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Hot Forging of a Cladded Component by Automated GMAW Process

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Abstract. Weld cladding is employed to improve the service life of engineering components by increasing corrosion and wear resistance and reducing the cost. The acceptable multi-bead cladding layer depends on single bead geometry. Hence, in first step, the relationship between input process parameters and the single bead geometry is studied and in second step a comprehensive study on multi bead clad layer deposition is carried out. This paper highlights an experimental study carried out to get single layer cladding deposited by automated GMAW process and to find the possibility of hot forming of the cladded work piece to get the final hot formed improved structure. The experiments for single bead were conducted by varying the three main process parameters wire feed rate, arc voltage and welding speed while keeping other parameters like nozzle to work distance, shielding gas and its flow rate and torch angle constant. The effect of bead spacing and torch orientation on the cladding quality of single layer from the results of single bead deposition was studied. A hot bending test at different temperatures of cladded plates with different dilution and nominal energy carried out.

INTRODUCTION

The main idea is to inverse the classical fabrication layout to get a finished cladded simple preformed part as shown in figure 1.The concept of forgeability of the welded pre-form is investigated for dissimilar metal pre-forms to assess workability and the resulting mechanical properties. The findings related to the possibility to clad a simple form and to get the post hot forged surface structure is under study.
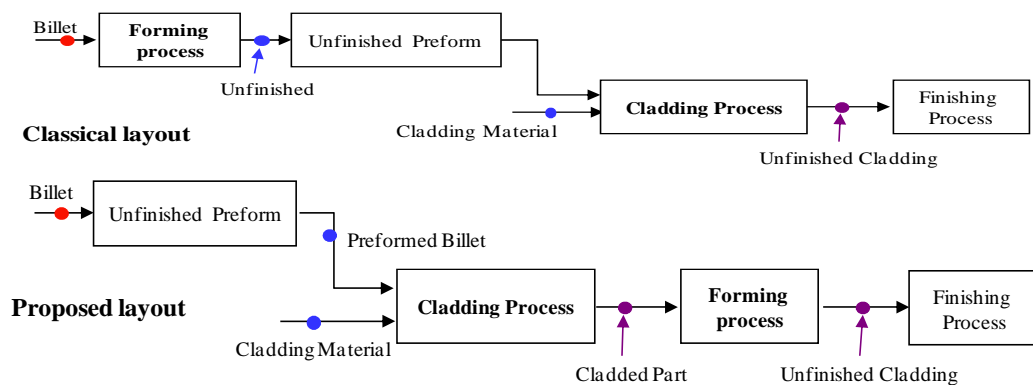

FIGURE 1 The layout of classical and proposed fabrication scheme

Stainless steel cladding on low carbon steel by automated MIG welding is carried out. In first step, the methodology to characterize the clad quality parameters like bead geometry, dilution rate is studied. At the end, the cladded surface behavior after hot bending test is analyzed.

Methodology

An experimental plan is devised to study the hot forging behavior on weld cladded plate as proposed by Joseph et al.[1]. Here robotized MIG welding process parameters are optimized to qualify the weld cladding profile to undergo further hot forging process to get overall improved cladding structure.
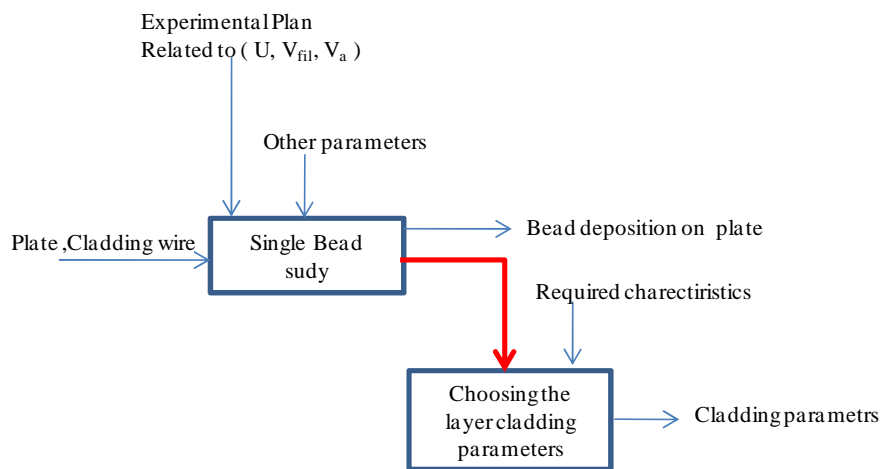

FIGURE 2 The layout of proposed methodology

The input parameters of cladding process are shown in figure 2.In addition to the classical cladding parameters, the position and torch orientation parametrs with respect to the work piece are considered. The cladding position (flat), cladding wire diameter (1.2mm) and shielding gas (Prodinox© at flow rate 20L/min) and torch inclination angle ($\alpha=18°$) are fixed.

