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OPTIMIZATION OF MECHANICAL PROPERTIES OF FRICTION WELDING PARAMETERS OF AUSTENITIC STAINLESS STEEL (AISI 316) RODS USING DESIGN OF EXPERIMENTS CONCEPT

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ABSTRACT

Austenitic stainless steel (AISI 316) plays a wide range of applications in the area such as food processing, chemicals, cryogenics and heat exchangers. In friction welding process the joints are formed in the solid state by utilizing the heat generated by friction. The objectives of this experimental investigation on friction welded joints of Austenitic stainless steel rods and predict optimum parameters of friction welded joints. The welded joints are produced by varying Friction pressure (Fp), Forge pressure (Up) and forging time (Fg_t) considering speed at constant rate. Parameters optimization of mechanical properties such as Hardness values and ultimate strength are analyzed by S/N ratio and analyzed by ANOVA techniques. The results of the friction welding parameters are increasing the Hardness values and decrease the ultimate strength by increasing friction time.

Keywords*: Austenitic stainless steel, Friction welding, welding parameters, ANOVA, optimization.*

1. Introduction

Friction welding is a solid state joining process that produces coalescence by the heat generated between two surfaces by a mechanically induced rubbing motion[1.2] The friction welding process can be considered as a series of sequential stages. Stage 1: heat is generated by sliding friction and the torque reaches its maximum value. Stage 2: heat is generated by mechanical dissipation in the plasticized material and softened material flows radially outward. Stage 3: a steady state situation is attained and the torque, temperature distribution and rate of axial shortening (burn-off) are essentially constant. Stage 4: the rotation terminated. Stage 5:upsetting occurs. Friction welding has a number of advantages over other welding processes and Opportunity to join without weld defects, thus producing joints with strengths matching to that of the base metal material. The input variables that control the joints are Heating Pressure (HP), Heating Time (HT), Upsetting Pressure (UP) and Upsetting Time (UT). The output variable is tensile strength.The identification of joining problem for austenitic stainless steel (AISI 316) which cannot be tackled using conventional technique because of following problems such as. Liquid Cracking, Weld Solidification, Low weld efficiency, Transformation induced plasticity. The above problems are to be overcome by using austenitic stainless steel AISI 316 rods are to weld solid state Friction welding process and optimized. [3,4] investigated the effects of the parameters such as rotation speed, friction pressure, and forging pressure in friction welding methods for steel. [5,6] investigated the mechanical and the metallurgical properties of dissimilar materials (Al-Cu) welded by friction welding.[7,8] illustrates the mechanical properties of similar friction welded joints.[9,10] Investigation on the continuous drive friction welding process of similar joints and predict high tensile strength. [11,12] explains the mechanical properties of similar material weld joints in friction welding process parameter and optimization using a statistical approach. In this experimental study carried out on similar material (AISI 316) with the same diameters (12mm).

2. Experimental Details

In this Experimental study, Austenitic stainless steel (AISI 316)rods are used for friction welding process which contains chemical composition of Cr 18,Ni 14,Mo 3.0,S 2.0,Si 0.75,C 0.08,P 0.045 in weight percentage. Cylindrical test specimens of 20mm diameter and 100mm length were prepared for friction welding. Before friction welding the surfaces of specimen, facing operation was performed in the centre

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lathe. Joining of Two similar materials are performed on a continuous drive friction welding machine (KUGA – Germany) at Welding Research Institute of BHEL, Trichy(Fig 1).

Friction welding parameters are Friction pressure (100Mpa,125Mpa,150Mpa),Forging pressure (140 Mpa,180Mpa,220Mpa) and Friction time (3sec,5sec,7sec),Hardness test are conducted in Vickers's Hardness Machine to determine the Hardness of Joints. Tensile specimens are prepared as per ASTM standard and ultimate tensile strength and Yield strength are measured (Fig 2).

