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Analysis of weld bead parameters of overlay deposited on D2 steel components by plasma transferred arc (PTA) process.

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Abstract. Plasma Transferred Arc (PTA) process is increasingly used in applications where enhancement of wear, corrosion and heat resistance of metals surface is required. The shape of weld bead geometry affected by the PTA welding process parameters is an indication of the quality of the weld. PTA is a versatile method of depositing high-quality metallurgically fused deposits on relatively low cost surfaces. The overlay deposited is an alloy that is hard and more corrosion resistant than counterparts laid down by Gas Tungsten Arc Welding (GTAW) or Oxy Fuel Welding (OFW) processes. Weld deposits are characterized by very low levels of inclusions, oxides, and discontinuities. This process produces smooth deposits that significantly reduce the amount of post weld machining required. Metal-Mechanic industry continuously requires recovering tool steel components subjected to severe wear. The steel known as D2 is considered to be a high carbon, high chromium cold work tool steel. In this research, weld beads were deposited on D2 steel by using PTA process with different parameters as welding current and travel speed using base nickel filler metal. In order to evaluate the metallurgical features on the weld beads/substrate interface a microstructural characterization was performed by using Scanning Electron Microscopy (SEM) and to evaluate the mechanical properties was conducted the wear test.

Introduction

In the recent years, PTA surfacing has an extensive use in applications such as valve industries, hydraulic machineries, mining industries, chemical and thermal power plants etc. PTA process can be considered as an advanced Gas Tungsten Arc welding process more widely used for overlay applications. Weld deposition of hardfacing alloys is commonly employed to enhance the tribological life of engineering components subjected to hostile environments. The reclamation of worn out metal parts is demanded worldwide and for this demand PTA hardfacing of hard, wear resistant thin surface layer of metals and alloys on suitable substrates is one of the proven surfacing techniques [1]. This Process stands out for its high quality, metalurgically bonded with substrate and low diluted overlays. These overlays also exhibit high homogeneity, low oxide content, and low concentrations of other unwanted inclusions [2]. In this process the metal and alloy powder is carried from the powder feeder to the central electrode holder in the arc-gas stream. From the electrode holder the powder is directed to the constricted arc zone, where it is melted and fusion bonded to the base metal. Thus, smooth, thin deposits of overlays can be made through this way of precise control of feedstock by PTA welding process [3,4].

Weld pool geometry plays an important role in determining the mechanical and corrosion properties of the weld. Therefore, it is very important to select and control the welding process parameters for obtaining optimal weld pool geometry [5,6]. The hardfacing process normally uses materials consisting of a metallic matrix material and hard particles as reinforcement. The metallic matrix acts as a binder for the hard particles where iron, nickel and cobalt are used. Investigations showed under abrasive conditions that an increase of hard phase content in the metallic matrix is beneficial [7]. Ni base alloys are widely used due to their outstanding oxidation, wear and corrosion resistance. These materials exhibit a high resistance to temperature. Additional elements can be added to achieve further improvement of the functional properties of these coatings. Particularly NiCrBSi is mostly used for fabrication of the wear and corrosion resistant coatings [2].

The tool steel is high in both carbon and chromium for the purpose of forming large volumes of secondary chromium carbides as a result of the precipitation of the carbides during the tempering procedure. D steel series were original developed as a possible alternative group of steels to the high speed steels and for use as a less expensive source to manufacture cutting tools. A duplex microstructure with coarse complex carbides provides steel with high wear resistance and good toughness. The applications of D2 steel are: high duty cutting tools (dies and punches), long run form rolls, tube mill rolls, deep drawing tools for sheet and strip, shear blades, circular shears, thread rolling dies, and small moulds for plastic industries [8].