The clad quality parameters are defined by:
- The geometry of the cladding layer
  - o The thickness of weld overlay with average value of its variation
  - o The bead penetration with average value of its variation
- Cladding defects : Porosity, lack of penetration and overlap
- The cladding structure
  - o The dilution rate determines the cladding chemical composition
  - o The nominal energy effects the cooling rate which determines the structure of heat affected zone of the substrate and cladding
- The forgeability of the bimaterial will be determined primarily by the hot bending test.

The torch layout and experimental setup of cladding process is shown in figure 3 a) and b) respectively.
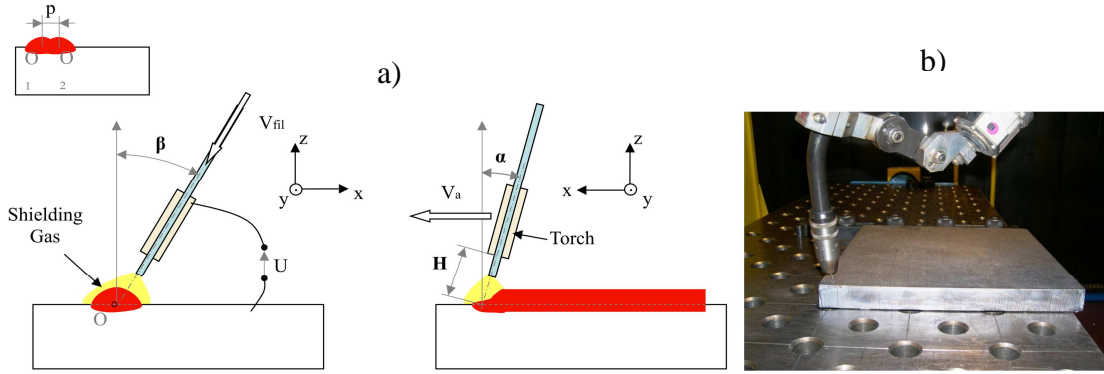
FIGURE 3   a) Torch layout and different process parameters   b) Experimental set-up used

Cladding

The methodology is applied for Stainless steel 316L cladding on a plate of low carbon steel S235 (composition shown in table 1) of thickness 30mm by automatic MIG welding. The experimental plan under study deals with three main cladding process variables i.e. voltage, wire feed speed and welding speed.Several studies correlating bead dimensions with process parameters are reported for different welding processes considering parameters like nozzle to work distance, torch angle, and gas flow rate as variables [2,3,4,5].

	C	Si	P	S	Cr	Mn	Fe	Ni	Cu	Mo	N
Filler	.03	.65-1	≤0.02	≤0.03	18-	1-2.5	Bal.	11-	-	2-3	-
Base	0.1	0.9	0.04	0.04	-	0.9	Bal	-	0.55	-	0.012

TABLE: 1 Chemical Composition of the base and Cladding material

The adjacent bead over lap or in other words offset distance for layer cladding is based on the single bead thickness as shown in figure 4.To select overlapping value *p*, two criteria were proposed, first concerning the top surface profile and second deals with the lack of fusion at the precedent bead foot toe.

Rajeev et al. [6] proposed criteria to minimize the weld clad top surface unevenness by the adjacent bead overlapping or offset distance variation. In this article two other models of bead overlapping are proposed (see figure 4). These criteria (equations 1 and 2) are based on simplified geometrical overlapping assumptions. The bead reinforcement is assumed to be a 4th degree symmetric polynomial to have an analytical expression for the selected criteria.

$$Z\left(\frac{P_H}{2}\right) = \frac{r}{2} \qquad (1) \qquad \int_{\frac{P_A}{2}}^{\frac{L}{2}} Z(x)dx = \int_0^{\frac{P_A}{2}}\left(r - Z(x)\right)dx \qquad (2)$$

