Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 17
ISSUE 1-2
July-August
2006

Study of properties of manual metal arc electrodes for gray cast iron defects repair works

A. Klimpel*, D. Janicki, A.St. Klimpel
Welding Department, Silesian University of Technology,
ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: andrzej.klimpel@polsl.pl

Received 15.03.2006; accepted in revised form 30.04.2006

Manufacturing and processing

ABSTRACT

Purpose: of these researches was to determine influence of MMA technique and surfacing parameters of gray cast iron using CASTOLIN 27 coated electrodes on quality of deposits.

Design/methodology/approach: single layer weave bead deposits and one layer overlapped multi weave bead deposits were MMA surfaced on gray cast iron type GG25. All deposits were surfaced on no preheated gray cast iron plate. To determine quality of deposits hardness HRC measurements on the cross section of deposits, macrostructure and microstructure observations were done.

Findings: properties of deposits strongly depend on MMA surfacing parameters and the technique of surfacing. Increase of surfacing current (dilution) provided increase of deposits hardness. One layer overlapped multi weave bead deposits MMA surfaced with no control of interpass temperature showed higher HRC hardness then deposits MMA surfaced with interpass temp. 20^{o}C.

Research limitations/implications: for complete information about properties of manual metal arc electrodes for gray cast iron cladding it is needed to compare properties of CASTOLIN 27 with other coated electrodes for gray cast iron cladding

Practical implications: results of this paper is to increase quality of deposits on gray cast iron.

Originality/value: properties of deposits strongly depend on the technique of MMA surfacing.

Keywords: Welding, surfacing; MMA (Manual Metal Arc); CASTOLIN 27; Gray cast iron type GG25

1. Introduction

Gray cast iron has an excellent compressive strength, graphite microstructure provides vibration damping for general engineering and automotive applications as dies, machine tool bases or engine blocks, crankshafts in large diesel engines etc. [1-4]. In many cases gray cast iron parts have to be welded or surfaced. The most frequent reasons are: repair of castings defects such as porosity, sand inclusions, cold shuts, shifts or washouts, corrections of fabrication errors, repair of worn or damaged castings or welding simple cast shapes into more complex cast welded structures. Compared to steels gray cast irons have relatively poor weldability due to lack of plastic ductility. Basic solution is to use arc welding consumables minimizing welding stresses. Most popular arc welding consumables are high carbon, nickel and nickel-iron base alloys which do not need preheating during surfacing or welding processes. Second group of consumables are high carbon iron base alloys where preheating is not generally necessary but special technique of welding or surfacing has to be employed. The third group of cast irons welding and surfacing consumables are materials of similar chemical composition as cast irons to be welded or surfaced but high temperature preheating is needed [1-9].

The paper describes results of study of properties manual metal arc welding electrodes CASTOLIN 27, designed to produce high quality deposits to correct castings defects or for surfacing parts subjected to abrasion wear.

2. Experimental procedure

Manual metal arc electrode CASTOLIN 27 is recommended for repair works of surface defects of cast iron castings with no preheating. To study properties of CASTOLIN 27 coated electrodes dia. 3,2 [mm], following specimens were prepared:

- all weld metal deposits in accordance to standard PN-EN ISO 6847, APRIL 2005, Welding consumables – Deposition of a weld metal pad for chemical analysis",
- single layer weave bead deposits and one layer overlapped multi weave bead deposits MMA surfaced on gray cast iron type GG25 18,0 [mm] thick plate casting.

Procedure of MMA surfacing of specimens of all weld metal deposits, single layer weave bead deposits and one layer overlapped multi weave bead deposits was set in accordance to CASTOLIN Co. recommendations contained in: Technical Data Reference Document – MMA ELECTRODE, no DQ 01/IQ/10/0077 and CASTOLIN 27 Data Sheet.