Experimental Procedure

In this work, automatic PTA hardfacing was carried out for depositing a mixture of nickel base metal alloy and tungsten carbides over D2 tool steel plates of size 140 mm x 60 mm x 20 mm. Chemical composition of the D2 steel is shown in Table 1. Microstructural characterization of the brazed joints is performed by using a JEOL scanning electron microscope (SEM) equipped with EDXS semi quantitative analysis using an accelerating voltage of 15 kV, spot size of 40 and a working distance of 11 mm. The independently controllable process parameters identified based on their significant effect on weld bead geometry to carry out the experimental work were welding current, oscillation width, travel speed, preheat temperature and powder feed rate as shown in experiment design of Table 2. Preheat temperature and oscillation amplitude [9] which may affect crack formation during hardfacing, have to be properly controlled. The gas flow rate and torch standoff distance were kept at constant levels. Considering preliminary research the feasible limits of the parameters were chosen in such a way that the D2 steel substrate could be harfaced without any weld defects.

Table 1. Chemical composition (wt. %) of the D2 steel.

C	Si	Mn	Cr	Mo	V
1.55	0.35	0.35	11.8	0.8	0.8

Table 2. PTA parameters and its levels.

		Factor levels				
Parameter	Units	-2	-1	0	1	2
Welding current	A	65	75	85	95	105
Travel speed	m/min	0.3	0.6	0.9	1.2	1.5
Preheat temperature	°C	200	250	300	350	400
Oscillation width	mm	14	16	18	20	22

Results and Discussion

Fig. 1a shows the cross section of the weld bead or overlay deposited by PTA process. As it can be appreciated the microstructure consists of the base metal, the heat affected zone (HAZ) and a fine carbide precipitation zone. The EDXS spectrum corresponding to weld bead presents a high content of W and Ni, Fig. 1b. In the weld bead there are a tungsten carbide zone (C), the interface zone between weld bead and base metal (IZ) and the base metal (BM), Fig. 2a. As it can be seen in Fig. 2b the EDXS spectrum carried out at the interface zone shows practically the same composition of the weld bead area with a high content of W. Weld deposits are characterized by very low levels of inclusions, oxides and discontinuities.

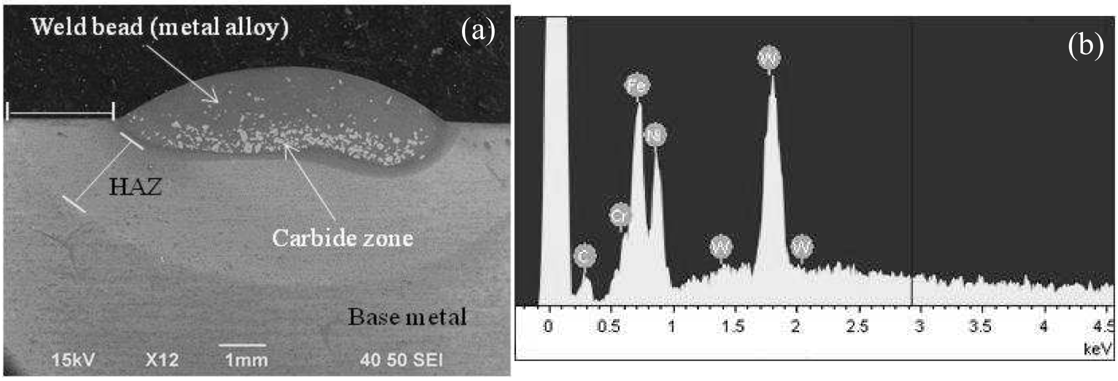


Fig. 1. (a) Cross section microstructure of the weld bead. (b) EDXS spectrum of the metal alloy.

