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Mini Review

Influence of Welding Regimes and Filler Metal on Weld Bead on 30CrMoV9 Steel Base Material

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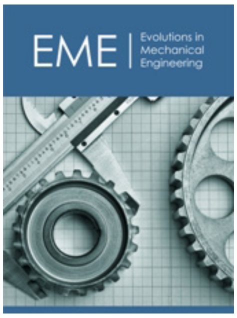
ISSN: 2640-9690



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Submission: October 8, 2024
Published: October 18, 2024

Volume 5 - Issue 4

How to cite this article: Svetislav Marković*. Influence of Welding Regimes and Filler Metal on Weld Bead on 30CrMoV9 Steel Base Material. Evolutions Mech Eng. 5(4). EME.000620. 2024.
DOI: 10.31031/EME.2024.05.000620

Abstract

The research was aimed to determine the influence of the welding regimes and the filler metal types on the hard-faced weld bead and its Heat Affected Zone (HAZ). The welding process was performed on the plate samples (bead-on-plate test) of low-alloy steel 30CrMoV9. Five filler metals were used, four gas shielding welding wires of different chemical composition and one flux-cored wire. The welding regimes (electricity, voltage and welding speed) were varied, two regimes for each filler metal. After welding, the weld bead dimensions and hardness were measured and the bending test was carried out, as well. Based on the performed measurement and analysis, appropriate conclusions were drawn. Applied filler metal and arc energy can significantly affect the properties of weld beads and HAZ, but used base material 30CrMoV9 requires preheating and/or subsequent heat treatment.

Keywords: Welding; Hard facing; Filler material; Weld bead bending test

Introduction

Low-alloy steel is often used in the design of machine parts. When machine parts made of this steel wear out during the machine system operation, losing operational ability, it is necessary to replace or repair them. Repair of worn-out parts is carried out by hard facing, which is still one of the most important repair procedures. Hard facing is the deposition of thick coatings of hard, wear-resistant materials on a worn surface. Welding is one of the used processes to apply the hard facing layer using appropriate additional material-filler metal. It is very important to know what type of filler should be applied, as well as which welding method is the most appropriate. Also, it is necessary to know how repair welding affects the mechanical properties of the weld bead and whether the load capacity of the repaired machine part will be similar or the same as it was before failure and repair. After subsequent heat treatment (post heating), repaired hard-faced surface should have mechanical properties at the level of properties of the base material. Hard face welding on sample plates made of low-alloy steel 30CrMoV9, using different fillers and welding regimes, is considered in this paper.

Experimental Part with Results

The steel plates with dimensions of 150x80x10mm were used for hard face welding. The Base Material (BM) is the low-alloy steel 30CrMoV9 of chemical composition given in Table 1 [1]. Weld beads of various fillers were applied onto the 30CrMoV9 plates (Figure 1) by different single pass welding regimes of semi-automatic welding, using CO_2 protective gas (C type [2]). Four fillers in the form gas shielding welding wire (diameter 1.2mm) and one filler as flux-cored wire (No.5) were used. The chemical composition of the fillers is given in Table 2 [3,4]. The welding input parameters, electricity, voltage and welding speed (travel speed of the welding torch) are varied for every type of filler metal. Each of the five used fillers was welded on the plate by two regimes. The welding regime parameters are presented in Table 3. Based on the values of current I, voltage U, and welding speed v, the energy supplied by the welding arc to the hard facing plate is calculated by the following equation:

$$AE = \frac{UI}{v} \qquad (1)$$

Table 1: Chemical composition of BM-low-alloy steel 30CrMoV9 (1.7707), %.

C	Si	Mn	Ni	P	S	Cr	Mo	V
0.26–0.34	max 0.4	0.4–0.7	max 0.6	max 0.035	max 0.035	2.3–2.7	0.15–0.25	0.1–0.2

Table 2: Filler metal designation and chemical composition.

No.	Designation		Chemical Composition, %					
	ASW [3]	Other Standards	C	Si	Mn	NI	Cu	S
1	ER70S-6	SG-2 (DIN); 3Si1 (EN) [4]	0.087	0,83	1.86	0.12	/	0.018
2	ER70S-6	SG-3 (DIN); 4Si1 (EN) [4]	0.087	0.95	2.21	0.12	/	0.018
3	ER70S-G	/	0.088	0.99	1.9	1.26	/	0.012
4	ER70S-G	/	0.102	0.93	1.73	0.54	0.47	0.012
5	ER110T5-K4	/	0.15	0.8	1.73	2.18	/	0.03

Table 3: Welding regimes.