Fig. 1 KUGA –Friction welding (Germany)

Fig. 2 Friction Welding Joints

3. Methodology

- The major steps involved in Design of Experiments
- State the problem.
- State the objectives of experiments.
- Select the quality characteristics of measurement system.
- Select the factors that may influence the selected quality characteristics.
- Identify quality and noise factors.
- Select levels for the factors.
- Select appropriate orthogonal array(L-array)
- Select interactions that may influence the selected quality characteristics.
- Assign factors to orthogonal arrays & locate interactions.
- Conduct the tests described by trials in orthogonal array.
- Analyze and interpret results of the experimental trails.

Table 1. L_9 Orthogonal Array

Test No.	Friction Pressure	Forge Pressure	Friction time
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 2. Friction welding parameters

Test No.	Friction pressure Mpa	Forge pressure Mpa	Friction time Sec
1	100	140	7
2	100	180	5
3	100	220	3
4	125	140	5
5	125	180	3
6	125	220	7
7	150	140	3
8	150	180	7
9	150	220	5

3.1 Conduct confirmation experiment.

Taguchi Design of Experiments

Taguchi method is a powerful tool in quality optimization makes use of a special design of orthogonal array (OA) to examine. Number of experiments used to design the orthogonal array for 3 parameters and 3 levels of welding parameters (Table 2)

Minimum experiments = [(L-1)X p]+1

= [(3-1)X 3]+1 = 7 ≈ L9

4.1 Hardness test

Vickers hardness test were conducted across the cross sections of friction welded joints and hardness values were tabulated in the table 3.It shows that increase in hardness at the joint may be attributed to the heating of materials at the weld region. This result indicates the hardness increases with increases in friction pressure for all specimens are considered and increasing hardness in the weld surface.

4. Result and Discussion

Table 3. S/N ratio for hardness values of friction welding parameters

Friction pressure Mpa	Forge pressure Mpa	Friction time Sec	Hardness Value (VPN)	S/N Ratio
100	140	7	210	46.444
100	180	5	214	46.608
100	220	3	218	46.769
125	140	5	235	47.421
125	180	3	238	47.531
125	220	7	210	46.444
150	140	3	253	48.624
150	180	7	255	48.130
150	220	5	240	47.604

Table 4. ANOVA for Hardness values of Friction welding parameters of AISI 316 joints

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	1904.67	1904.67	952.33	11.57	0.080
B	2	278.00	278.00	139.00	1.69	0.372
C	2	194.67	194.67	97.33	1.18	0.4580
Error	2	194.67	194.67	82.33		
Total	8	2542.00				

