Parametric Effects on Mechanical and Metallurgical Properties of Rotary Friction Welded UNS S30400 & UNS S31803 Tubes

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Abstract- Welding industry has been continuously facing challenges when it comes to improving productivity, efficiency, and quality of the products being manufactured. There is limitation in conventional welding because most metal combinations are not compactible when using conventional method. One of the factors that make rotary friction welding popular among manufacturers is its unique ability to join dissimilar metals. Both Austenitic stainless steel(ASS) and Duplex stainless steel (DSS) have mainly used in the area of natural gas pipe lines and oil, marine etc. because its enhanced corrosive resistance and good strength. In the present study, the dissimilar welding of AISI 304 and AISI 2205 pipes were carried out by rotary friction welding process. The welded joints were created by changing friction pressure, friction time, upset pressure and upset time while rotational speed was kept as constant. The dissimilar welded specimens were characterized through tensile test and microstructure examination. And also examine the optimized welding parameter by using design of experiments (DOE). From DOE the parameter effects were analyzed using ANOVA and it was shown that upset pressure and friction time has greater influence over tensile strength. The mixture of fine re-crystallized grains were observed in the weld zone and finer deformed grains were observed in partially deformed zone.

Keywords: Rotary friction welding, Dissimilar welding, Austenitic stainless steel, Duplex stainless steel, Design of experiment, Micro-examination.

I.INTRODUCTION

The friction welding quality is much higher than conventional fusion welding process. The variation in the friction welding parameters directly affect the weld strength. The optimization of friction welding parameter is required for getting higher strength. Weld geometry is also studied for getting higher bonding strength and high quality weld [1]. From the observations made, it can be summarized that the Rotational speeds is the major factor affecting the tensile strength among the varients of Stainless steel materials (higher tensile strength is obtained with increase in rotational speeds) [2]. Duplex stainless steel showed that heating time, upset load are the effective parameters and it was found that heating time has the greater influence on the joint strength [3]. It also revealed that the hardness of the weld metal zone was less than that of the base metal zone. It also showed that the joint strength decreased with an increase in the friction time [4]. The ultimate tensile value of weld joints expanded among increment in rubbing time and forge stress values till it reaches at its critical point and further increment prompts decrease of tensile [5]. Austenitic stainless steel concluded that Rotary Friction welding decreases the grain size of the material at the weld joint eventually increasing its tensile strength, hardness of the material and breaking load [6]. It has been observed that if the diameter and rotational speed increases, tensile strength also increases. They also found that from the thermal analysis, the stresses generated because of temperature distribution along weld specimen [7]. The ductile mode in pin type for all cases while both, brittle and ductile mode in the flat joint was noticed. Finally, it was concluded that the impact strength improved with designing a pin and hole shape at the joint interface [8]. The joint strength increased with increase in upset load and heating load. The detailed fracture analysis reveals the weld sample joints had experienced a ductile mode of fracture at parent metal location. The microstructure analysis revealed coarse grain structure in the weld zone compared to base metal [9]. Among the welding parameters, the friction pressure and forging pressure were found to be more influencing over hardness and tensile strength properties [10].

From the above literatures, there are many studies on welding different stainless steel plates or rods using conventional joining process. But the study on dissimilar weld of austenitic and duplex grades using solid state welding processes were less studied. In this study the dissimilar stainless steels are welded by rotary friction welding process using design of experiments.

II.MATERIALS AND METHOD

2.1 MATERIALS

The material composition and mechanical properties are shown in table 1, table 2 and table3.

Table 1 Chemical Composition of UNS S30400

C%	Si%	Mn%	P%	S%	Cr%	Ni %	N%	Fe%
0.054	0.98	1.67	0.036	0.024	18.2	8.2	0.1	Rem.

Table 2 Chemical Composition of UNS S31803

C%	Si%	Mn %	P%	S%	Cr%	Ni %	N%	Mo %	Fe%
0.026	0.84	1.20	0.030	0.02	21.7	4.8	0.14	3.2	Rem.

Table 3 Mechanical Properties

PROPERTIES	UNS S30400	UNS S31803
Tensile Strength	700 Mpa	900 Mpa
Hardness	215 Max HB	32 HRC

2.2 METHOD

The welding method chosen here is rotary friction welding. At present, AISI 304 with AISI 2205 are welded using rotary friction welding as per welding parameters. The experimental data is shown in the table. So the welding is done as per the experimental data. The most important parameters in friction welding are friction load, forging load, friction time and forging time. The components are brought together under axial friction pressure for a certain friction time. Then, the drive is closed and the rotary component is quickly stopped while the axial pressure being increased to a higher forging load for a predetermined time, forging time. The below given table shown that design matrix by using Taguchi method for dissimilar Austenitic-Duplex stainless steel.

Table 4 Design matrix

Exp. No.	Friction Load Fr_L (Mpa)	Forging Load Fo_L (Mpa)	Friction Time Fr_t (sec)	Forging Time Fo_t (sec)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

AISI 304 and AISI 2205 tube with dimension of 33mm outer diameter and 3 mm thickness is cut into 18 pieces with the length of 80mm. Cutting takes place by using abrasive cutting wheel and all the samples are subjected to facing operation in lathe machine on both sides for better surface finishing. 9 specimens were prepared under different friction load and forging load along with friction time and forging time. The rotational speed was kept as constant.

