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Resumo Hardfacing involves the application of a deposition on the surface of a metallic workpiece by employing a welding method such as plasma transferrd arc (PTA) and has found widespread application in the steel, power, mining and in the petroleum industry. The process of hardfacing should be aimed at achieving a strong bond between the deposit and the base metal with a high deposition rate. Therefore, it is very important for the proper selection of PTA process parameters to improve weld qualities i...

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OPTIMIZATION OF PLASMA TRANSFERRED ARC WELDING PROCESS PARAMETER FOR HARDFACING OF STELLITE 6B ON DUPLEX STAINLESS STEEL USING TAGUCHI METHOD

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Abstract: Hardfacing involves the application of a deposition on the surface of a metallic workpiece by employing a welding method such as plasma transferrd arc (PTA) and has found widespread application in the steel , power , mining and in the petroleum industry . The process of hardfacing should be aimed at achieving a strong bond between the deposit and the base metal with a high deposition rate. Therefore, it is very important for the proper selection of PTA process parameters to improve weld qualities in hardfacing. The properties of the hardface materials such as mechanical strength, hardness are influenced not only by the chemical composition but also by the process parameters. The acceptable properties depends on heat input and the heat input, in turn, depends on welding current, arc voltage, etc. Therefore, weld hardfacing can be considered as a multi input, multi-output process , Stellite 6 has an outstanding resistance to seizing or galling as well as cavitation erosion and is extensively used to combat galling in valve trims, pump sleeves and liners. Hardfacing is a surface modification technology in which a specially designed alloy is surface welded in order to enhance surface properties depending on the characteristics of selected alloys. In this process, metallurgical bond forms between the coating and the substrate in this concern PTA welding process parameter are optimized for maximum hardness and defect free process, using Taguchi method for the hardfacing of Stellite on duplex stainless steel.

Key-words: PTA, hardfacing,Taguchi method, Regression

1. **Introduction**

Hardfacing involves the application of a deposition on the surface of a metallic workpiece by employing a welding method. The process of hardfacing should be aimed at achieving a strong bond between the deposit and the base metal with a high deposition rate.Hardfacing is applied in numerous industries, including chemical and fertilizer plants, nuclear and steam power plants, pressure vessel, as well as valves and valve seats in the automotive industry. (Jong-Ning, et al., 2001) Plasma transferred arc welding (PTA) is a commonly used technology and efficient method to coat a surface with such wear-resistant hardfacings. Single or multilayer depositions provide strong metallurgical bonding between the deposit and the base metal, as well as porosity-free coating and low dilution with substrate. In the PTA process, the heat of the plasma (arc of ionized gas) is used to melt the surface of the substrate and the welding powder, where the molten weld pool is protected from the atmosphere by the shielding gas. (Y.S. Tarng, et al., 2002)

Surface treatments of metals are commonly based on the use of high energy density sources, as they offer a means of rapid heating and subsequent quenching from the melt, leading to fine microstructures and consequently to possible improvement of mechanical, corrosion or tribological properties. Superficial layers of the appropriate thickness, free of cracks and with high hardness may be obtained by suitable control of the process variables. In this respect there has been considerable interest in the use of laser and electron beam sources for surface treating and melting of low carbon steels and stainless and tool steels. The impact of the process variables on temperature profiles, microstructure and properties have been examined and the results already obtained may serve as a reference for further investigations. However, only a limited number of investigations concern the use of the plasma transferred arc (PTA), although there are serious indications that its use may be quite attractive in industrial applications. It is, therefore, interesting to investigate the PTA process, which—despite its lower energy density—has the main advantage to require rather inexpensive equipment and the possibility to work with a higher heat input (E. Bourithis, et al.,2002). Plasma transferred arc welding (PTAW) is an extension of the GTAW process where both utilize a gas shielded arc produced by a non-consumable tungsten cathode. In PTA hardfacing, transferred arc melts the powder and the local surface of the treated component so that the whole amount of powder and only a thin film of component surface under the arc will be melted. As a result, a solidified metallurgical bond between the deposit and substrate is obtained with minimum dilution (less than 10%), whereas the amount of dilution is 10 % - 30% in the case of other hardfacing techniques. (V Balasubrarnanian, et al., 2009)

Stellite 6 is a well-known Co–Cr–W–C alloy where chromium provides mechanical strength by formation of solid solution and corrosion resistance through the formation of chromium oxide protective layer. In addition, this element also acts as the chief carbide former during alloy solidification. Tungsten increases the strength of Co–Cr by solid solution strengthening (F. Madadi, et al., 2012).