All weld metal deposits were MMA surfaced at (DC+) arc current 90 [A], following recommendations of PN-EN ISO 6847 standard. Single layer weave bead deposits were surfaced at (DC+) arc current in the current range - 70 [A], 90 [A], 110 [A] and 120 [A], arc length approx. 4,5-5,0 [mm], at vertical electrode position and the slow weave motion, at stroke 6,0-7,0 [mm]. One layer overlapped multi weave bead deposits were surfaced at (DC+) arc current 90 [A], arc length approx. 5,0 [mm], vertical electrode position at the slow weave motion at stroke 6,5-7,0 [mm]. The length of all deposits was limited to approx. 50,0 [mm]. All deposits were surfaced on no preheated gray cast iron plate, when it temperature was below 20 [^{o}C]. For CASTOLIN 27 coated electrodes a specimen of one layer overlapped multi weave bead deposits was surfaced with no interpass temperature control to simulate MMA surfacing process with no WPS. Power source CastoTIG 2002 AC/DC was used.

Following properties of CASTOLIN 27 coated electrodes dia. 3,2 [mm], were tested:

- chemical composition analysis,
- HRC hardness tests on the surface and on the cross section of specimens,
- macro and microstructure examinations.

2.1. Chemical composition analysis

In accordance to data of Technical Data Reference Document – MMA ELECTRODE, no DQ 01/IQ/10/0077 chemical composition analysis of all weld metal specimen of CASTOLIN 27 coated electrodes dia. 3,2 [mm] was limited to following elements content: carbon - C, manganese - Mn and silicon - Si, Table 1.

Table 1.
Chemical composition of all weld metal of CASTOLIN 27 coated electrodes

Type of the all weld metal	Composition wt. [%]		
	C	Mn	Si
C-95778 lot	0,87	1,45	0,42
Technical Data Reference Document DQ 01/IQ/10/0077	0,86	1,53	0,22

2.2. Hardness tests

To test hardness of all weld metal deposit specimens and single layer weave bead deposits and one layer overlapped multi weave bead deposits specimens HRC hardness test was chosen. Newest model 8150 LK ZWICK 2HR Rockwell Hardness tester was used. Following hardness measurements were done:

- on the 0,5 [mm] deep ground surface of all tested specimens, along principle axis of the specimen with the distance in-between measurement points approx. 8,0 [mm], Table 2,
- on the cross-section of single layer weave bead deposits and one layer overlapped multi weave bead deposits, Fig. 1 and Table 3.

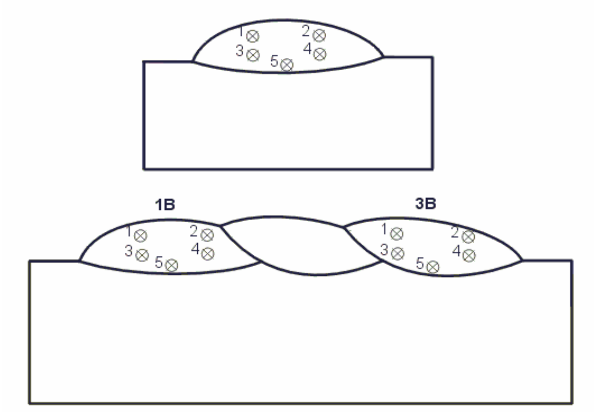


Fig. 1. Distribution of hardness points measurements on the cross section of single layer weave bead deposits and one layer overlapped multi weave bead deposits, Table 3

2.3. Metallographic examinations

Samples taken for metallographic examination from specimens of all weld metal deposits, single layer weave bead deposits and one layer overlapped multi weave bead deposits were prepared by grinding. Next STRUERS machine polishing and etching by $FeCl_3$ aqueous solution of specimen's cross section were done for metallographic examinations of macrostructures and microstructures of deposits.

Results of macrostructure and microstructure examinations are shown in Figs. 2 to 5.

