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Research Paper

INTEGRAL APPROACH OF WELDING PROCESS PARAMETER ON STEEL FE410A USING FRICTION STIR WELDING

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This paper presents a systematic approach to develop the Quantitative prediction effect of (FSW) friction stir welding process parameter such as tool rotational speed, welding speed, and axial force on Mechanical Properties of Steel FE410A to know the acceptable limit. The Conducted experi-ments can be predict the moderate process parameter justify the Steel FE410A for friction stir weld-ing in tensile strength and yield stress. Higher and lower speed failure in mechanical properties. Earlier welded samples failed in regions corresponding to the base metal and demonstrated yield and ultimate tensile strengths comparable to those of the base metal for hot rolled mild steel AISI 1018 at travel speed 042 to 1.68 mm/sec. Ultimate tensile strength were measured for friction stir weld of steel FE410A with the help of universal testing machine. Hardness of weld were examined using the Vickers hardness testing machine. Crack propagation is evaluated with the notch tough-ness test using Izod test.

Keywords: Stir welding, Process parameter, Mechanical properties, Steel FE410A

INTRODUCTION

In a Past it has realize that weld may contain residual stress and distortion that can promote to weld failure In later part, methods to identify the significance of weld defects to the end fracture It has often being question to test the failure due to defects .one technique was develop wide plate test credited by well (1956) The pure tensile loading and the residual welding stresses contained in the large sample make the wide plate test more structurally relevant than a CTOD test. This wide plate test used for testing of curved plate. This technique known as curved wide plate test. CWP testing for stress-induced applications was normally used through the 1990s. This paper focus CWPT results by traditional testing methods Elastic-plastic Finite Element Analysis (FEA)

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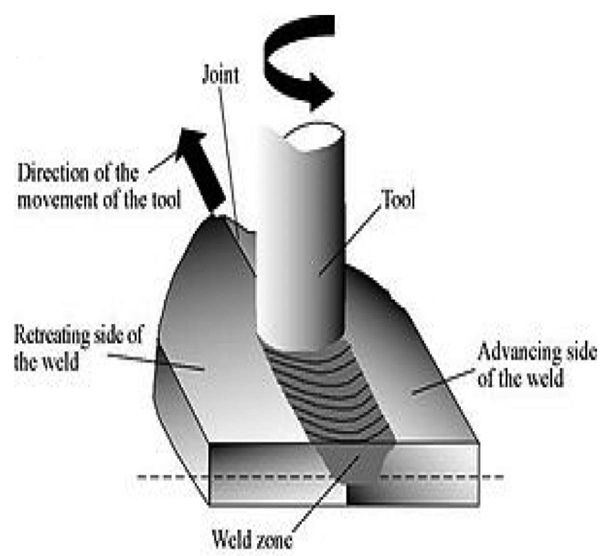
was used to model these CWPT to better understand post yield strain distributions. This aided in CWPT specimen design for testing higher-strength steels. Unloading Compliance (UC) was used in combination with FEA to assess defect tearing. Acoustic emission was used to monitor cracking noncontact photographic measuring system was used to quantify surface strains, and these results were compared to FEA predictions. The volume of data collected in these tests, along with the FEA, has generated a sufficient data and analysis is ongoing.

Friction-Stir Welding (FSW) is a solid-state joining process (the metal is not melted) and is used when the original metal characteristics must remain unchanged as much as possible. It mechanically intermixes the two pieces of metal at the place of the join, then softens them so the metal can be fused using mechanical pressure, much like joining clay, dough, or plasticize. It is primarily used on aluminium, and most often on large pieces that cannot be easily heat-treated after welding to recover temper characteristics. The solid-state nature of FSW leads to several advantages over fusion welding methods as problems associated with cooling from the liquid phase are avoided. Issues such as porosity, solute redistribution, solidification cracking and liquation cracking do not arise during FSW. In general, FSW has been found to produce a low concentration of defects and is very tolerant of variations in parameters and materials. The FSW process is applied presently for welding aluminum and magnesium alloys as well as copper, steel, composites and dissimilar materials.

EXPERIMENTAL WORK

Test plate of steel size 100 mm × 50 mm × 6 mm are prepared from steel rolled plate using Cutting machine. The Chemical Composition and mechanical properties of base material are presented in Tables 1 and 2 experiment is conducted using FWS Machine shown in Figure 1.

