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EFFECT OF PROCESS PARAMETERS ON DILUTION IN CLADDING OF STAINLESS STEEL ON MILD STEEL PLATE DEPOSITED BY GMAW

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Abstract—The corrosion resistant property and mechanical strength of cladded stainless steel is completely depends on the clad bead geometry which can be obtained by the controlled parameters. Hence, the aim of this work was to examine the effect of process parameters on stainless steel cladding deposited by GMAW and also the micro-structural changes at the interface and corrosion resistance behaviour were studied. Cladding is the process of depositing any corrosive resistant material over the base metal, to achieve the corrosion free surface in order to get the higher economical and longevity output. In this paper the analysis of result was done by design of experiment (DOE) method using L_4 orthogonal array, followed by S/N ratio, main effect plots and interaction plots to analyze the effect of process parameters on dilution. This experimentation reveals that welding current and voltage significantly affect the dilution and also the dilution increases on increasing welding current and voltage. The result obtained from the experiments was analyzed using MINITAB 14.

Keywords—Dilution, microstructure, cladding, gas metal arc welding, corrosion resistance, MINITAB 14

I. INTRODUCTION

Weld Cladding is the surfacing process in which thick layer of corrosive resistant material deposited on carbon or low alloy steel base metal [1-3]. It helps to achieve the corrosion free surface in order to get the higher economical and longevity output. . Automatic weld surfacing is widely used in most of the field and control enterprises due to o its high relentless quality, usability, minimal effort and high efficiency, gas metal arc welding (GMAW) has turned into a characteristic decision for automatic surfacing. Weld cladding process have recently developed and significantly used in various field such as chemical, fertilizers, steam power plant and petrochemical industries [4-7]. Application of weld cladding process involves the carbon and low compound steel pressure vessels inner surface, paper digesters, urea reactors, tubes, control vessels of atomic reactor. This technology prevents metallic surface from corrosion and increase service life [8-12].Cladding is mainly applies to the components which operates under the corrosive environment, wear and to reduce their cost by repeated rebuilding [13,14]. Due to specific properties such as great corrosion resistance and mechanical property and good machinability 304 L stainless steel is widely used in many fields i.e. chemical and fertilizers industries, nuclear power plants etc [15-19]. During the cladding process because of large composition difference between cladded material and base metal, precipitation of the phases occurs due to the exchange of elements at interface. At the interface due to the diffusion of carbon and other element micro structural change takes place which depends on temperature during cladding [20]. This grade of stainless steel i.e. 304 L is used as the structural materials in liquid handling and hydraulic systems [21, 22].

II. EXPERIMENTAL PROCEDURE

To conduct the experiment mild steel IS -2062 plate was cut into 200×50×6 size. Using design of experiment the number of trial run was selected. After the experimentation S/N ratio, interaction plot and main effect plot was used to analyse parameters and response variables. The distance between the electrode tip and nozzle tip was 15 mm. for shielding gas 100% Ar was used at flow rate of 20 LPM. After all these setting GMAW was performed to form weld bead on mild steel plate with welding speed 5mm/sec. The chemical composition of mild steel IS-2062 and filler wire (ER 304L) of 1.2 mm diameter is shown in Table no. 1.

TABLE 1 CHEMICAL COMPOSITION OF MS PLATE AND FILLER METAL

Element	**C**	**Si**	**Mn**	**P**	**S**	**Ni**	**Cr**	**Al**	**Fe**
Base Plate (M.S)	0.13	0.16	0.58	0.02	0.021	0.02	0.04	0.02	Balanced
Filler Metal	0.03	1	2	0.045	0.030	10	19	-	Balanced

Taguchi L_4 orthogonal array was used for two levels of welding parameters i.e. welding voltage and current. After performing the experiment from each plate 15 mm of weld bead samples was cut and polished using amery paper and alumina paste of 1µ grain size as a coolant, then samples were etched using etchant (ethanol-25ml, HCl-25 ml, HNO_3 12.5 ml, $FeCl_3$-3.5 gm and $CuCl_2$-0.5 gm) for calculating percentage of dilution and microstructure. For calculating the percentage of dilution sample were scanned with the help of Acrobat reader DC. The metallographic study was done by using optical microscope (De winter classical PL). A different level of parameter used in experiment is shown in Table no. 2.