2. Experimental Procedure:

2.1 Determining the effective process parameters and their working limits

A large number of trial runs were carried out on for the PTA hardfacing, different combinations of PTA hardfacing process parameters were used to carry out the trial runs on Inconel 825 and duplex stainless steel UNS32205 and stellite grade 6B powder was used as hardfacing material. To set the ranges of operating parameters, following inferences were drawn during operation.

(1) If the transferred arc current was less than 100 A, the incomplete melting of powders and lack of penetration were observed. For the transferred arc current greater than 140 A, the undercut and spatter were noticed on the weld

bead surface.

(2) If the travel (hardfacing) speed was less than 80 mm/min, there was an over deposition of

Weld metal and higher reinforcement height was observed. Travel speed greater than 140 mm/min resulted in incomplete penetration and very thin weld bead.

(3) If the powder feed rate was lower than 10 g/min, over melting of base metal and overheating of tungsten electrode were noticed. When the powder feed rate was greater than 20 g/rnin, weld bead formation was not smooth owing to incomplete melting of powders.

(4) For torch oscillation speed less than 475 mm/min, the bead appearance and contours were not so smooth and very narrow bead was obtained. When the oscillation speed was greater than 525mm/min, wider bead width and smaller reinforcement height were observed.

The hardness, surface defects, bead contour, bead appearance, and weld quality were inspected to identify the working limits of the welding parameters, the parameter and their working limit are shown in table 1.

Table 1. Parameters and their working limits

Sr.no	Parameters	Low level	Moderate level	High level
1	Transferred arc current(Amp)	100	120	140
2	Travel(hardfacing) speed(mm/min)	80	100	120
3	Powder feed rate (gms/min)	10	14	18
4	Oscillation speed (mm/min)	475	500	525

2.2 Material

The base material used in this investigation is casting plates of duplex stainless steel of grade S32205 UNS no.S31803 which is widely used for the fabrication of valves, valve cones, spindles, and pressure vessel parts. Plates of 30 mm in thickness are used as the base material. In this investigation, the composition of base material duplex stainless steel and stellite grade 6B. Shown in table 2 and table3.

Table 2. Composition of stellite 6B

Name	C%	Si%	Cr%	Co%	W%
Stellite 6 B	1.08	1.09	28.75	Balance	4.37

Table 3. Composition of duplex stainless steel

Name	C%	Si%	Cr%	Ni%	P%	S%	Mo%	Mn%	N%
Duplex stainless steel	0.026	0.45	22.41	6.12	0.007	0.007	3.15	1.28	0.16

2.3 Experimental set up and data collection

For conducting the experiment, An automatic PTA hardfacing machine, designed and fabricated by M/s Primo Automation Systems, Chennai, India with the support of KOSO India Pvt. ltd, Ambad, Nashik is employed to conduct the experiments .KOSO India Pvt.ltd, Ambad, Nashik a valve manufacturing company, a machine is fully automated by PLC control unit, with touch screen display to control the various parameters, as shown in figure 1.