Figure 1: Friction Stir Welding



The plunge depth is defined as the depth of the lowest point of the shoulder below the surface of the welded plate and has been found to be a critical parameter for ensuring weld quality (Su *et al.*, 2006). Plunging the shoulder below the plate surface increases the pressure below the tool and helps ensure adequate forging of the material at the rear of the tool. Tilting the tool by 2-4 degrees, such that the rear of the tool is lower than the front, has been found to assist this forging process. The plunge depth needs to be correctly set, both to ensure the necessary downward pressure is achieved and to ensure that the tool fully penetrates the weld. Given the high loads required, the welding machine may

Table 1: Mechanical Properties of Steel

Type of Steel		Ultimate Tensile Strength (MPa)	Yield Strength Thickness	Elongation Guage	Charpy V Notch Values Joules (min)
Standared Structural Steel	Fe 410A	410	250 for 20 mm Thickness	23	27
Standared Structural Steel	Fe 410A	410	240 upto 40 mm Thickness	23	27
Standared Structural Steel	Fe 410A	410	230 Greater than 40 mm Thickness	23	27

Table 2: Chemical Composition of Material

Chemical Composition	
Constituent	**Percent**
Carbon, Max.	0.160
Manganese, Min	0.300
Silicon, Max.	0.250
Sulphur, Max.	0.030
Phosphorous, Max.	0.030
Aluminium, Min	0.020

deflect and so reduce the plunge depth compared to the nominal setting, which may result in flaws in the weld. On the other hand, an excessive plunge depth may result in the pin rubbing on the backing plate surface or a significant under match of the weld thickness compared to the base material. Variable load welders have been developed to automatically compensate for changes in the tool displacement while TWI have demonstrated a roller system that maintains the tool position above the weld plate.

Scientific Approach of Analysis

Research work is to carried out in a certain procedure:

- Workout important process parameter.
- Apply the statistical control method for the process parameter viz., tool rotational speed (N), welding speed (S), axial force (F).
- Implementation of design structure.
- Conduct the welding process as per design structure.
- Recording the response of ultimate tensile strength, yeild strength, percentage elongation, hardness, bend.
- Construction of mathematical model.
- Cheking the accuracy of model by comparing the standared data.
- Conducting the confirmation of test result and compare with output.
- Presenting the effect of process parameter on mechanical properties on graphical view and synthesis the result.

Identifying the Important Process Parameter

Based on preliminary trials, the independent process parameters affecting the mechanical properties were identified as: tool rotational speed (N), welding speed (S) and axial force(F), hardness and bend.

Application of Statistical Control Method

To know the effect of process parameter on the mechanical properties of weld plate which has been by different methods practically runs are conducted to find the upper and lower limit of process parameters, by varying one of the parameter and keeping the rest of them at constant values. Feasible limits of the parameters were chosen in such a way that the joint should be free from visible defects shown in Figure 3. The upper limit of a factor was coded as +2 and lower limit as –2. The intermeterate coded values being note.

Development of Design Construction of Friction Stir Welding

Selected design matrix consist of three parameter used for 20 experimental runs allowed to know the the effects of process parameter on mechanical properties experiment were conducted randomly to avoid the systematic error encounter in the system.

Evaluation of Experiment Result

Tensile test specimen are prepared at room temperature as per ASTM E8 standard shown in Figure 2 and transverse tensile properties such as ultimate tensile strength, yield strength, and percentage of elongation of the FS welded joints are evaluated using computerized UTM. For each welded plate, three specimens are prepared and tested. Figure 3 shows tensile specimen after fracture for three set of welds. The average values of the results obtained from those specimens are tabulated and presented in Table 3.

Figure 2: Typical Tensile Specimens

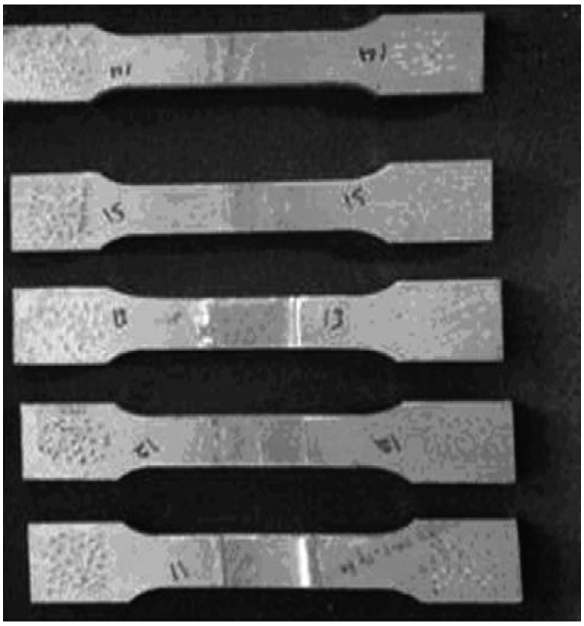


Figure 3: Tensile Specimen After Fracture

Table 3: Process Parameter and Its Stages

Parameter	Units	Symbols	–2	–1	0	1	2
Rotational Speed	rpm	N	450	500	550	600	650
Welding Speed	mm/s	S	0.4	0.5	0.8	1	1.4
Axial Force	KN	F	14.8	15.3	18.2	17.4	18.9