TABLE 2 WELDING PARAMETERS AND THEIR LEVELS

Welding Parameters	**Levels**	
Welding current (A)	120	140
Welding voltage (V)	20	25

Fig. 1 Cladded specimen

III. **RESULTS AND DISCUSSION**

To study the effect of input parameters on the output response variables statistical analysis was carried out by the Taguchi experimental design method using statistical software MINITAB 14 in which S/N ratio analysis, mean effect plot and interaction plot were generated. The result of response output are shown in the Table no. 3.

TABLE 3. L4 ORTHOGONAL ARRAY WITH VALUES OF RESPONSE VARIABLES

S.No.	**Current (A)**	**Voltage (V)**	**Dilution %**
1	120	20	15
2	120	25	15
3	140	20	16
4	140	25	18

A. Main effect plots

Main effect plot shows the variation of individual response variable with input parameters. The main effect plot was drawn by considering the mean average of the response parameter and their level where value of each input parameter is represented by x-axis and response variable represented by y-axis. In fig. 2 it has been observed that. On increasing welding dilution percentage increases this can be due to the reason that on increasing voltage arc cone increases which spread the arc over the greater area of the base metal. And also dilution percentage increases with increase in current at all levels because of high deposition rate.

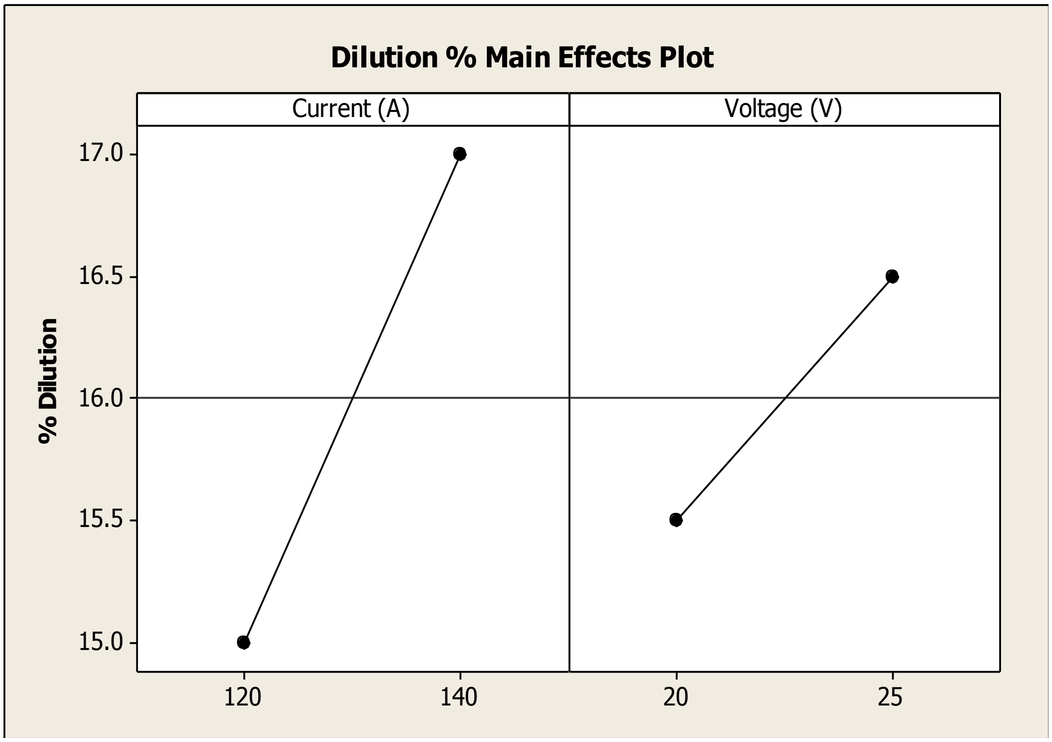


Fig. 2 Dilution % main effect plot

B. Interaction plot

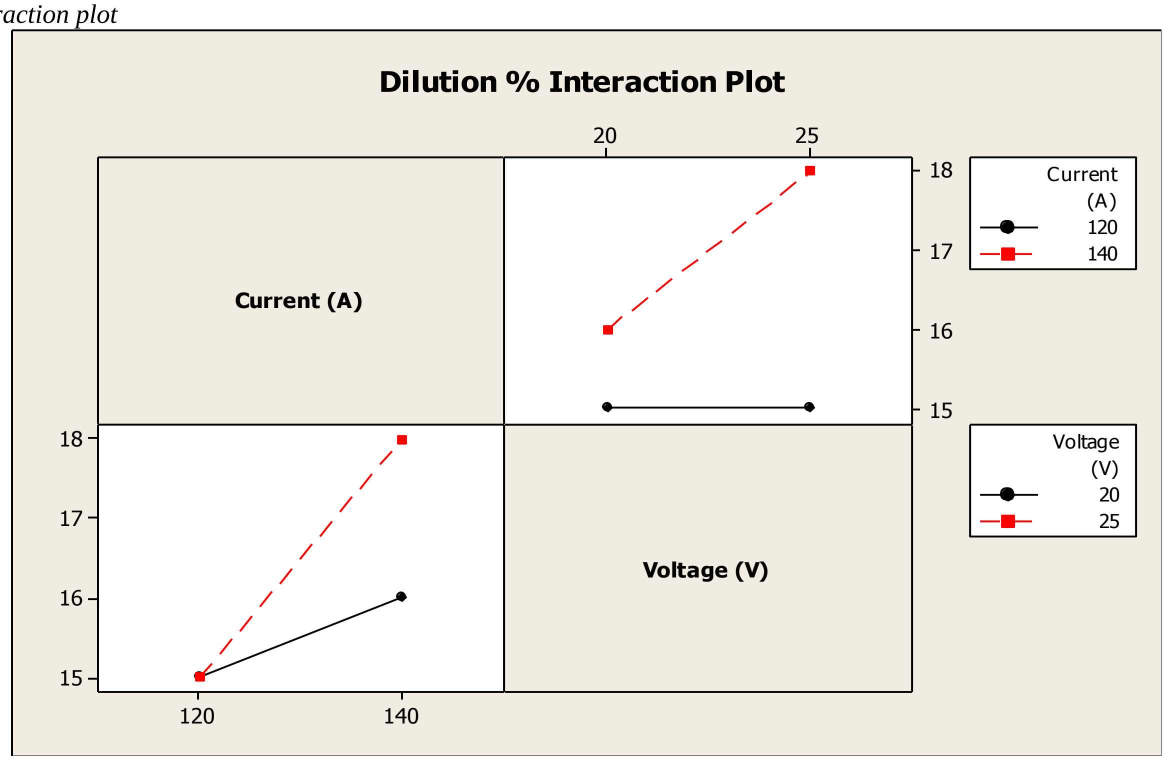


Fig. 3 Dilution % in interaction effect plot

The effect of one factor depend on the level of the other factor is called interaction. Fig 3 shows the interaction plot for dilution percentage. It was observed dilution increases on increasing voltage at higher level of current .but at lower level of current change in voltage does not affect the dilution percentage this may be due to the fact that at lower level the deposition rate is very low. Also it was observed that dilution increases on increasing current for all level of voltage because of high deposition rate.

C. S/N ratio analysis

The characteristics affectability to uncontrolled external factors (noise factors) is measured by S/N ratio. In this experiment the aim is to obtain the highest S/N ratio because it specifies that the random effect of the noise factor much lower than the signal. The S/N ratio is used to find out the optimal combination of parameter for optimum dilution. The response table for signal to noise ratios and different value of dilution ratio is shown in Table no.4 and 5.