Fig.1 PTA machine

2.4 Preparation of specimen for test

As per the design of experiment based on Taguchi design of experiment of L9 orthogonal array created in MINITAB software, Plates of thickness 30 mm was taken as deposition is above 2 mm, according to the WPS EN ISO 11970:2007, the welding joint is G1 as applicable for the casting plate. And the length of the run is taken (3*thickness of the plate) up to 9 mm and width of deposition is (is up to

1.5*thickness of the plate) that is 4.5 cm according to EN ISO 11970:2007. Deposit are prepared on each plate using the first 3 combination of parameters as described in the design of experiments matrix (same parameter), similarly deposition is carried out on the remaining plates according to design matrix. The experiments were conducted by forming layers of stellite grade 6 powder (size 45-125 micron) on the substrate plate with the electrode negative (DCEN) according to the welding process specification (WPS) ASME21 with position of groove 1G. Tungesten electrode size 4 mm diameter (2% Thoriated Tungesten),torch orifice diameter 25mm Industrially pure argon (99.99%) is used at a constant flow rate of 15 L/min for shielding, 2.5 L/min for centre, and 3 L/min for powder feeding. And a constant standoff distance is 4 mm

For the discard part of specimen the length of run is increased to 15 cm. After hardfacing the welding coupons (specimens) are grind by using portable grinding machine and then superfine using emery paper, now the specimen are ready for hardness testing.

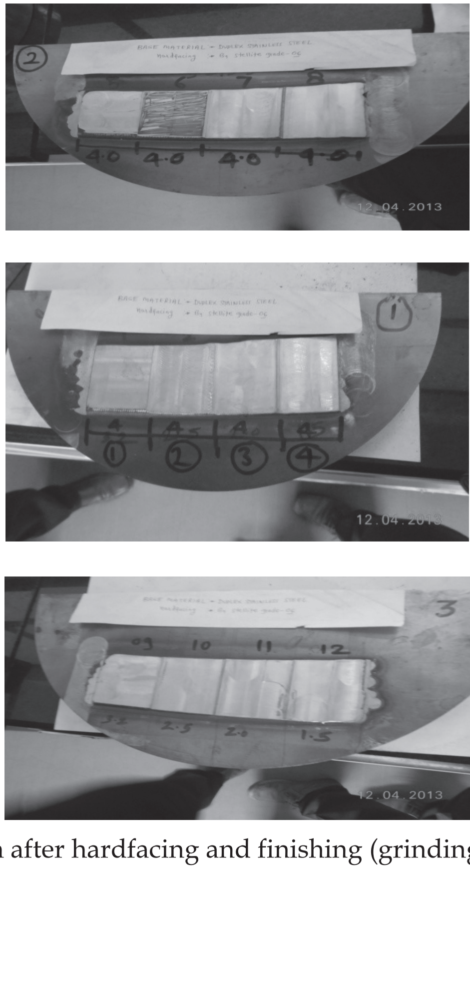

Fig.2 Specimen after hardfacing and finishing (grinding)

2.5 Recording the response (measuring the hardness)

A load of HV10 performed on digital Vickers tester available in QC Lab, hardness is measured in the weld cross section, as the main aim to optimize (increase) the hardness of weld cross-section. For the measurement of hardness weld section is divided into three sections, of each specimen transverse to the weld travel, as shown in fig.2, then hardness is measured at each section and the average value of hardness is marked for the one range of parameters each from top section, middle section and the bottom section and hardness is note down as shown in table 4.

2.6 Calculation of signal to noise (S/N) ratio

S/N ratio is calculated for the hardness. The objective function is to be maximized. Thus, Larger-the-better S/N ratio is used.S/N ratio= -10 Log10 (1/ Hardness2).

Table 4:.Design of experiment (D.O.E.) and data collection:

Sr. No.	Current I(amp)	Travel Speed TS(mm/min)	POWDER PF (gms/min)	Oscillation OS (mm/min)	Hardness HRC	HRC*HRC	S/N ratio
1	100	80	10	475	37	1369	31.364
2	100	80	10	475	35	1225	30.881
3	100	80	10	475	36	1296	31.126
4	100	100	14	500	38	1444	31.595
5	100	100	14	500	39.3	1544.49	31.887
6	100	100	14	500	39.2	1536.64	31.865
7	100	120	18	525	44.8	2007.04	33.025
8	100	120	18	525	44.9	2016.01	33.044
9	100	120	18	525	44.8	2007.04	33.025
10	120	80	14	525	38.1	1451.61	31.61
11	120	80	14	525	38	1444	31.595
12	120	80	14	525	37.9	1436.41	31.572
13	120	100	18	475	39.6	1568.16	31.951
14	120	100	18	475	40.3	1624.09	32.106
15	120	100	18	475	40.6	1648.36	32.170
16	120	120	10	500	39.6	1568.16	31.953
17	120	120	10	500	36	1296	31.126
18	120	120	10	500	36.2	1310.44	31.174
19	140	80	18	500	41	1681	32.255
20	140	80	18	500	41.4	1713.96	32.340