RESULTS AND DISCUSSION

Effect of Rotational Speed (N)

Strength of the material weld zone at values of the rotational speed of below 450 rpm and above 650 rpm, respectively. At lower rotational speed of 500 rpm, the heat required for softening the weld zone have not been achieved sufficiently, therefore these can lead in a failure of the weld strength. The good quality welding joint can be achieved with the proper melting temperature on the welding zone by applying the proper control compressive Axial force, rotational and welding speed. While, the low heat input in the welding zone result in insufficient softened materials that could cause to the porosity and low penetration, residual stress the more heat input result in the distortion of edges built up at the welding bead and also decrease the welding cross-section area. Therefore, improper heat input result in the decrease the tensile strength. The maximum strength of the weld zone was obtained at 500 rpm tool rotational speed. The tensile strength of the weld zone was determined to be 398 Mpa, is in the acceptable limit for steel when applying 650 rpm rotational speed, whereas the tensile strength of the base material 420 Mpa. crossing the design strength of material. The maximum tensile strength decreased when the rotational speed was dropped from 550 rpm to 450 rpm and when raised up to 650 rpm maximum tensile strength increased shown in Figure 4 and Table 4. High rpm is not suitable for Steel FE410A. In the weld zone the fine grained microstructure was observed and the tensile strength of the welded joint was found lower than that of the base material at high rpm It is obvious that the best macroscopic appearance was achieved in the weld joints produced with 500 rpm and 550 rpm rotational speeds. Due to low alloy high strength material. The columnar grain will form at 450 rpm rotational speed. Therefore, the calculated values of the tensile tests is slightly lower than the values of the tensile strength performed with 550 rpm. The lower and higher values of rotational speeds cause in sufficient