Weld Regime WR No.	Filler (Table 2)	Welding Input Parameters				
		Current I A	Voltage U V	Welding speed cm/s	Arc energy AE J/cm	Heat input HI (η=0.75) J/cm
1	1	120	20	0.875	2742.9	2057
2		170	22.5	0.47	8138.3	6104
3	2	120	20	0.875	2742.9	2057
4		175	20	0.875	4000	3000
5	3	120	20	0.875	2742.9	2057
6		175	23	0.824	4884.7	3664
7	4	170	23	0.933	4314	3236
8		170	22.5	0.481	7952.2	5964
9	5	120	20	0.636	3773.6	2830
10		170	22.5	0.875	4371.4	3279

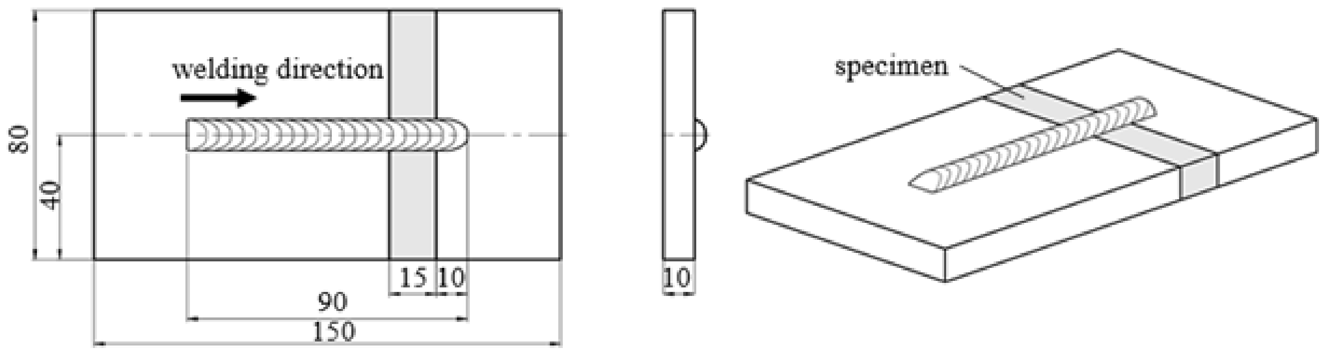

Figure 1: Hard face welded steel plate.

Calculated arc energy, depending on welding fillers and regimes is given in Table 3. Heat input considers the influence which process efficiency has on the energy that reaches the workpiece to form the weld. HI is given by the equation:

$$HI = \eta AE \qquad (2)$$

Heat input, calculated based on arc energy considering the efficiency of 75% is given in Table 3. After welding, specimens (of width 15mm) were cut from the test plates (Figure 1), which were used to measure dimensions and hardness of the weld beads, as well as for bend testing. The measured cross-sectional dimensions of the weld beads are shown in Figure 2 and measured values (bead width, reinforcement height and penetration depth) are given in Table 4. Based on the measured weld bead dimensions, the weld penetration shape factor is:

$$WPSF = \frac{w}{P} \qquad (3)$$

Dilution-the area of base metal melted in relation to the cross-sectional area of the bead (Figure 2) was determined using the formula:

$$D = \frac{A_P}{A_R + A_P} 100\% \qquad (4)$$

Table 4: Geometry parameters of the weld bead.

Welding Regime (Table 3)	Bead Width w mm	Reinforcement Height R mm	Penetration Depth P mm	Bead Height R+P mm	Weld Penetration Shape Factor WPSF	Dilution D %
1	5.5	1.8	1.3	3.1	4.2	41
2	10	3.5	2.2	5.7	4.5	38
3	5.5	1.7	1.3	3	4.2	43
4	7	2.9	1.8	4.7	3.9	38
5	5.5	1.8	1.4	3.2	4	43
6	7.5	2.3	2.2	4.5	3.4	50
7	6.3	2.1	2	4.1	3.1	49
8	10	3.3	2.2	5.5	4.5	40
9	5	1.9	1.4	3.3	3.6	42
10	8	2.7	1.3	4	6.2	32