To observe the bead penetration behavior and "Marangoni effect" on its shape, some criterion to analyze the bead and substrate interface may be chosen which may be

based on the assumption that weld bead toe should reach the maximum penetration zone of the precedent bead. The experimental scheme allowed us to establish a relation between cladding input parameters, clad quality parameters (dilution, clad geometry) and bead centre to centre off-set distance to get the uniform top surface profile.
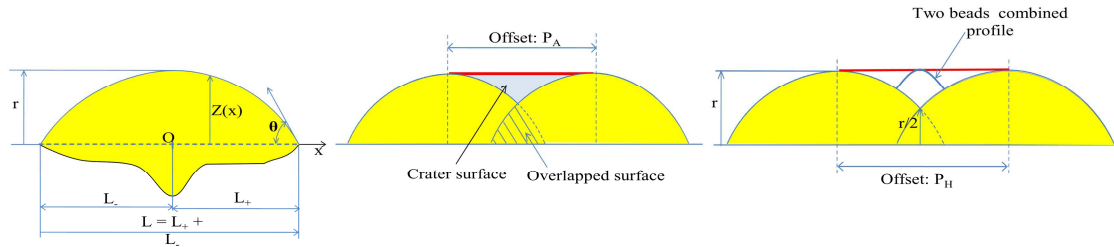

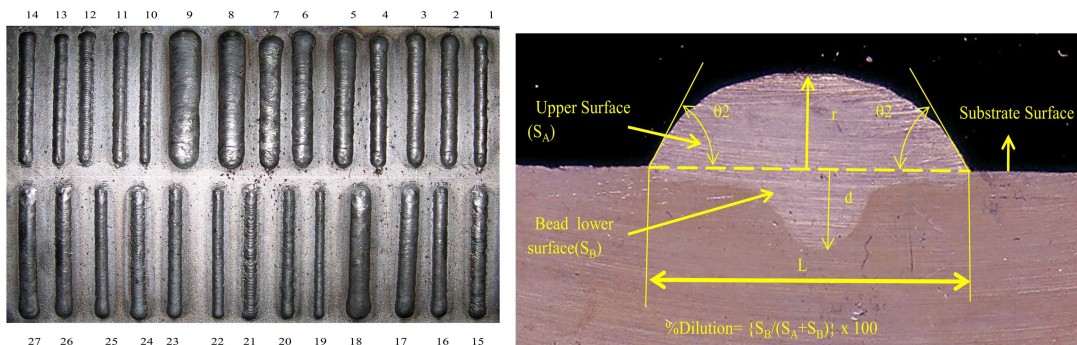**FIGURE 4** Different Criteria of single layer cladding

FIGURE 5 27 Cladded beads obtained and typical clad quality parameters

Different sets of cladding input parameters were tested with above mentioned criteria. Initial results revealed that the penetration defect at the toe of adjacent beads is vital while selecting the cladding criteria. For larger values of bead centre to centre offset distance, the deposited bead cannot access the maximum penetration zone of the precedent bead while for smaller value the wetting of the cladded beads increase gradually even more than 90° (shown in figure 6 (b)) causing the lack of penetration problem at the bead toe. One solution to enlarge the working range is to consider different values of β. Figure 6(b shows the effect of torch inclination angle β (see figure 2) at different beads overlappings.The results reveals that wetting angle for 30° inclined torch is less compared to 0° for all values of overlapping, which ultimately decrease the bead toe penetration defect and improves the top clad surface profile.

