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A NOVEL APPROACH FOR HARDNESS MEASUREMENT TIG WELDING OF GRADE 304 STAINLESS STEEL

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Abstract:

304L stainless steel (SS) is one of the most consumable materials in orthopedic implants. Certain types of orthopedic implants such as monobloc hip stems are often made of two elements welded together. In this study, effect of TIG welding on corrosion behavior of 316L stainless steel in physiological solution was investigated. In this paper, the experimentation has been carried out by using L-9 OA as standardized by Taguchi and the analysis has been accomplished by following standard procedure of data analysis on raw data as well as S/N data. It is revealed that all the three selected parameters—current, no. of passes and gas flow rate—affect both the mean value and variation around the mean value of the selected response i.e. metal deposition rate and hardness of weld bead.
Keywords: S/N ratio, 304L, Hardness.

1. Introduction

Type 304 Stainless Steel is a variation of the basic 18-8 grade, Type 302, with higher chromium and the lower carbon content. Its lower carbon minimizes chromium carbide precipitation due to welding and its susceptibility to intergranular corrosion. In many instance, Type 304 can be used in the “as-welded” condition, while Type 302 must be annealed in order to retain adequate corrosion resistance. Type 304L is an extra low carbon variation of type 304 with 0.03% maximum carbon content that eliminates carbide precipitation due to welding. As a result, this alloy can be used in the “as welded” condition, even in severe corrosive condition. In many cases it eliminates the necessity of annealing weldments excepted for application specifying stress relief. Type 304L has slightly lower mechanical properties than Type 304

Stainless steel	Cr	Ni	C	Mn	Si	P	S	N
Type 304	18-20	8-11	0.08 max	2 max	0.75 max	0.045	0.030	0.10

Physical Properties

- Density, 0.29 lbs/in3(8.03g/cm3)
- Electrical Resistivity microhm-in (microhm-cm) 68°F (20°C) – 28.4(72)
  1200°F (659°C) – 45.8(116)
- Specific Heat, BTU/lb/oF (kJ/kg•k)

32 -212°F (0-100°C) – 0.12 (0.05)

- Thermal Conductivity, BTU/hr/ft2/ft/oF(W/m•K)

At 212°F (100°C) – 9.4 (16.2)
At 932°F (500°C) – 12.4 (21.4)

- Modulus of Elasticity, ksi (MPa)
  28×103 (193×103) in tension
  11.2×103 (78×103) in tension
- Melting Point, °F (°C) – 2550 – 2650 (1399 - 1454)

2. HARDNESS MEASURMENT

Hardness is a resistance to deformation. The hardness of steel is generally determined by testing its resistance to deformation. There are three general types of hardness measurement [33, 34]

Scratch Hardness

- The ability of material to scratch on one another
- Important to mineralogists, using Mohs' scale 1=talc, 10= diamond
- Not suited for metal – annealed copper = 3, martensite = 7.

Indentation Hardness

- Major important engineering interest for metals.
- Different type: Brinell, Meyer, Vickers, Rockwell hardness tests.

Rebound Or Dynamic Hardness

- The indenter is dropped onto the metal surface and the hardness is expressed as the energy of impact.

The hardness was tested by Rockwell hardness -testing machine with 'C' scale. Photographic view of Rockwell hardness-testing machine is shown in Fig. 4.3. Hardness is measured for two runs of each experiment are given below:-

Major Load: - 150kg
Minor Load: - 10kg
Scale: - Rockwell 'C' scales (HRC)
Indenter: - Diamond Indenter

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TABLE: 1.1- HARDNESS

Replication 1

Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
1st Run=36	1st Run=39	1st Run=42.5	1st Run=39	1st Run=41
2nd Run=40	2nd Run=38	2nd Run=43	2nd Run=38.8	2nd Run=45
3rd Run=37.2	3rd Run=41.5	3rd Run=49.7	3rd Run=53	3rd Run=41
4th Run=44	4th Run=44	4th Run=49	4th Run=46.5	4th Run=41.5
5th Run=42	5th Run=51	5th Run=54.5	5th Run=49	5th Run=48.5
Mean=39.84	Mean=42.7	Mean=47.74	Mean=45.26	Mean=43.4
Experiment 6	**Experiment 7**	**Experiment 8**	**Experiment 9**	
1st Run=34	1st Run=42	1st Run=38.5	1st Run=45.9	
2nd Run=37	2nd Run=42.3	2nd Run=34.2	2nd Run=46	
3rd Run=34.5	3rd Run=43	3rd Run=32	3rd Run=43	
4th Run=27.5	4th Run=45.5	4th Run=33	4th Run=41.5	
5th Run=33	5th Run=44	5th Run=40	5th Run=45	
Mean=33.2	Mean=43.36	Mean=35.54	Mean=44.28	

Replication 2

Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
1st Run=33	1st Run=33	1st Run=41.28	1st Run=35	1st Run=35
2nd Run=36	2nd Run=43	2nd Run=46	2nd Run=36.6	2nd Run=49