21	140	80	18	500	40.3	1624.09	32.106
22	140	100	10	525	37	1369	31.364
23	140	100	10	525	36	1296	31.126
24	140	100	10	525	37	1369	31.364
25	140	120	14	475	38.2	1459.24	31.641
26	140	120	14	475	40	1600	32.041
27	140	120	14	475	41	1681	32.255

Table 5:.average S/N ratio and regression analysis

Variable/levels	1	2	3	Maximum	Minimum	Multiple R	=0.9187
I (Amp)	31.979	31.696	31.832	31.979	31.696	R Square	=0.8440
TS(mm/min)	31.651	31.714	32.143	32.714	31.651	Adjusted R Square	=0.8157
PF(gms/min)	31.275	31.786	32.447	32.447	31.275	Standard Error	=1.1619
OS(mm/min)	31.726	31.811	31.970	31.970	31.726	Observations	=27

Resultados

The output shows the results of fitting a multiple linear regression model to describe the relationship between hardness and 4 independent variables. The equation of the fitted model is

$$\text{Hardness} = 14.4306 - 0.0197222*TC + 0.0577778*TS + 0.665278*FR + 0.024*OS \quad (1)$$

The R-Squared statistic indicates that the model as fitted explains 84.4066% of the variability in result (Hardness). The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 81.5714%. The standard error of the estimate shows the standard deviation of the residuals to be 1.16196.

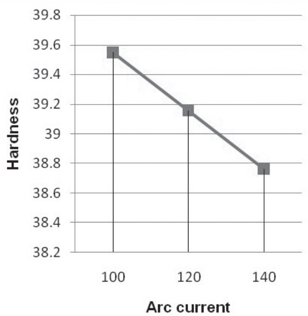

Fig. 3 Effect of current on hardness

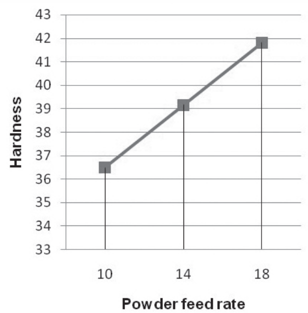

Fig. 4 Effect of Powder feed rate on hardness

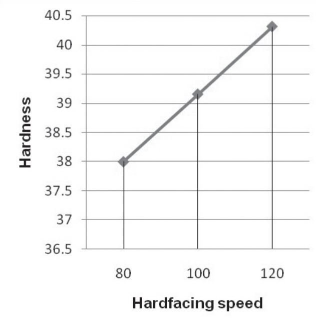

Fig.5 Effect of Travel speed on hardness

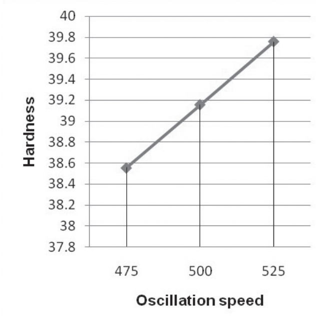

Fig.6 Effect of oscillation speed on hardness

Conclusion

By using Taguchi method and larger the better criteria the optimum levels of parameter are current at minimum level i.e.100 amp and powder feed rate which shows a maximum effect at maximum level i.e.18 gms /min and oscillation speed at maximum level i.e. 525 mm/min and travel speed at moderate level i.e.100 mm/min to yield a hardness of 42.81HRC.

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