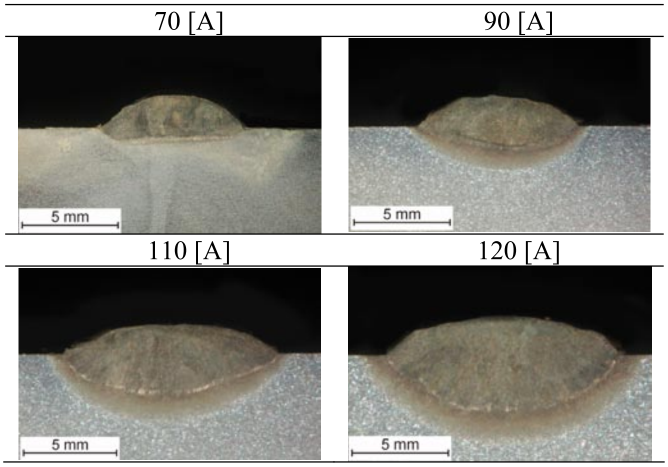


Fig. 2. Macrostructure of single layer weave bead deposits of CASTOLIN 27 coated electrode MMA surfaced at (DC+) arc current 70 [A], 90 [A], 110 [A] and 120 [A]

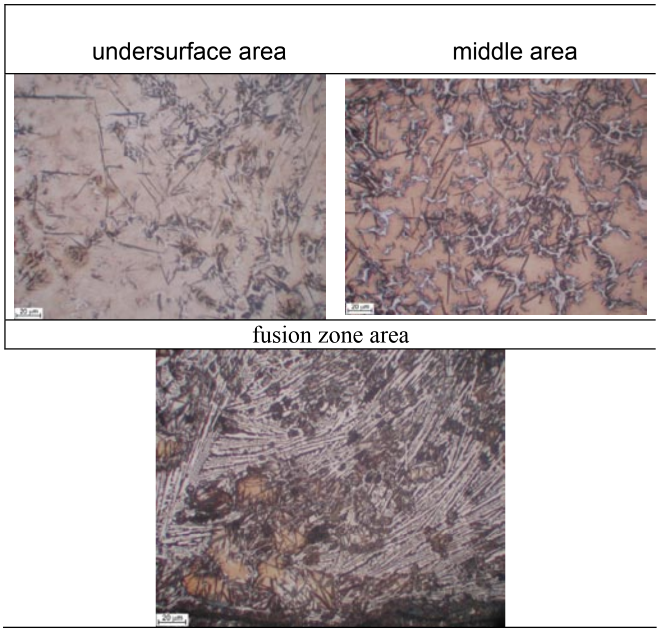
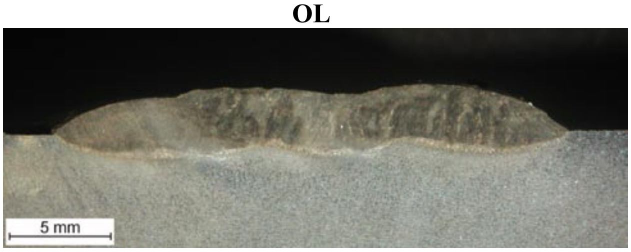


Fig. 3. Microstructure of single layer weave bead deposit of CASTOLIN 27 coated electrode MMA surfaced at (DC+) arc current 90 [A]

OL



OL-N

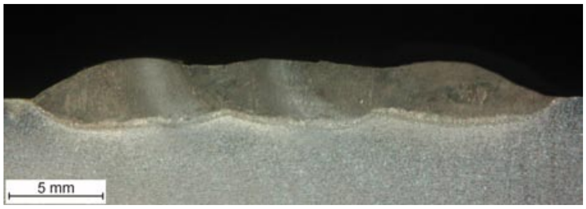


Fig. 4. Macrostructure of one layer overlapped multi weave bead deposits of CASTOLIN 27 coated electrode MMA surfaced at (DC+) arc current 90 [A] and interpass temperature 20 [^{o}C] - OL, and no interpass temperature control – OL-N