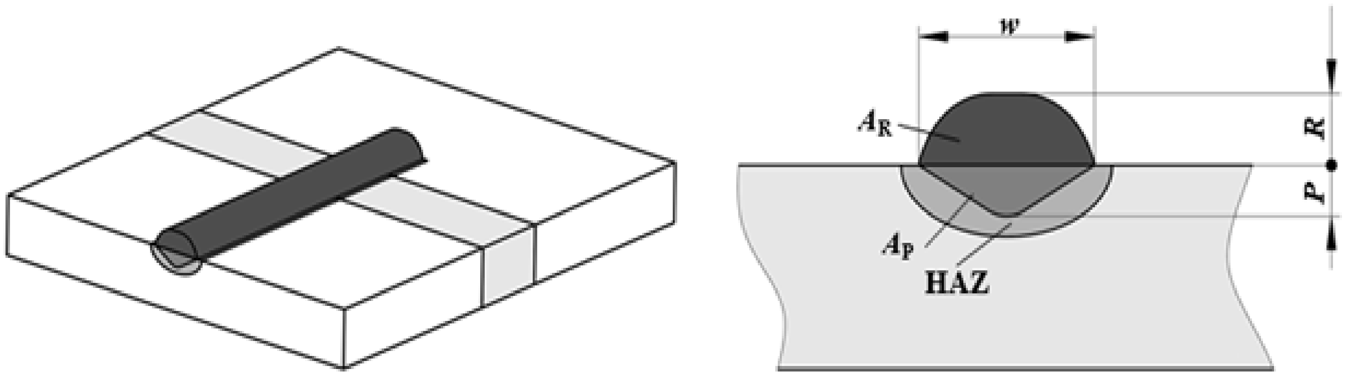

Figure 2: Cross-section of the weld bead (R-Reinforcement; P-Penetration; W-Width).

The hardness of the weld bead reinforcement area was measured, as well as the HAZ (Heat Affected Zone) hardness on different distances from the hard-faced surface (Table 5). The hardness distribution in HAZ is shown by the diagram in Figure 3. The hardness of HAZ is high near to the bead, decreasing under the hardness of the base material, on the depth of approx. (0.2 ... 0.5) mm (Figure 3). The scheme of the bend test is shown in Figure 4. The weld bead is in the tension zone of the bent specimen. During the test, each specimen was bent until the first crack appeared on the weld bead. At that moment, the bending angle α (Figure 4) was registered (Table 6).

Table 5: Hardness of bead and HAZ.

	Bead Hardness HV5	HAZ Hardness HV5												
		0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1	1.25	1.5	1.75	2
1	420	-	-	-	-	-	-	-	-	-	-	-	-	-
2	371	-	-	-	-	-	-	-	-	-	-	-	-	-
3	516	589	625	558	535	530	492	410	342	386	386	380	386	386
4	441	549	565	553	551	551	515	437	414	321	363	390	386	386
5	491	560	584	544	544	545	499	380	306	381	371	380	386	381
6	488	559	630	622	610	570	545	501	457	336	350	370	392	390
7	479	562	572	565	551	535	532	450	438	356	364	401	390	392
8	367	489	494	490	470	470	439	427	419	410	324	337	390	371
9	445	558	568	568	560	537	508	465	361	330	376	394	394	386
10	453	509	531	525	525	520	511	478	468	343	328	394	386	386