TABLE 4 RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS AND DIFFERENT VALUE OF DILUTION RATIO

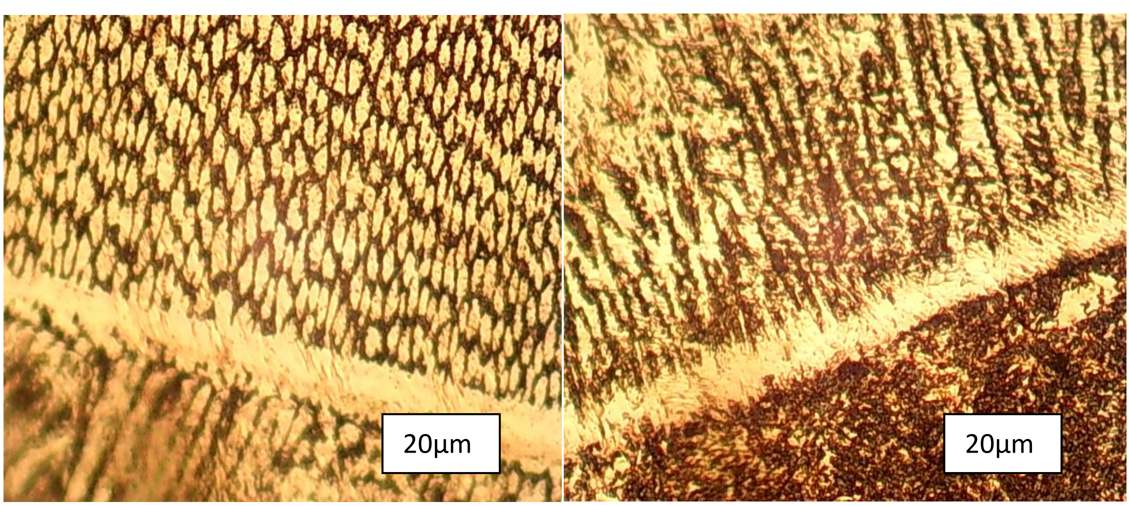
S.No.	Current (A)	Voltage (V)	SN RATIO
1	120	20	-23.5218
2	120	25	-23.5218
3	140	20	-24.0824
4	140	25	-25.1055

TABLE 5 SIGNAL TO NOISE RATIOS FOR DIFFERENT PARAMETER AT DIFFERENT LEVEL

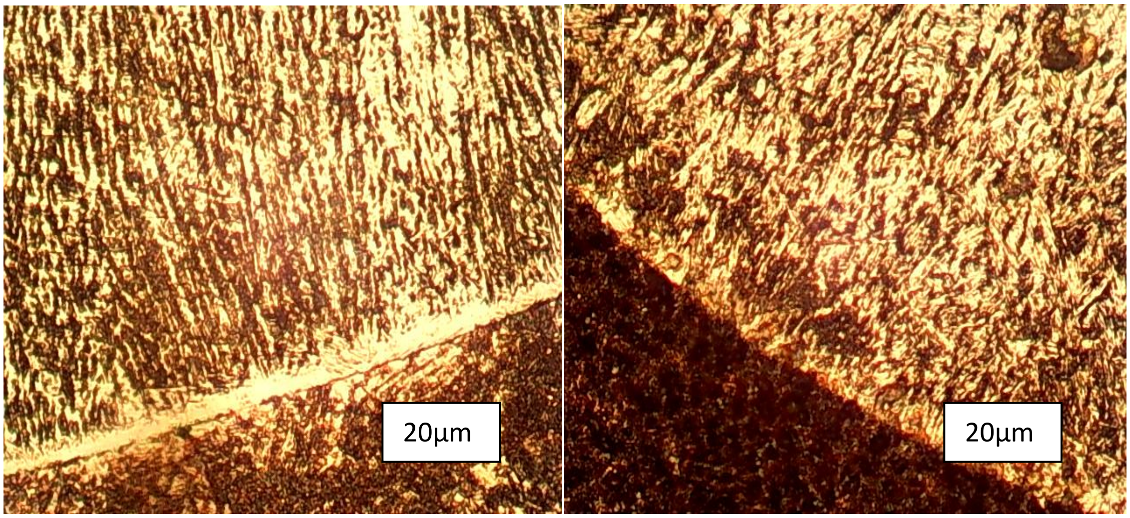
Level	Current (A)	Voltage (V)
1	-23.52	-23.80
2	-24.59	-24.31
Delta	1.07	0.51
Rank	1	2

The dilution ratio is used as the quality criteria (smaller the dilution ratio, better will be the cladding process).Lower dilution ratio means that less base metal is melted indicating that less heat is absorbed by the work piece, which leads to the less distortion and residual stress. In this experiment the S/N ratio were calculated for two factors at two different levels. It was observed that highest value of S/N ratio was obtained: A1B1, This is the optimal combination which gives the15% i.e. lowest dilution ratio.

D. Metallographic study



(a) *(b)*



(c) *(d)*

Fig 4 Microstructure of cladded specimen (a) V=20, A=120 (b) V=25, A=120 (c) V=20, A-140 (d) V=25, A=140

Due to difference between the base metal and cladded material during cladding process precipitation of phases occurs due to which diffusion of carbon and other material takes place and as a result changes occurs in the microstructure of elements at the interface, these are affected by the temperature reached during the cladding process. This change in microstructure at the interface was studied by microstructure analysis.