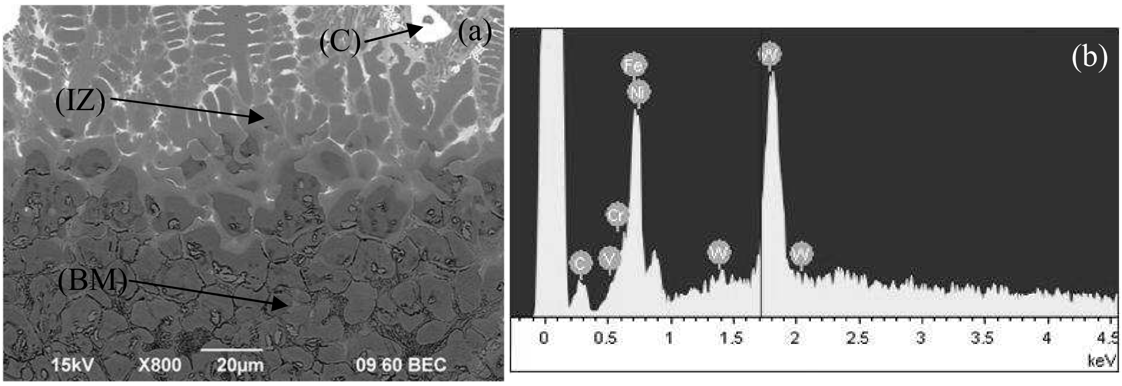
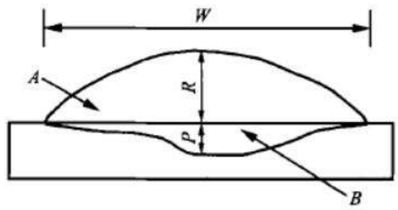


Fig. 2. (a) Microstructure of the interface zone between weld bead and base metal. (b) EDXS spectrum of the interface zone.

Compared to other welding processes PTA requires less quantity of material to be deposited with improved metallurgical properties and allows precise metering of metallic powder feedstocks. All these wanted properties of coatings are degraded if dilution which is an interalloying of hard surfacing alloy with base metal increases. Dilution is based on the weld bead geometry as shown in Fig. 3. The shape of the weld bead geometry is affected by the values of PTA process parameters kept during deposition [10]. These process parameters should be well established and categorized to enable automation of PTA overlay depositing. This process produces smooth deposits that significantly reduce the amount of post weld machining required.



$$DI = \frac{B}{A+B} \times 100$$

Fig. 3. Weld bead geometry.

Fig. 4 illustrates a series of images showing the weld bead geometry and dilution obtained with different PTA parameters. Right images exemplify low values of dilution and left images correspond to high values. The selection of welding procedure must be more specific to ensure that adequate bead quality is obtained [11]. Further, a complete control over the process parameters is very important to produce quality welds with required bead geometry based on which the integrity of the weldment is known. It has been reported by researchers that in PTA surfacing, process quality can be represented by bead shape [12]. Thus the weld bead geometry plays an important role in determining the mechanical properties of the weld.