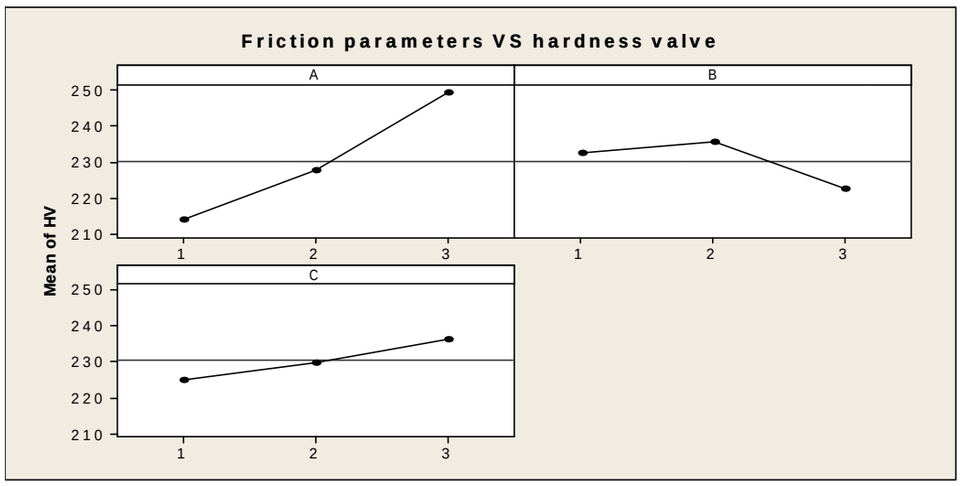


Fig 3 Main effect plot for Hardness values of Friction welding parameters

The figure 3 represents Hardness values of Austenitic stainless steel rods are high at level 3 (150Mpa) in friction pressure and Forge pressure at level 2 (140 Mpa) and Friction time at level 3(3 sec) for friction welded process. It is indicate that optimum parameters of friction welded joints of AISI-316 rounds are 150 Mpa for friction pressure, 140Mpa forge pressure and 3 sec for Friction time. Hence Friction pressure plays an important role in increasing Hardness value in friction welding process.

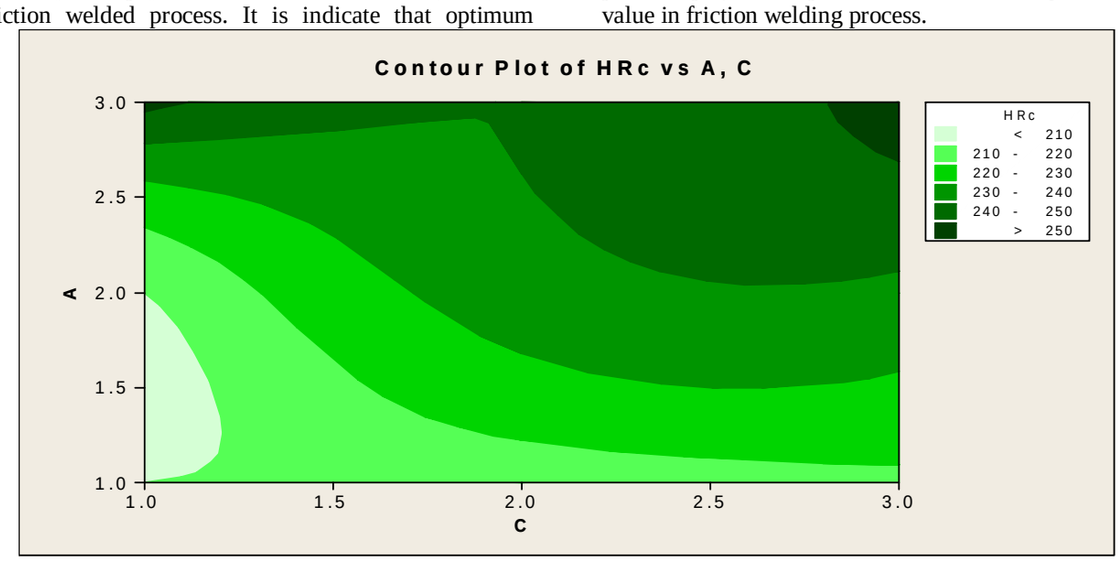


Fig 4 Contour plot for Hardness value of friction welding parameters

The figure 4 shows the graphical representation of 3 dimensional relations between Friction pressure and friction time of friction welding process along with hardness values.It Indicates level 3 of friction pressure are greatly influence hardness values. The hardness values are high as it posses minimum at intersection of Fusion zone. Hence friction pressure and friction time are interact the welding parameters in friction welding process.

4.2 Tensile test

Tensile test was conducted in universal testing machine and Ultimate tensile strength were tabulated in Table 5.This result shows that the joint strength decreased with increasing friction time. It may noted that UTS and Yield strength increased by friction pressure and axial shortening. The effect of friction time and friction pressure increases contact areas are also significantly increases and heat is generated. Hence friction time is a dominating parameter on friction welding process.

The effect of friction time and friction pressure increases contact area also significantly increases and heat generation in welded joints. The Friction time is a dominating parameter in ultimate tensile strength. As the temperature of bonding interfaces directly related to mechanical properties of welded joints and prior knowledge can optimized the process parameters.(Table 6)

The joint have the highest tensile strength in 100Mpa for friction pressure and 220 Mpa for forge pressure and 3sec for friction time and get 620 Mpa for ultimate tensile strength and joint strength increased with an increasing friction time. It can be understood that the joints had experienced on ductile mode of fracture with shear flow of material. However the plastic deformation does not peak temperature at the bonding interface the welding region.