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3rd Run=41	3rd Run=46	3rd Run=53.4	3rd Run=50	3rd Run=43
4th Run=48	4th Run=46.5	4th Run=52	4th Run=47.2	4th Run=42
5th Run=39.5	5th Run=54	5th Run=51.6	5th Run=52	5th Run=50.3
Mean=39.5	Mean=44.5	Mean=48.85	Mean=44.16	Mean=43.86
Experiment 6	**Experiment 7**	**Experiment 8**	**Experiment 9**	
1st Run=39	1st Run=40	1st Run=41.28	1st Run=49	
2nd Run=36	2nd Run=44	2nd Run=30.2	2nd Run=43.6	
3rd Run=34	3rd Run=41.9	3rd Run=33	3rd Run=41.2	
4th Run=31	4th Run=47	4th Run=36	4th Run=40	
5th Run=34.9	5th Run=43.2	5th Run=40.3	5th Run=44.3	
Mean=34.98	Mean=43.22	Mean=36.1	Mean=43.62	

After conducting the experiment with different setting of input parameters and the value of output variable were recorded and plotted as per DOF methodology. The analysis of result obtained has been performed according to the standard procedure recommended by Taguchi.

3. ANALYSIS

The analysis part of the experimental results is performed by using Taguchi Approach.

a) S/N RATIO

The S/N ratio obtained by using Taguchi Approach. Here the term SIGNAL represent the desirable value (mean) and NOISE represent the undesirable value. Thus S/N ratio represents the amount of variation present in the performance characteristics.

- For the Deposition Rate the Larger is Better S/N ratio corresponding to different experimental runs has been tabulated in the table along the mean value of deposition rate.
- For Hardness the Larger is Better S/N ratio was also applied for transforming the raw data. The variation for the different experimental run has been tabulated in the table.
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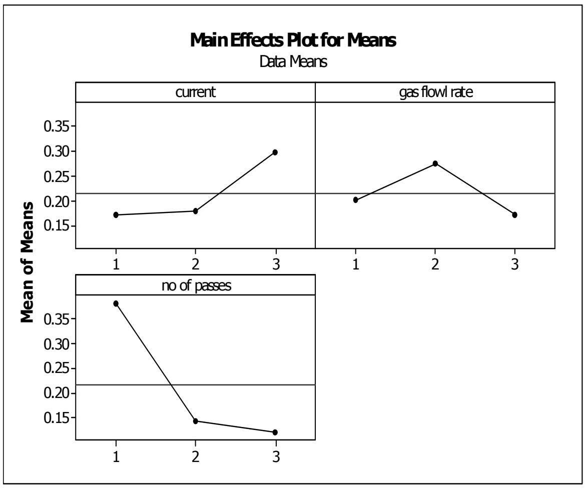
b) MAIN EFFECT DUE TO PARAMETERS

The main effect can be studied by the level average response analysis of mean data and S/N ratio. The analysis is done by averaging the mean and S/N data at each level of each parameter and plotting the value in graph. The level average response from data helps in analyzing the trend of performing characteristics with respect to variation of the under study.

Table: 1.2 Test Data for Hardness

Experiment No	Hardness		Hardness Mean Value	Hardness S/N Ratio
	1st Run Mean Value	2nd Run Mean Value		
1	39.84	39.50	39.67	31.97
2	42.70	44.50	43.60	32.78

3	47.74	48.86	48.30	33.68
4	45.26	44.16	44.71	33.01
5	43.40	43.86	43.63	32.80
6	33.20	34.98	34.09	30.64
7	43.36	43.22	43.29	32.73
8	35.54	36.10	35.82	31.08
9	44.28	43.62	43.95	32.86
Average			41.90	32.39
Maximum	47.74	48.86	48.30	33.68
Minimum	33.2	34.98	34.09	30.64



Effect on Hardness

It can be seen from the figure that the current and no. of passes are the most significant factor that are affecting the hardness. The different input parameters used in the experimentation can be ranked in order of increasing effect as current, gas flow rate and no. of passes. From the figure it is conclude that gas flow rate effect less to hardness as compared to effect of current and no. of passes. It can be concluded that with increase in current their decreases in hardness. It was observed that increasing the welding current caused the decreasing in mechanical properties of welded metal. These phenomena can be related to metallurgical behavior of weld melt during solidification and chance of formation the defects in different conditions of welding. It related when increasing in arc voltage and welding current or reducing in welding speed increases the welding heat input. With increasing the input energy, grain size in welded microstructure increases and grain boundaries are reduced in the background. Reduction in grain boundaries as locks for movement of dislocations, increases possibility and amount of dislocation movement as line defects in structure. It will cause a reduction in strength and hardness of welded metal. In graph plotted of no. of passes versus hardness, we can see there is increase of

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hardness with increase in no. of passes. This result can be compared to the phenomenon that melting metal is settled in weld zone layer by layer with shielding layer in between so that a good strength weld is formed

4. Conclusion

Current and no. of passes significantly affected on the hardness of the weld bead. It was observed that increasing the welding current caused the decreasing in mechanical properties of welded metal. These phenomena can be related to metallurgical behavior of weld melt during solidification and chance of formation the defects in different conditions of welding.

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