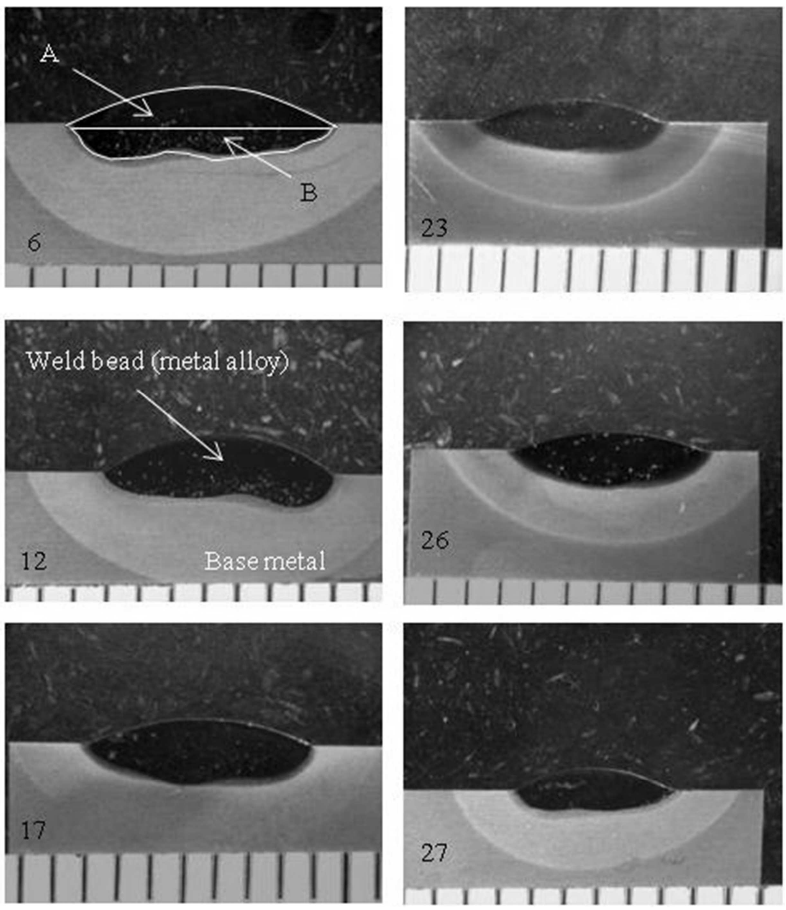


Fig. 4. Stereoscope images of the weld bead geometry.

It is evident from Fig. 5 that dilution percentage decreases steadily with increase in travel speed (S). This is attributed to the reduced heat input per unit length of weld bead when S is increased. Fig. 6 shows that dilution percentage increases significantly when welding current increases. This is attributed to the fact that heat input to the base metal increases when this parameter is increased. Therefore, it is very important to select and control the welding process parameters for obtaining optimal weld pool geometry [13,14]. The results show that is recommended using high travel speed and low values of welding current.

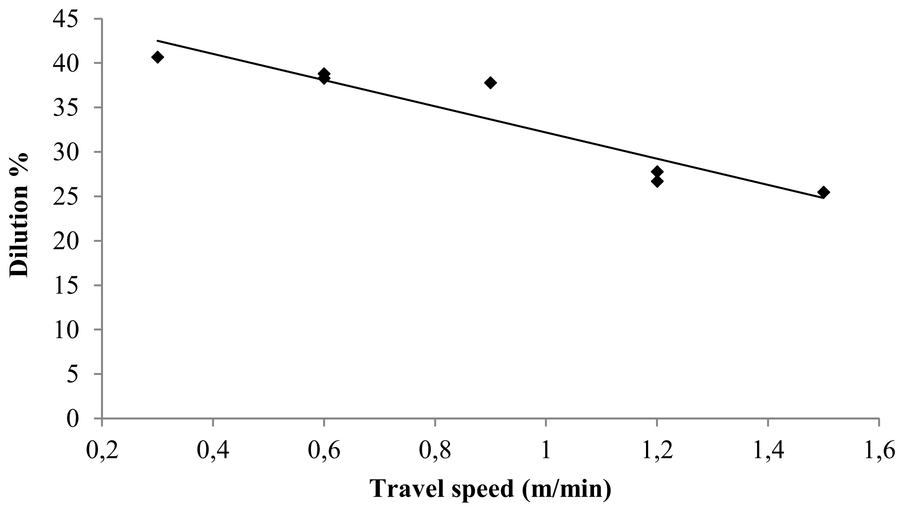


Fig. 5. Effect of travel speed on dilution percentage.

