc spatter. It allowed determining the range of arc current (wire feed speed) providing proper quality of stringer bead deposits. Additionally the influence of the angle of inclination of the torch of push technique of MCAW surfacing was studied.

It was found that metal transfer mode through the arc stream of both tested DO*11 wires is basically globular type, with spatter increasing with increase of value of arc current. MCAW XDO11 wire surfaced stringer bead deposits at the wire feed speed range 1,9-7,0 [m/min]

(range of arc current 77-258 [A]) and DO*11-P wire surfaced at the wire feed speed range 1,2-5,3 [m/min] (range of arc current 100-247 [A]) indicated good or very good quality. Deposits show smooth surface of the reinforcement and no undercuts but all deposits are transverse cracked, as shown in Fig. 1. The stringer bead deposits of XDO*11 wire no. X-02-1, X-03-1 and X-04-1, MCAW surfaced at the wire feed speed 1,2 [m/min] (i.e. arc current 52-65 [A]) are low quality with uneven surface of deposits face and irregular shape.

The results of study of influence of the angle of inclination of the torch of push technique of surfacing on dilution, geometry, and hardness of stringer bead deposits MCAW EnDOtec XDO*11 and EnDOtec XDO*11-P surfaced have shown that there is no interrelation between them, probably due to fluctuation of arc current and arc voltage. The lowest dilution 19,79% of EnDOtec XDO*11 wire deposits is for 90^o angle of inclination and the highest dilution 25,09% for 75^o angle of inclination. The lowest dilution 12,43% of EnDOtec DO*11-P wire deposits is for 75^o angle of inclination and the highest dilution 21,60% for 65^o angle of inclination. To find reliable relation between the angle of inclination and dilution much more extensive study are needed.

Table 1.
Chemical composition wg % of as welded, MCAW surfaced of EnDOtecDO*11 wires deposits, hardness of the weld metal and WC carbides and EnDOtecDO*11 wires and weld metal densities

Metal cored wire EnDOtec DO*11	Ni	C	Si	Cr	B	WC	Hardness	
							Weld metal	WC carbides
XDO*11	Bal.	0,5	0,2	3,05	2,2	52	55 HRC	2400 HV0,3
DO*11-P	Bal.	0,4	2,5	3,0	1,5	50	55 HRC	2400 HV0,3

	WC granules size [μm]	linear density of wire [kg/m]	density of wire [g/cm^3]	density of weld metal [g/cm^3]
XDO*11-S2	1,0-400	0,0185	9,20	10,42
DO*11-P	1,0-400	0,0197	9,78	11,36

2. QUALITY ASSESSMENT OF STRINGER BEAD DEPOSITS

MCAW EnDOtec DO*11 wires surfacing parameters (heat input) have very distinct influence on the geometry and dilution - U of stringer bead deposits. Increase of surfacing heat input provides deeper penetration and thicker and wider deposits. The width of EnDOtec XDO*11-S1 deposits distinctly increases with increase of heat input, from 6,48 [mm] to max. 20,19 [mm]. In opposite the height of reinforcement of EnDOtec XDO*11-S1 deposits insignificantly increases with increase of heat input of surfacing in the range of from 1,59 [mm] to max. 3,20 [mm]. Depth of penetration is strongly increasing with increase of heat input of surfacing from 0,14 [mm] to max. 2,40 [mm] and similarly dilution from 3,97% to 44,35%.

The width of EnDOtec DO*11-P deposits distinctly increases with increase of heat input of surfacing, from 5,49 [mm] to max. 15,98 [mm]. In opposite the height of reinforcement of EnDOtec DO*11-P deposits insignificantly increases with increase of heat input of surfacing in the range of from 1,61 [mm] to max. 3,10 [mm]. Depth of penetration is strongly increasing with increase of heat input of surfacing from 0,14 [mm] to max. 2,94 [mm] and similarly dilution from 3,36% to 39,94%.

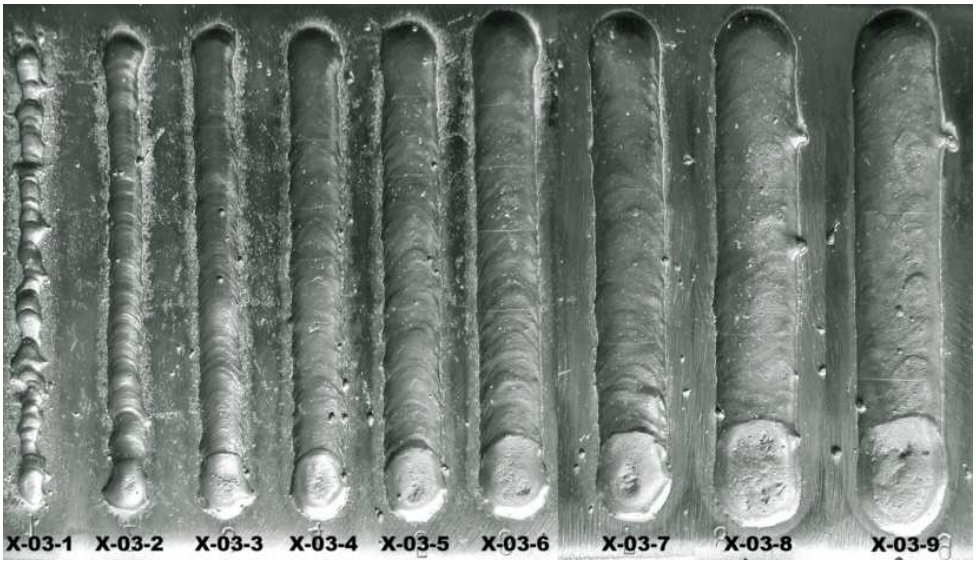

Figure 1. The effect of MCAW EnDoTec XDO*11 wire surfacing parameters on the quality of stringer bead deposits, assessed by visual inspection