In cladding process mild steel and austenitic steel were separated by line which is clearly visible and called "cladding line". The microstructure of base plate and austenitic stainless steel depends on cladding parameters. With the help cladding line ferritic grain and the deformed austenitic layers interface can be distinguish easily. An austenitic structure shift towards the C-steel is not observed due to the sharp diffused Ni. At the boundary of the austenitic grains carbide precipitation started quickly. Due to the lesser content of Ni and Cr copper is little soluble and Cr carbide precipitation occurs at grain boundaries. The carbide precipitation zone width depends on the bonding temperature. In the cladding region far from the cladding line stainless steel contain austenitic microstructure without carbide precipitation. There is inter-diffusion of carbon towards the austenitic side and substitution elements towards the ferritic side at the interface.

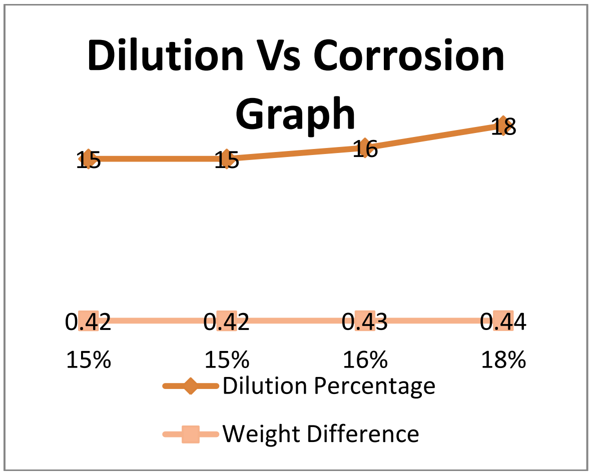
E. *Corrosion Behaviour*

After conducting the corrosion test it was observed that corrosion behavior of the specimen changes on increasing or decreasing dilution ratio. For corrosion testing mixture of 42gm ferric chloride, 300 ml HCL and 500 ml Distilled water was used as the solution in which only the clad portion of specimen was immersed and rest was coated with Teflon. After immersing for 24 hour the specimen was washed and their weight was measured and compare with the weight before emersion in solution and the result obtained is shown in Table no. 6.

TABLE 6 CORROSION TESTING RESULTS

S.No.	**Dilution %**	**Weight difference (gm)**
1	15	0.42
2	15	0.42
3	16	0.43
4	18	0.44

After experiment it was observed that the corrosion resistance property of clad specimen decreases on increasing dilution ratio since weight difference is increasing. Hence dilution ratio is inversely proportional to corrosion resistance property.



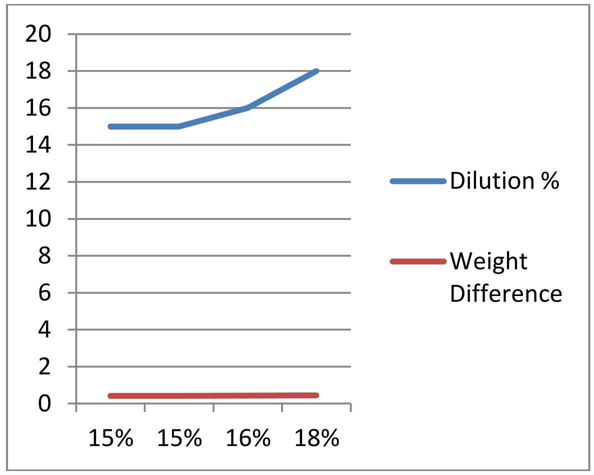


Fig 5. Relation between dilution and rate of corrosion

IV. CONCLUSIONS

1. It was observed that highest value of S/N ratio was obtained at A1B1.This is the optimal combination which gives the15% i.e. lowest dilution ratio
2. It was observed that dilution increases on increasing voltage at higher level of current .but at lower level of current change in voltage does not affect the dilution percentage this may be due to the fact that at lower level the deposition rate is very low. Also it was observed that dilution increases on increasing current for all level of voltage because of high deposition rate.
3. In the cladding region far from the cladding line stainless steel contains austenitic microstructure without carbide precipitation. There was inter-diffusion of carbon towards the austenitic side and substitutional elements towards the ferritic side at the interface.
4. Corrosion resistance is inversely proportional to the dilution percentage. Corrosion resistant property of the samples decreases (i.e. loss of weight increases) as the dilution percentage increases.

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