Figure 4: Effect of Rotational Speed

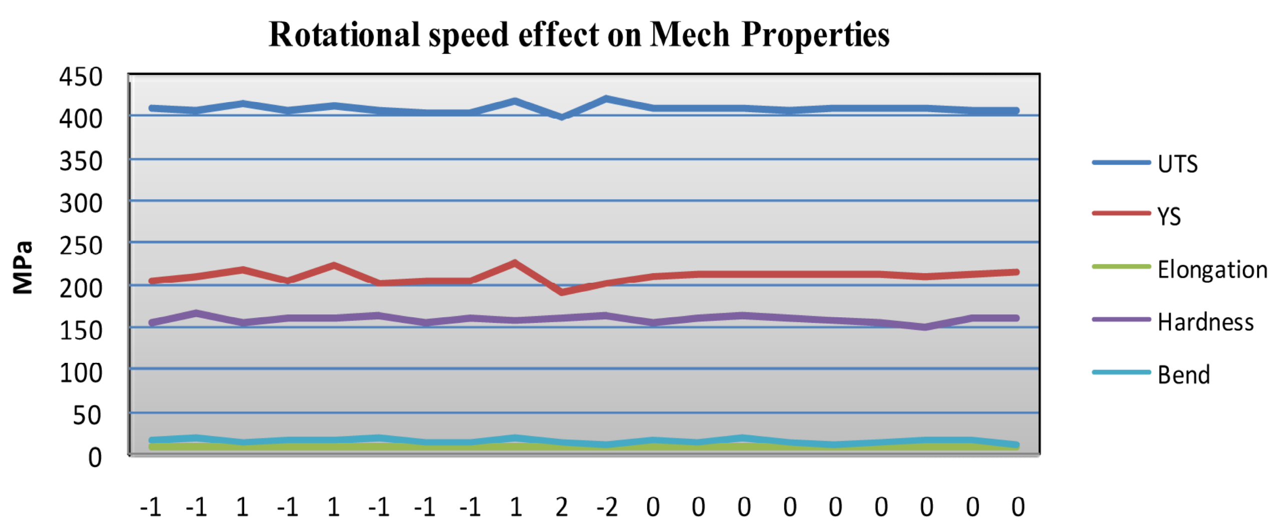


Table 4: Design Matrix and Estimated Mechanical Properties

Trial No.	Design Matrix					Estimated Mechanical Properties		
	FSW Process Parameter			MPA		VHN		%
	N(rpm)	S(mm/sec)	F(KN)	UTS	YS	Elongation	Hardness	Bend
1.	–1	–1	–1	408	206	7.2	155	17
2.	–1	1	–1	406	210	8.1	167	18
3.	1	–1	1	414	220	8.0	156	14
4.	–1	1	–1	406	207	7.4	162	17
5.	1	–1	–1	412	224	7.3	160	17
6.	–1	–1	1	407	204	8.2	165	19
7.	–1	1	–1	403	206	8.5	157	14
8.	–1	–1	1	404	206	8.7	160	15
9.	1	–1	–1	416	228	8.9	159	19
10.	2	0	0	420	192	8.5	161	14
11.	–2	0	0	398	202	8.0	164	13
12.	0	2	0	410	212	7.8	155	16
13.	0	–2	0	409	214	7.9	161	15
14.	0	0	2	409	215	7.9	163	18
15.	0	0	–2	407	213	8.8	161	15
16.	0	0	0	408	214	9.0	158	12
17.	0	0	0	408	215	8.5	156	14
18.	0	0	0	408	212	8.4	150	16
19.	0	0	0	407	215	8.4	161	17
20.	0	0	0	407	216	8.1	162	13

penetration and quality of the welding. The lower tool rotational speeds result in slight tendency for the elements C, Mn, Sito decrease (in the composition of the weld) when the heat input increase an insufficient grain orientation at base metal tends to random at base metal reduce the strength of base metal than weld zone.

Effect of Welding Speed

From the above figure it is indicate effect of welding speed on mechanical properties such as ultimate tensile strength seems to be failure in many trial runs, the material steel Fe410 A is not acceptable for friction stir welding at low speed or high speed, it is acceptable for moderate speed. Effect of welding speed was against the previous variables. Increasing the welding speed between 0.4 and 1.4 mm/sec caused the increasing the mechanical properties of weld metal. Lower and higher welding speed changes the various grain structures developed through a complex process including the rearrangement of low angle boundaries, continuous dynamic re crystalization and phase transformation. These phenomenon's can be related to metallurgical behavior of weld in thermo mechanically heat effected zone and shear texture in the SZ became considerably weak due to the phase transformation during the FSW process forming the defects in different conditions of welding. reducing in welding speed increases the welding heat input. With increasing the input energy, grain growth in weld microstructure increases and grain boundaries are reduced in background. Reduction in grains boundaries as locks for movement of dislocations, increases possibility and amount of dislocations movement as line defects in structure. It will cause reduction in strength and hardness of weld metal very low welding speed can increase the chance of defects formation such weld bead through in weld which affect on mechanical properties of weld Quality. increasing in welding speed decreases the welding heat input and chance of defects formation in weld metal. Thus, increasing the welding speed increases the hardness, yield strength and a significant decrease in and the rotational tool speeds result in an excessive heat generation. Both process conditions parameters cause insufficient penetration in the welding bead. Lower speed bit higher strength and hardness than the Base Metal and among the Stir Zone, these mechanical properties increase with increasing welding speed. The higher welding speed leads to smaller and grain sizes in the SZ. This is the reason why the strength and hardness are significantly affected.

Effect of Axial Load

Compressive force influences the welded strength of the joined parts. As shown in Figure 6, the change of compressive force from 5 to 7 kN leads to a sharp raise in the strength value from 273 Mpa to 479 Mpa and the change of compressive force from 7 to 9 kN leads to a drop the strength value from 479 MPa.

Hardness and Elongation is Influence by Process Parameter

Vickers micro hardness were made in mitutoya micro hardness tester employing 500 gm Load, variation of hardness from the various tool rotational speed and welding