Heat input - [kJ/mm]

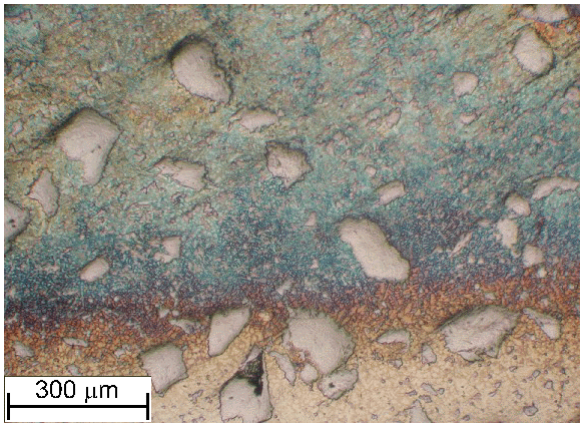

Figure 2. Microstrucutre of stringer bead deposit no X04-2 (0,22-0,26 [kJ/mm]), MCAW EnDoTec XDO*11 wire surfaced

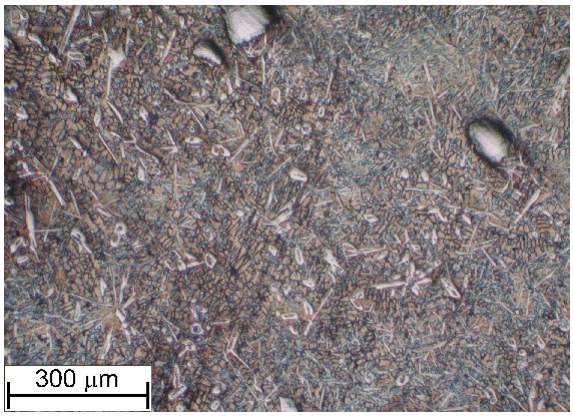

Figure 3. Macrostructure of stringer bead deposits MCAW EnDoTec DO*11-P wire surfaced

Consequently results of hardness tests of stringer bead deposits MCAW EnDOtec DO*11 wires surfaced indicate that the value of heat input of surfacing has distinct influence on the hardness of the surface of deposits and hardness distribution on the cross-section of deposits. Hardness measured on the surface of deposits corresponds to the hardness measured on the

cross section of the stringer bead deposits. The maximum hardness was measured for low heat input stringer bead of deposits, e.g. 610 HV30 of stringer bead deposit no X-04-2 and 661 HV30 of stringer bead deposit no P-04-2. Due to WC carbides uneven distribution and density of population on the cross-section of low heat input deposits the highest hardness of HV30 was measured in the areas of middle part and fusion zone of deposits where highest density of population of large and heavy WC carbides of 150-270 [μm] appeared. Stringer bead deposits MCAW EnDOtec DO*11 wires surfaced at the highest heat input, X-02-9 and P-02-9, show even hardness on the deposits cross-section as almost all WC carbides are dissolved in nickel alloy matrix and max. dimension of WC carbides is in the range 50-150 [μm].

Results of metallographic macro and microscopic examinations have shown high quality of the stringer bead deposits, no external and internal defects but transverse cracks, as shown on Figs. 2, 3. Population density, size and distribution of WC carbides of MCAW EnDOtec DO*11 wires surfaced stringer bead deposits is a function of heat input of MCAW surfacing and the distance from surface area to fusion area of deposits. At the area just under surface of all low heat input stringer bead deposits there is less or almost no WC carbides and the highest population density of WC carbides is in the middle area and fusion zone area of deposits. When heat input increases and weld pool becomes more liquid much heavier WC carbides (density of WC - 15,72g/cm^3) sink toward fusion zone of nickel matrix deposit (density of Ni - 8,9 g/cm^3).

Surprisingly there is distinct deference in carbides size and population density between low heat input stringer bead deposits of both tested EnDOtec DO*11 wires 2, 3. Average size of WC carbides of X-04-2 deposit is 70-90 [μm] (max. size approx. 140-160 [μm]) and distance between carbides is in the range 60-300 [μm], Fig. 2,. In contrary average size of WC carbides of P-04-1 deposit is 130-150 [μm] (max. size approx. 270-300 [μm]) and average distance between carbides is in the range 30-50 [μm], Fig 3. Population density and size of WC carbides of are decreasing when heat input of MCAW surfacing is increasing.

Average distance between WC carbides of X-02-9 deposit is in the range 300-350 [μm] and max. size is 60-80 [μm] and again average distance between WC carbides of P-02-9 deposit is smaller then X-02-9 deposit and in the range 120-150 [μm] and WC carbides are bigger of max size of is 150-200 [μm]. Scanning Electron Microscopy - SME was used to characterize morphology and structure of stringer bead deposits surfaced at min. heat input. It was proved that WC carbides are partially dissolved in nickel alloy matrix and there is no distinct difference between shape, size and distribution of tungsten carbides in the austenitic matrix.

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