The figure 5 shows the main effects of friction welding parameters in different levels. The maximum values of UTS in Level 1 of friction pressure, Level 3 of Forge pressure and Level 3 of friction time. Ultimate strength is increased with an increasing friction pressure along with friction time. Axial shortening is increasing with increasing friction time and friction pressure due to increasing heat and plastic deformation region increases from the central and peripheral region because this region experienced more severe plastic deformation and reaches high temperature. The figure 6 shows the graphical representation of 3 dimensional relations between Forge pressure and friction time of friction welding process along with Ultimate tensile strength and Indicate level 3 of friction time are greatly influence of Ultimate tensile strength. The effect of friction time increases contact area also significantly heat generation

of interfaces created and in return flash is formed. Hence friction pressure and friction time are interact the welding parameters in friction welding process.

Table 5. Tensile strength values of Friction welding parameters

Test No	Friction pressure (Mpa)	Forge Pressure (Mpa)	Friction Time (sec)	Yield strength (Mpa)	Ultimate strength (Mpa)
1	100	140	7	265	546
2	100	180	5	273	590
3	100	220	3	286	620
4	125	140	5	255	580
5	125	180	3	280	600
6	125	220	7	237	548
7	150	140	3	255	560
8	150	180	7	280	545
9	150	220	5	260	590

Table 6. Rank of Friction welding parameters

Level	Friction Pressure	Forge pressure	Friction time
1	55.34	54.99	54.73
2	55.19	55.24	55.37
3	55.04	55.33	55.46
Delta	0.30	0.34	0.72
Rank	3	2	1

Table 7. Ultimate tensile strength for friction welding parameters

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	620.2	620.2	310,1	1.31	0.433
B	2	840.2	840.2	420.1	1.77	0.360
C	2	4056.9	4056.9	2028.4	8.57	0.105
Error	2	473.6	473.6	236.8		
Total	8	5990.9				

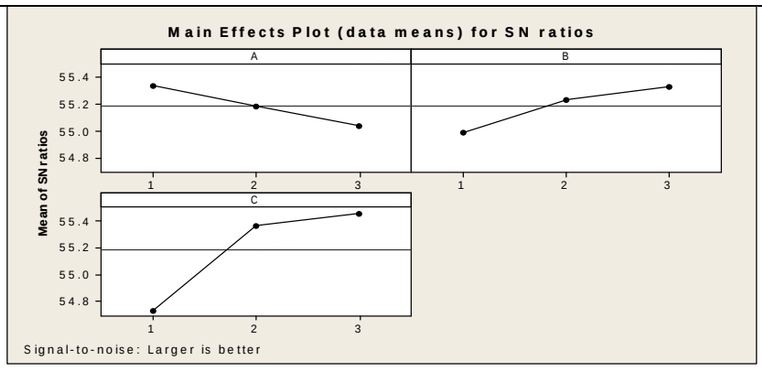
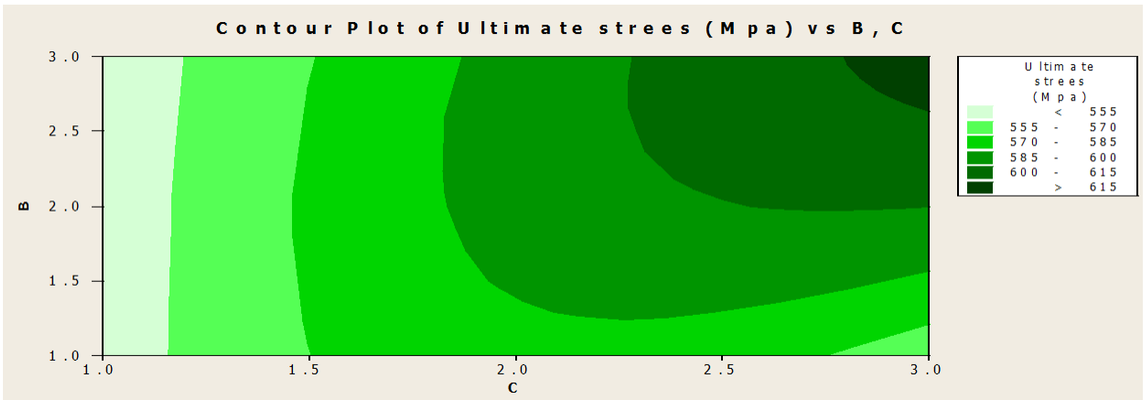