Hot bending Test

The hot bending test setup is shown in figure 7. The cladded plate was heated in an electric oven under inert environment of argon at a flow rate of 8L/min. Results of hot bending test of a cladded plate with beads of different dilution rate and nominal energy at different temperatures are shown in table 2.
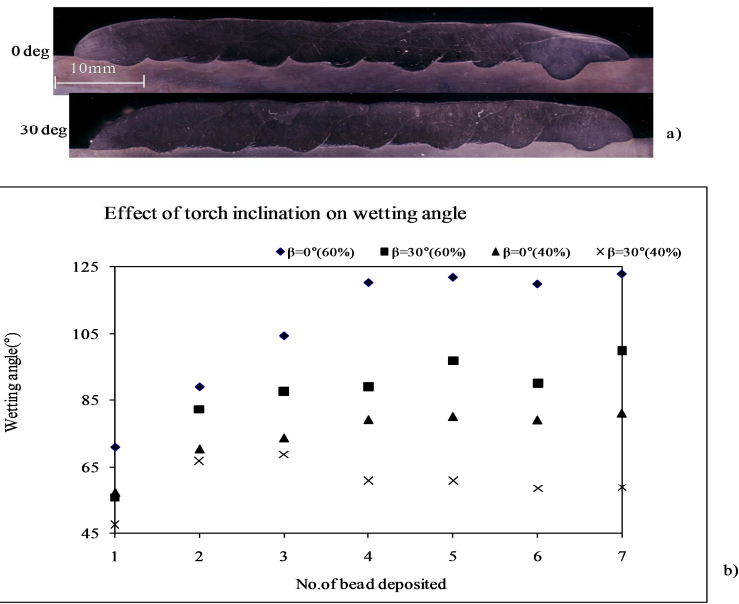
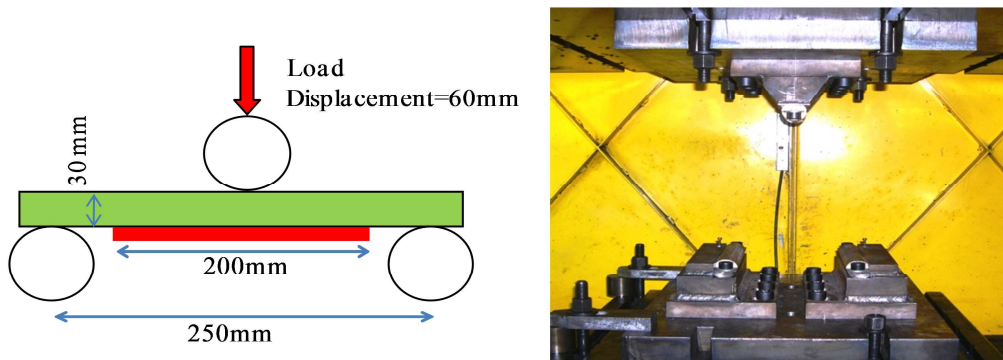FIGURE 6 Macrographs of cladded beads at different torch angles (a) and its effect on wetting angle (b)

FIGURE 7 Hot bending test apparatus setup

HOT BENDING TEMPERATURE	DILUTION	NOMINAL ENERGY	HOT CRACKING	DILUTION	NOMINAL ENERGY	HOT CRACKING
	%	(KJ /cm)		%	(KJ /cm)	
750℃	18		YES	38		YES
900℃	18	9.47	NO	38	13.44	NO
1050℃	18		YES	38		YES

TABLE: 2 Results of hot bending tests

The plate was cladded with different input parameters with an overlap of 40% of total bead width with different dilution and torch angles α=18° and β=0°.The cladded plates showed the defect of lack of penetration at the junction to two beads which is not visible in macro and micrographs of the clad without hot bending test. Depending on

hot bending temperature, cracks can be propagated from junction to top cladding surface as shown in figure 8. The initiation of crack is linked with the hot ductility of the cladding.
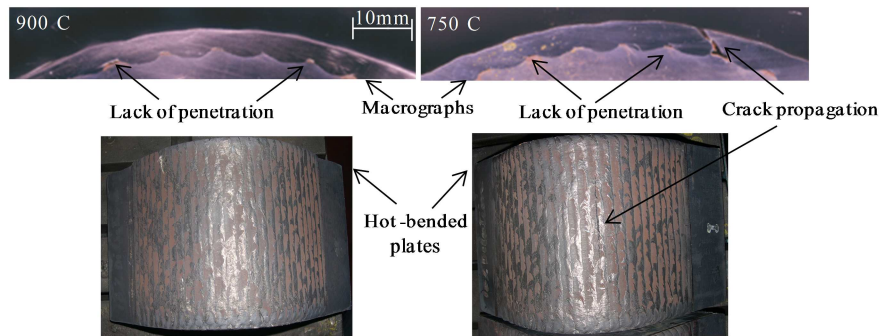

FIGURE 8 Hot bending test results of 18% diluted cladded plate at different temperatures

CONCLUSION

Hot forging behavior of a cladded work piece is characterized. A set of experiments is carried out to establish a relation between cladding process and clad quality parameters. The clad quality parameters are not only linked with the cladding layer mechanical and physical properties but also with forming behavior. The post hot forged cladding layer properties are not explored in this article but it will be our future work objective. Another perspective of this work is related to the dissimilar metals forming of work piece.

ACKNOWLEDGMENTS

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