Table 5 Welding Parameters

Exp. No.	Friction Load Fr_L (Mpa)	Forging Load Fo_L (Mpa)	Friction Time Fr_t (sec)	Forging Time Fo_t (sec)
1	116	116	12	1
2	116	122	14	2
3	116	128	16	3
4	122	116	14	3
5	122	122	16	1
6	122	128	12	2
7	128	116	14	2
8	128	122	12	3
9	128	128	14	1

Fig 1: Welded Samples

III. RESULTS AND DISCUSSION

3.1 TENSILE TEST

The specimens undergone for the tensile test and finally the results of the tensile test have been listed below on table and ASTM Standard A370 for proper tensile testing machine.

Table 6 Tensile test results for welded specimen

Exp. No.	Tensile strength for dissimilar SS 304 – SS 2205
1	569
2	584
3	534
4	562
5	540
6	502
7	586
8	602
9	622

Fig 2: Tensile test of welded samples

From the tensile values it is established experiment no.9 has highest strength regarding 622 MPa this is because of effect of high upset pressure & heating time. Experiment no.6 has minimum value of about 386 MPa because of lesser upset pressure.

3.2 OPTIMIZED PARAMETER

From the DOE calculated values and the experimental values, optimized parameters of dissimilar UNS S30400 – UNS S31803 tubes were found out.

Table 7 Optimized Parameter

Welded Samples	Friction Load Fr_L (Mpa)	Forging Load Fo_L (Mpa)	Friction time Fr_t (sec)	Forging time Fo_t (sec)
Austenitic-Duplex SS	128	128	12	3

3.3 MICROSTRUCTURE EXAMINATION

Here we have used the equipment optical microscope with a magnification of 100X. The microstructure was taken only for weld zone which is welded using low, high and optimized parameters. The explanations behind the development of various microstructures can be summarized as uneven friction heat distribution and differences in deformation behavior of UNS S30400 and UNS S31803 materials.

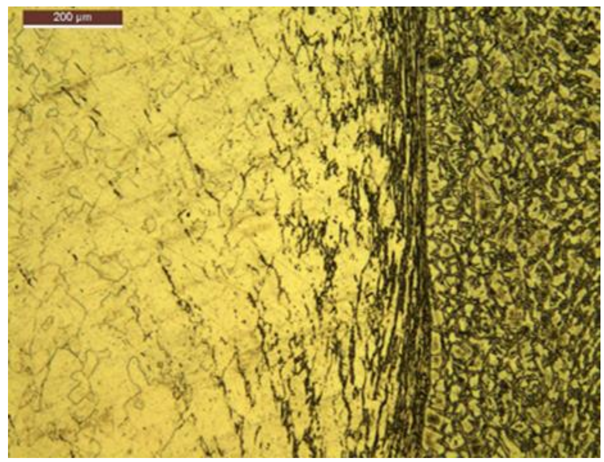

Fig 3: Microstructure for Joint with least strength

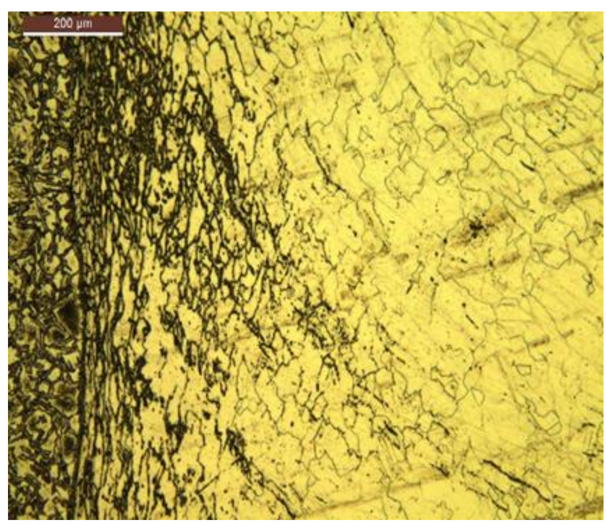

Fig 4: Microstructure for Joint with high strength

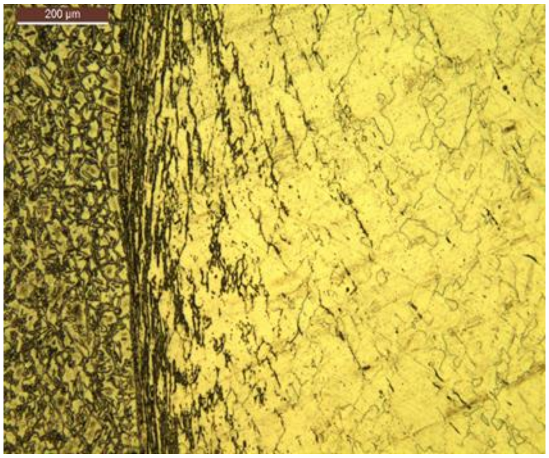

Fig 5: Microstructure for Joint with optimized parameter

The microstructure of weld zone dissimilar metal Austenitic-Duplex stainless steel shows the structure of fine grains of austenite and ferrite respectively. It was shown that the structure of the mixture of the fine re-crystallized grains. Compared to low, high parameter weld zones, optimized weld zone showed clear mixed zone. The strength and hardness were increased due to grain refinement in Weld zone and partially deformed zone.

IV. CONCLISION

The impact of forging pressure and friction pressure on the tensile strength and microstructure of dissimilar metal joints were evaluated and based on the experimentation & optimization the following conclusions are stated:

- The joining of dissimilar UNS S30400 and UNS S31303 was successfully done using design of experiments (DOE).
- The tensile strength value of welded materials increases with increase in upset pressure. It was found that upset pressure and heating time has the greater influence on the joint strength.
- From the optical micrograph examination, fine grains of austenite and ferrite were observed. And also the mixture of fine re-crystallized grains were observed in the weld zone.

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