Fig. 5 Main effect for Ultimate tensile strength



5. Conclusion

The feasibility of friction welding of Austenitic stainless steel welding the characteristics of weldabilty property, Hardness value and Tensile strength of welded joints were investigated. The main conclusions are summarized as follows

(i)Friction welding can be used successfully to joint Austenitic stainless steel rods (AISI316) .The processed joints exhibited better mechanical property as compared to those made with fusing welding Technique.

(ii) The axial shortening exponentially increased by increasing friction pressure and friction time and plays an important role in Hardness and Ultimate strength of Austenitic stainless steel (AISI 316) rods.

(iii) The optimum parameters of High Hardness value of Austenitic stainless steel rods are 140Mpa for friction pressure, 150Mpa for forge pressure and 3Sec for friction time.

(iv) The optimum parameters of high Tensile strength of Austenitic stainless steel rods are 100Mpa for friction pressure, 220Mpa for forge pressure and 3Sec for friction time.

(v)Austenitic stainless steel rods of Welded joints provide good strength and better ultimate strength and improve toughness after welding process.

References

1. *Insu Woo, Masatoshi Aritoshi and Yaswshi Kikuchi (2002), "Metallurgical and mechanical properties of high nitrogen austenitic stainless steel friction welds", ISIJ International, 401.*

2. *Lippold JC and Odegard BC (2003), "Micro structural evolution during inertia friction welding of austenitic stainless steels", Welding Journal, 35.*

3. *Mortensen K S, Jensen C G, Conrad LC, Losee F (2001), "Mechanical properties & microstructures of inertia friction welded 416 stainless steel", Weld J November:268S–273S.*

4. *Sahin M and Erol Akata H (2003) Joining with friction welding of plastically deformed steel. J Mater Process Technol 142(1), 239–246.*

5. *Murti K G K, Sundarasan S (1983), "Parameter optimization in friction welding of dissimilar materials" Met Constr 15(6):331–335.*

6. *Nicholas E D (1999), "Friction Welding: An introduction to process, Exploiting friction welding in Production", The welding Institute, London, 1–9.*

7. *Sketchly P D, Threadgil P L and Wright I G (2002), "Rotary friction welding of an Fe3Al based ODS alloy", Mater Sci Eng A329-331:756–762.*

8. *Yilbas B S, Sahin AZ, Kahraman N and Al-Garni AZ (1995), "Friction welding of steel - Al and Al-Cu materials", J Mater Process Technol 49(3,4):431–443.*

9. *Meshram S D, Mohandas T and Reddy G M (2007), "Friction welding of dissimilar pure metals", J. Mater. Proces. Techn. (184), 330–337.*

10. *Yabharath K, Ashfaq M, Veugopal P and Achar D R G (2007), "Investigations on the continuous drive friction welding of sintered powder metallurgical (P/M) steel and wrought copper parts", Materials Sci. & Eng. A 454: 114–123.*

11. *Ozdemir N, Sarsilmaz F and Hascalik A (2007), "Effect of rotational speed on the interface properties of friction-welded AISI 304L to 4340 steel", Mater. & Design 28: 301–307.*

12. *Takeshi S, Hoshinu K and Yamashita R (1994), "Effect of friction welding parameters on mechanical properties of cast iron joints", Q J Japan Weld Soc 12(3) 328–33.*