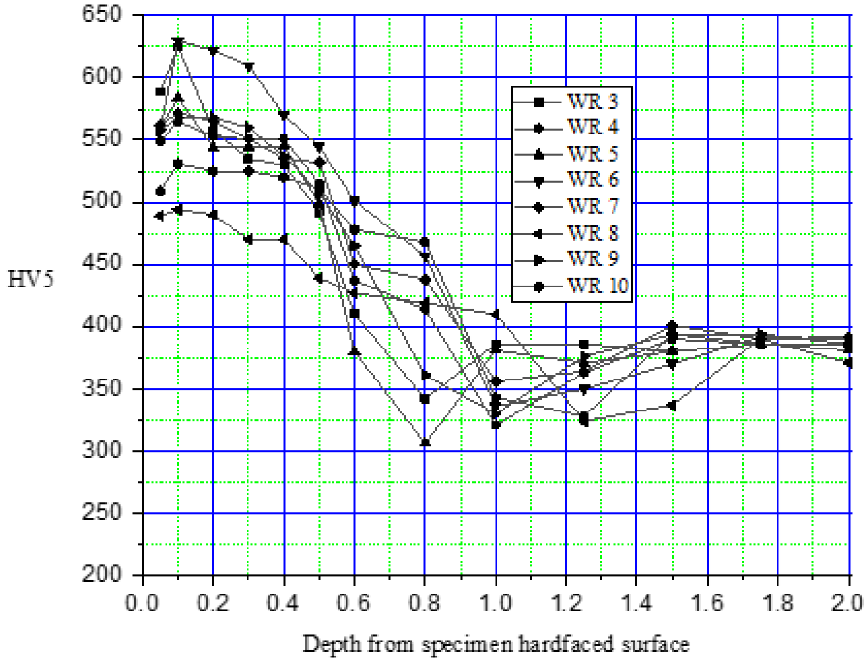

Figure 3: Hardness distribution in the HAZ area.

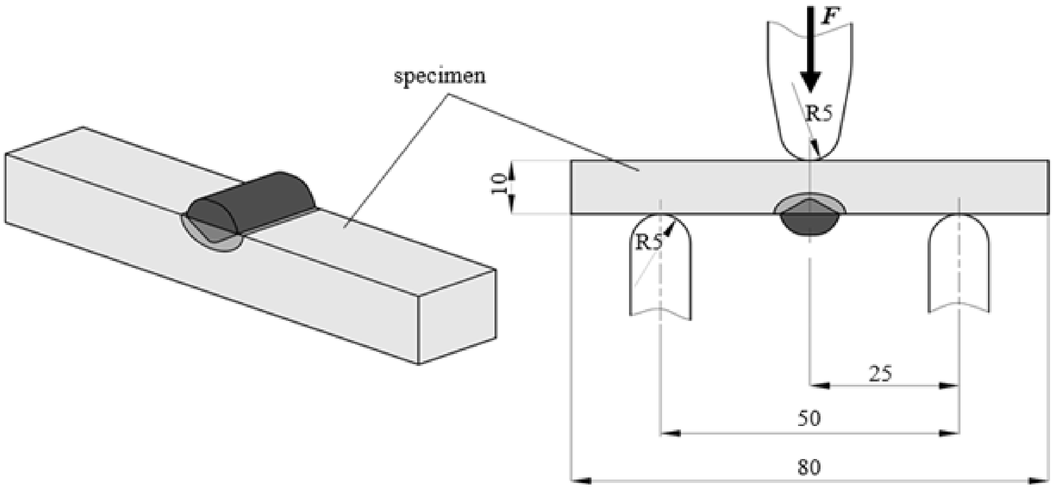

Figure 4: Weld bead bend test.

Table 6: Bending angle corresponding to the first crack appeared on the weld bead.

Weld Regime (Table 3)	Bending Angle α°
1	7.2
2	11.3
3	5.4
4	7
5	8
6	8.3
7	7.1
8	14
9	10
10	12.2

Discussion

Under the applied experimental conditions and due to extremely large mass of the test plate concerning the beam mass (both reinforcement and penetration) and the high content of the base material in the beam, high values of the beam hardness with low plasticity were obtained. Furthermore, when the plates welded with higher arc energy and heat input, lower beam hardness and greater bending angles (until the appearance of the first crack) were obtained.

Based on the results from Tables 4-6, it may be concluded that:

A. Under all used regimes, a reinforcement height was higher than the penetration depth in the base material;

B. With increasing of arc energy and heat input the width of the beam is increasing as well;

C. In the case of welding with flux-cored wire (regimes 9 and 10), at the same arc energies and heat inputs, a smaller penetration depth is achieved compared to welding with gas shielding welding wires, followed by the higher values of the weld penetration shape factor WPSF;

D. With the increase of the arc energy and heat input, the penetration depth also increases, whereby there is no clear relation between the cross-section area Ap (beam penetration) and the overall beam cross section area A;

E. Bending angle welding beam bending resistance) is increased with increasing arc energy, heat input and bead width, but with decreasing bead hardness.

The hardness distribution in the HAZ is given in Figure 3. Under applied welding conditions and concerning base material properties, high HAZ hardness is obtained near the bead, as well as decreasing hardness on the depth of (0.2…0.5)mm below the hardness of base material before welding.

Conclusion

The obtained results show that significant influence on the mechanical characteristics of the weld bead and the heat affected zone of the hard-faced steel 30CrMoV9 could be achieved, selecting the proper type of the welding filler and the arc energy, i.e. heat input. However, products made of this steel, with high demand in sense of resistance to crack damage, it is necessary to apply preheating and/or post heating treatment.

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