Evaluation of quantitative and qualitative parameter involved in the frictional welding procedure of steel sample

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Abstract -- *Friction welding works on basic principle of friction. In this welding process, the friction is used to generate heat at the interference surface. In the present study, some of the quantitative and qualitative parameter involved in the frictional welding procedure of steel sample was determined. The results obtained suggested that the frictional welding is the best procedure for the welding of the steel sample.*

Keywords — *Friction, welding, steel, qualitative, quantitative*

I. INTRODUCTION

Friction welding works on basic principle of friction. In this welding process, the friction is used to generate heat at the interference surface. This heat is further used to join two work pieces by applying external pressure at the surface of work piece. In this welding process, the friction is applied until the plastic forming temperature is achieved. It is normally 900-1300 degree centigrade for steel. After this heating phase, a uniformly increasing pressure force applied until the both metal work pieces makes a permanent joint. This joint is created due to thermo mechanical treatment at the contact surface [1]. Friction welding is a solid state welding process. Solid state welding are those welding process in which no external heat is applied or no molten or plastic state involves. In this type of welding, welding occurs due to external pressure applied into the solid state. In friction welding process, both the plates or work piece to be joint are in either rotating or moving relative to one another. This relative movement produces friction which displaces material plastically on contact surface. A high pressure forced applied till completed the weld. This welding is used to joint steel bars, tubes up to 100 mm diameter. The application of the friction welding includes 1). For welding tubes and shafts. 2). It is mostly used in aerospace, automobile, marine and oil industries. 3). Gears, axle tube, valves, drive line etc. components are friction welded. 4). It is used to replace forging or casting assembly. 5). Hydraulic piston rod, truck rollers bushes etc. are join by friction welding. 6). Used in electrical industries for welding copper and aluminum equipment’s. 7). Used in pump for welding pump shaft (stainless steel to carbon steels). 8). Gear levers, drill bits, connecting rod etc. are welded by friction welding [2]. In the present study, the frictional welding was used for the joining of the steel sample materials and the parameters involved were determined for the determination of the efficacy of the frictional welding.

II. MATERIALS AND METHODS

Experimental design- Vertical Milling Machine as well as lathe machine may be used while friction welding. In case of my work Vertical Milling Machine was used for join the similar metal. There are two pieces of same material were used, mild steel.

Vertical Milling Machine – For Friction welding both vertical Milling Machine & Lathe both can be used. For this purpose Vertical Milling Machine (Fig. 2.1) was used because of its stability & less vibration as compared to Lathe machine.

Temperature Torch- Temperature during friction welding was noted down with the help of temperature torch (non-contactable). (Fig.2.2) Shows the Temperature torch.

Stop watch- Stop watch was also used to note down the weld time during friction welding.

Dial Indicator – A Dial Indicator with magnetic stand was used to note down burn off length during friction welding process.

Specimen Specifications-The following are the specifications which will be used: Diameter of specimen : 16mm and Length of specimen : 101mm (each)

Two cylindrical specimens of same size 16mm diameter & 101 mm lengths were used as shown in Fig.2.2

Sample Preparation
There are following steps for sample preparation:
Step1: Input: Lathe; Vernier Calliper; Cutting tools; Mild steel and mild steel
Step2: Cutting of 2 pieces of mild steel according to required length on band saw.
Step3: Fix the cutting tool on tool post & fix the piece of mild steel in rotating chuck on lathe
Step4: Turning of specimens to get the required diameter

Step5: Checking of required diameter with the help of Vernier caliper
Step6: If required diameter is attained then go to step 7 else
Step7: Sample is ready for welding and finish
Firstly mild steel rod having 16 mm diameter was cut into pieces of 101 mm Length (each) on lath. After cutting operation 16 mm diameter of both piece of mild steel having length 101 mm each was to be joined. It was found that the pieces did not join properly after running the setup for few minutes. So the pieces were turned on lathe to make 12 mm diameter from 16 mm diameter. It was found that the pieces could be joined well.

Variable Parameters
The following are the three parameters which have been varied

Revolutions per Minute: It is the revolutions of the rotating chuck in a minute. Revolutions can be set according to the requirement. Total of Eight experiments were done.

Burn off Length: It is the overall length loss of the specimens during the application of friction force & forges force. It can be original length minus length of welded component

Weld Time: Weld time is the overall time in which joint is obtained between the mild steel & Mild Steel.

Fixed Parameters
The following are the parameters that were kept constant throughout the experiment.

- Total length of the specimen: 202mm (101mm each)
- Diameter of the specimen: 12mm

Test Matrix
Three parameters Weld time, Burn off Length, RPM which have been varied at two levels and total number of specimens made for each experiment as shown in Table 2.1.