Table 2.
Results of HRC hardness tests on the surface of all specimens tested

Designation of specimen		HRC hardness measurement points along principle axis						HRC average
		1	2	3	4	5	6	
all weld metal deposit		59	58	56	62	60	60	59
		730	775	757	769	810	798	773 HV30
SLWBD 70		24,3	28,4	33,8	34,4	33,6	27,7	30,4
SLWBD 90		33,1	30,1	28,9	28,7	37,7	46,6	34,2
SLWBD 110		26,8	26,2	55,2	44,6	39,5	41,0	38,9
SLWBD 120		53,5	47,1	50,2	47,8	43,7	36,7	46,5
OL	1B	33,2	30,6	45,7	43,5	36,4	39,3	38,1
	3B	27,7	30,1	41,9	44,2	43,8	45,1	38,8
OL-N	1B	48,5	49,1	42,3	50,4	51,9	45,1	47,9
	3B	38,1	35,6	36,8	44,0	39,7	33,5	40,0

Remarks: SLWBD 70: Single Layer Weave Bead Deposit MMA surfaced at (DC+) arc current 60 [A], OL – one layer overlapped multi weave bead deposit MMA surfaced at (DC+) arc current 90 [A] and interpass temperature 20 [^{o}C], OL-N - one layer overlapped multi weave bead deposit MMA surfaced at (DC+) arc current 90 [A] and no interpass temperature control. 1B – first bead, 3B – third bead.

Table 3.
Results of hardness HRC tests on the cross section of single layer weave bead deposits and one layer overlapped multi weave bead deposits

designation		HRC hardness measurement points, Fig. 1				
		DEPOSIT				FUSION ZONE
		1	2	3	4	5
SLWBD 70		28,8	31,0	32,0	34,0	45,0
SLWBD 90		34,0	36,0	40,0	50,9	49,0
SLWBD 110		44,2	43,8	45,9	47,8	46,9
SLWBD 120		48,2	46,7	51,2	52,9	51,9
OL	1B	31,0	28,0	47,7	30,3	35,0
	3B	42,0	39,0	46,0	47,0	46,0
OL-N	1B	42,0	47,7	47,9	51,8	52,0
	3B	32,5	35,0	33,6	36,2	41,0

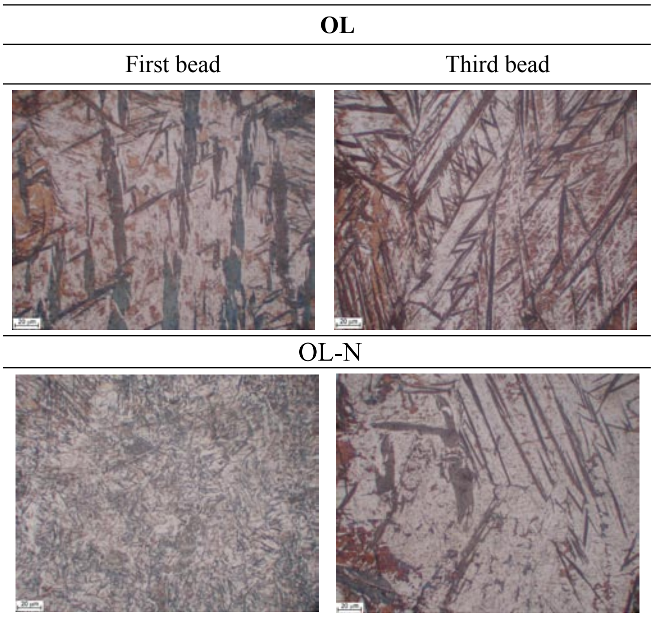


Fig. 5. Microstructure of middle area of one layer overlapped multi weave bead deposits of CASTOLIN 27 coated electrode MMA surfaced at (DC+) arc current 90 [A] and interpass temperature 20 [^{o}C] - OL and no interpass temperature control – OL-N