Figure 5: Effect of Welding Speed

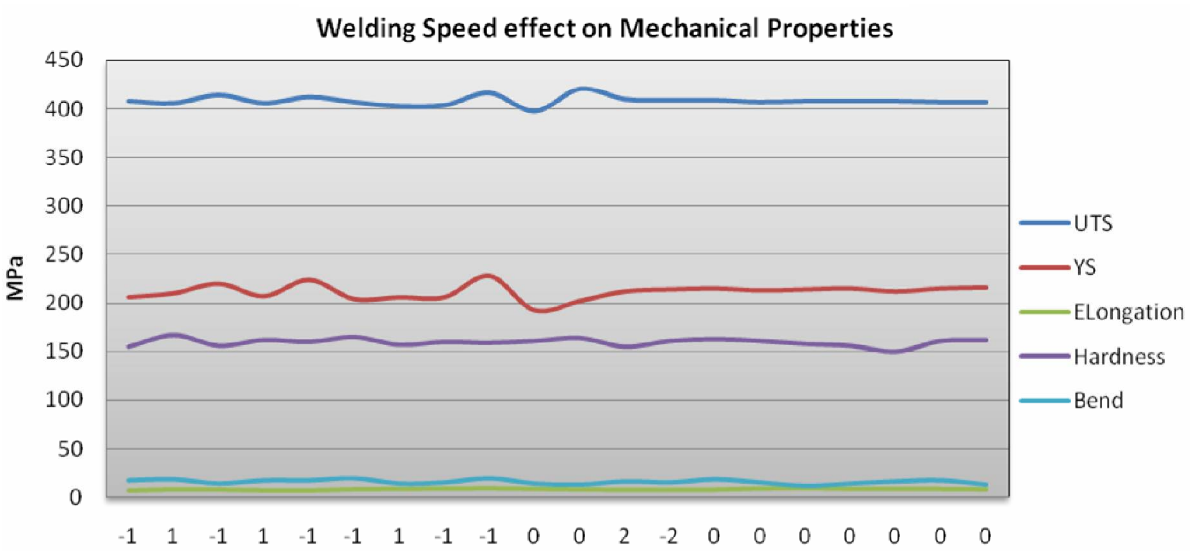
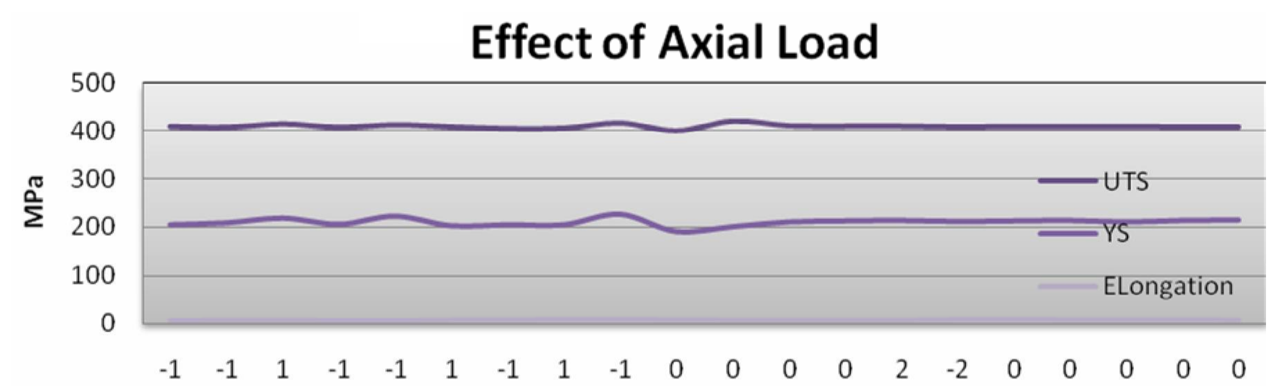


Figure 6: Effect of Axial Load



speed. It has observed that hardness decrease with increase in heat input, TRS at minimum rotational Speed and Welding speed at min range hardness become lower. Percentage elongation plotted against the welding speed and tool rotational speed shows maximum elongation at highest welding speed and lowest rotational speed. Heat influence is major factor effect on elongation.

CONCLUSION

It is observed from above figure tool rotational speed varies in range of maximum Control Limit and minimum Control Limit the ultimate tensile strength and yield strength is not exceed the maximum limit of specify for the material is 410 Mpa it is the acceptable range. As a result material steel Fe410A is acceptable for welding with use of friction stir welding, similarly yield strength is not crossing the maximum limit which is also in control limit for varying the rotational speed of tool between 450 rpm to 650 rpm. It is clear from diagram keeping the tool rotational speed at 550 rpm chance of failure of in tensile is less. Hardness is effected by Heat affected zone after FSW. Basically the hardness within the SZ is higher than in the base metal. Given the fact that the ratio is nearly uniform in all over the proûle, the increase of hardness. Experimental Data indicate Friction Stir welding is acceptable for steel FE410A but considerably risk of failure on yield stress and tensile failure, moderate speed can achieve a accptability of all mechanical properties which is integral approach of study.

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