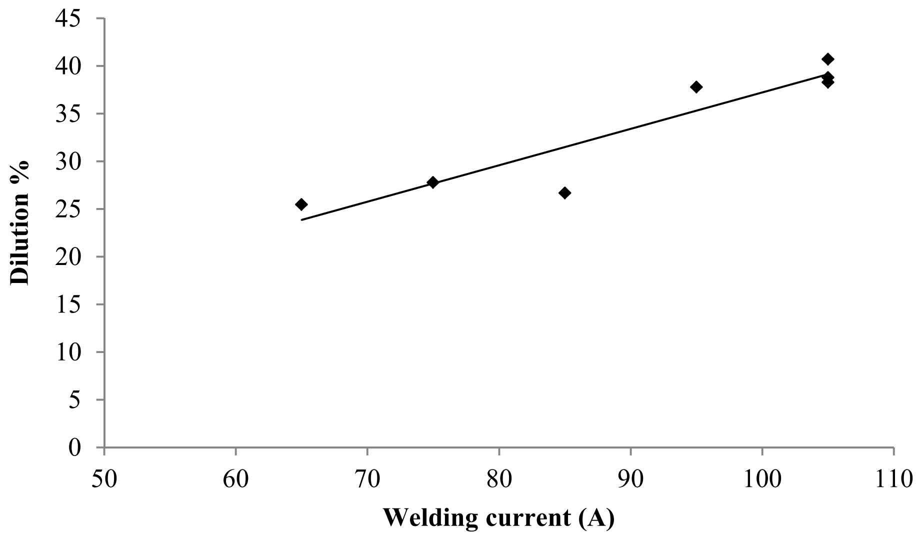


Fig. 6. Effect of welding current on dilution percentage.

The results of the hardness test of three samples are shown in Fig. 7a, the microstructure in Fig. 7b indicates the zones where hardness was measured. The hardness values are around 58 HRC at the top of the weld bead and increase at the tungsten carbide zone with a value of aproximately 72 HRC and decreasing a little at the interface zone at values of 50 HRC and finally at the base metal with values between 58 and 60 HRC. Fig. 8 shows the results of the wear test, in this plot can be appreciated the lost volume and the specific ratio. Compared with D2 steel filler metal, the nickel based filler metal NiCrBSi applied on D2 steel substrate presented a wear coefficient lower, and therefore the wear resistance on the surface is improved significantly. This behavior is due to the homogeneous carbide precipitation zone.

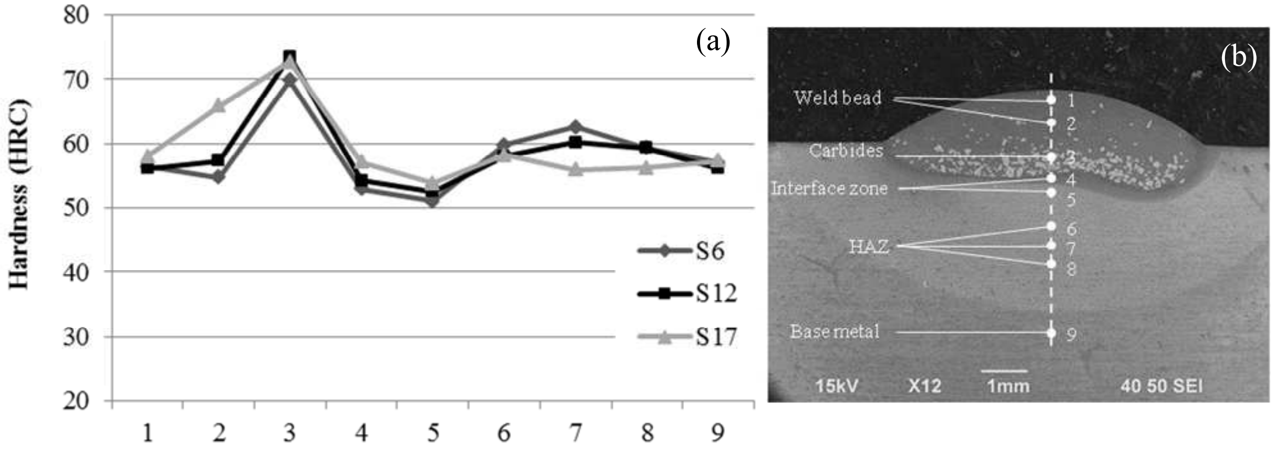


Fig. 7. (a) Hardness profile in the overlay. (b) Microstructure showing the indentation zones carried out in the overlay.