3. Summary

1. Chemical composition analysis of all weld metal deposits revealed that carbon and manganese content of CASTOLIN 27 coated electrodes is on the level of typical chemical composition indicated by Technical Data Reference Document DQ 01/IQ/10/0077, Table 1, but silicon content of all weld metal deposit is almost two times higher.
2. Welding properties of CASTOLIN 27 coated electrodes are good. When surfacing at arc current range 70 to 120 [A], arc is stable with minimal spatter and deposits show smooth face and uniform penetration to the base metal, Figs. 2 and 4. The surfacing process is unstable when arc current is approx. 60 [A] or over 140 [A].
3. HRC and HV30 hardness tests of all weld metal deposit indicated that the deposit is harder than typical all weld metal deposit of CASTOLIN 27 coated electrode as per Technical Data Reference Document DQ 01/IQ/10/0077.
4. HRC hardness measured on the surface of single layer weave bead deposits is much lower than indicated in CASTOLIN 27 Data Sheet – 54 HRC, Table 2. Increase of surfacing current (dilution) provides increase of deposits hardness from 30,4 HRC to 46,5 HRC.
5. One layer overlapped multi weave bead deposits MMA surfaced with no control of interpass temperature show higher HRC hardness then deposits MMA surfaced with interpass temp. 20^{o}C. Similar to single layer weave bead deposits, they show high scatter of hardness, i.e. deposits surfaced with control of interpass temp. in the range of 27,7 HRC to 45,7 HRC, and MMA surfaced with no control of interpass temp. in the range of 33,5 HRC to 51,9 HRC, Table 2.
6. Results of hardness HRC measurements on the cross section of single layer weave bead deposits and one layer overlapped multi weave bead deposits along with macrostructure and microstructure observations, Table 3 and Figs. 2 to 5, have proved that properties of deposits strongly depend on MMA surfacing parameters and what's more, the technique of surfacing. Even small change of speed of surfacing has strong influence on the dilution and microstructure of the deposits, what has strong influence on shape and volume of carbides precipitations and consequently hardness of the deposits. Thin one layer multi bead deposit – OL has the first bead 2,6 mm thick with reinforcement thickness 1,2 mm (high dilution) is very hard 50,4-59,7 HRC, but in the same deposit the third bead is 3,0 mm thick and has reinforcement thickness of 2,0 mm (lower dilution) has much lower hardness in the range of 38,5-44 HRC.

References

[1] ASM International. Metals Handbook, vol. 1, 9th ed. Materials Park, Ohio, 1997.
[2] Welding handbook, vol. 4, 8th ed. Materials and applications – Part 2. 1998.
[3] A. Klimpel.: Napawanie i natryskiwanie cieplne. Technologie. WNT, 2000.
[4] E. N.Gregory.: Welding cast irons. Welding of castings. Cambridge, England, TWI, 1977.
[5] A. Klimpel, L.A. Dobrzański, D. Janicki.: "The study of properties of Ni–W_2C and Co–W_2C powders thermal sprayed deposits", Journal of Materials Processing Technology, 2005, Volume: 164-165, pp. 1068-1073.
[6] A. Klimpel, L.A. Dobrzański, D. Janicki, A. Lisiecki.: The study of properties of Ni–WC wires surfaced deposits", Journal of Materials Processing Technology, 2005, Volume: 164-165, pp. 1046-1055
[7] A. Klimpel, L.A. Dobrzański, D. Janicki, A. Lisiecki.: "Abrasion resistance of GMA metal cored wires surfaced deposits", Journal of Materials Processing Technology, 2005, Volume: 164-165, pp. 1056-1061.
[8] A. Klimpel, L.A. Dobrzański, D. Janicki.: „A study worn wear plater of fan blade of steel mill fumes suction system", Journal of Materials Processing Technology, 2005, Volume: 164-165, pp. 1062-1067.
[9] A. Klimpel, Z. Bulski, M. Mazur, D. Janicki.: „GMA pad welding of aluminium bronze with nickel – based flux-core wire". Welding International, 2004, 18 (8) 593-598.