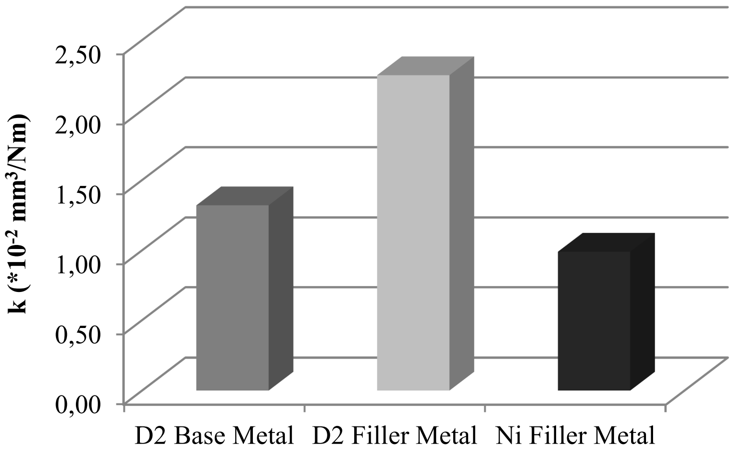


Fig. 8. Wear coefficient of the filler metals.

Conclusions

- Dilution percentage decreases constantly with increase in travel speed. This is attributed to the reduced heat input per unit length of weld bead when travel speed is increased.
- Preheat is very important because it reduces the cracking in the weld bead.
- There are not microstructural changes in the metal alloy during the PTA process application.
- The hardness values increase in the carbide zone, therefore after machining there will be an overlay with wear resistance properties.
- Wear resistance on the surface is improved using nickel based filler metal.
- Due to hardness of the deposited overlay by PTA is improved it can be used as refurbishment method in components where wear resistance is required as sheet metal dies.

References

[1] B. Howard, Surfacing for wear resistance, Stephen Helba et al. (eds.), Modern Welding Technology, Prentice Hall Inc., New Jersey 2002, 721-726.

[2] E. Gruzdys and S. Meskinis, Influence of Plasma Transferred Arc Process Parameters on Structure and Mechanical Properties of Wear Resistive NiCrBSi-WC/Co Coatings, Materials Science 17 (2011) 140-144.

[3] H. Eschnauer, Hard material powders and hard alloy powders for plasma surface coating, Thin Solid Films 73 (1980) 1-17.

[4] C.R. Das, S.K. Albert, A.K., Bhaduri and G. Kempulraj, A novel procedure for fabrication of wear-resistant bushes for high-temperature application, Journal of Materials Processing Technology 141 (2003) 60-66.

[5] A.I. Khuri and J.A. Cornell: *Response surfaces, Designs and analyses*, Marcel Dekker Inc., New York (1996).

[6] C. Katsich and E. Badisch, Effect of carbide degradation in a Ni-based hardfacing under abrasive and combined impact/abrasive conditions, Surface Coating Technology 206 (2011) 1062-1068.

[7] C. Katsich, A. Zikin and E. Badisch: 8th International DAAAM Baltic Conference, Industrial Engineering (2012).

[8] *Properties and Selection: Irons, Steels, and High Performance Alloys* ASM Handbook, Vol. 1 (1993).

[9] A. Scotti and L. Alves Albuquerque Rosa, Influence of oscillation parameters on crack formation in automatic Fe-B hardfacing, Journal of Materials Processing Technology 65 (1997) 272-280.

[10] V. Gunaraj and N. Murugan, Prediction and comparison of the area of the heat-affected zone for the bead-on-plate and bead-on-joint in submerged arc welding of pipes, Journal of Materials Processing Technology 95 (1999) 246-261.

[11] I.S. Kim, J.S. Son, Y.J. Jeung, Control and Optimisation of bead width for multi-pass welding in robotic arc welding processes, Australian Welding Journal 46 (2001) 43-46.

[12] K. Marimuthu, N. Murugan, Prediction and optimization of weld bead geometry of plasma transferred arc hardfaced valve seat rings, Surface Engineering 19 (2003) 143-149.

[13] J.C. Mc. Glone, Weld bead geometry prediction – a review, Metal Construction 14 (1982) 378-384.

[14] P.K. Palani, N. Murugan, Optimization of weld bead geometry of stainless steel cladding by flux cored arc welding using Excel Solver, IWS Journal 2 (2005) 15-19.