Complete Setup & Welding Procedure : One of the two specimens being welded (mild steel) was fixed in collets which were rotating at a given RPM while the other component (Mild Steel) was fixed which was tightened in a cast iron rectangular block with the help of a bolt. The function of cast iron material was to absorb vibration during friction welding. After setting the specimens in proper alignment machine was started and a vertical upward force was applied. Within 3 to 8 seconds flash was generated and within average 18-19 seconds specimens was welded. The generation of flash (Fig. 2.4) and weld time depends more on the force applied and RPM of the machine. A temperature torch (Fig. 2.4) was used to note down the temperature around the interface during friction welding. After welding machine was stopped and the samples were ready for testing.

Testing Of Friction Welded Specimens:
The specimen was tested by using universal testing machine shown in fig 2.5

Tensile testing: The tensile testing of friction welded specimens was performed on the Universal Testing Machine (Fig. 2.5)

Measurement of Temperature Profiles: Measurement of Temperature for every experiment was noted down with the help of a temperature torch (Non Contactable). On eight samples measurement of temperature was done in continuous manner after every two seconds from beginning to end of the weld. Most of the temperature reading was noted down from the interface of the weld at a distance of 40 to 50 mm. Temperature Torch (Non Contactable) was used for this purpose. The Table 2.5 shows the specimens used for temperature measurement for all experiments at different parameters.

Microstructure Examination: For Microstructure examination round specimens were made flat from two opposite sides on lathe machine. Than a Belt grinder with attached disc was used to grind the flat sides of the specimens (Fig. 2.6). Polishing of specimens were started with the help of rough emery paper after the completion of grinding process. For this purpose different grades of emery papers were used. Specimens were polished on different grades of emery papers viz. 100, 220, 320, 400, 600, 800, and 1000. After polishing etching of the specimens were done with the help of etching liquid. Etching contains 98% of water plus 2% of HNO_3.

Micro hardness Measurements: Micro hardness machine (Fig. 2.8) was used for the measurement of micro hardness. Micro hardness measurement of the specimens was done along the weld and at the cross. Hardness was taken in 4 steps from the interface at a constant distance of 0.10mm on both pieces of mid steel (EN 8). Total of 8 readings were taken on Mild Steel pieces. The test matrix used for Micro hardness measurements is shown in Table 2.6.

Microstructure of Mild Steel: The structure consists of austenite grains with annealing twins. No carbide observed within the grains & at grain boundaries (Fig.2.10).

Scanning Electron Microscope examination:
SEM results were carries out on Scanning Electron Microscope (Fig. 2.7) at 25X to 2500X magnification. The test matrix used for SEM is shown in Table 2.6.

Figure 2.1 Vertical Milling Machine used for friction welding

Figure 2.2 Temperature Torch used in friction welding

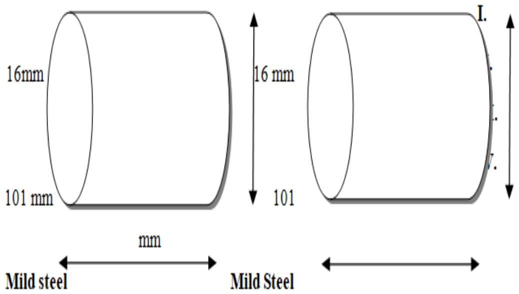

Figure 2.3 Dimensions of cylindrical pieces

Figure 2.4 Complete Setup while running the VMC & Temp.Measurement

Figure 2.5 Universal Testing Machine

Figure 2.6 Belt Grinder used for polishing and Optical Microscope used for Microstructure examination

Figure 2.7 Scanning Electron Microsope

Figure 2.8 Vicker micro hardness

Table 2.1 Test matrix showing parameters varied at different levels

No. of Experiment	Parameters			
	RPM (R)	**Burn off Length (L) in mm**	**Weld time in sec.**	**Max.Temp.in ^{0}Centigrade**
1	1600	.7	21	105
2	1600	.6	17	96
3	1600	.5	18	89
4	1800	.4	16	101
5	1800	.6	21	106
6	1800	.5	20	101
7	2000	.4	21	103
8	2000	.3	19	93

Table-2.2 Parameters for tensile testing.

No. of Experiment	Parameters			
	RPM (R)	**Burn off Length (L) in mm**	**Weld time in sec.**	**Max.Temp.in ^{0}Centigrade**
1	1600	.7	21	105
2	1600	.6	17	96
3	1600	.5	18	89
4	1800	.4	16	101
5	1800	.6	21	106
6	1800	.5	20	101
7	2000	.4	21	103
8	2000	.3	19	93

Table-2.3 Chemical Composition

Sr. No.	Element	Percentage
1	Fe	98.47
2	S	.039
3	Mg	.461
4	Si	.157
5	P	.037
6	Ni	.053
7	Mo	.019
8	Al	.018
9	Pb	.014
10	Sn	.016
11	Ti	.018
12	Cr	.046
13	C	.412

Table-2.4 Composition of mild steel in percentage

No. of Experiment	Parameters			
	RPM (R)	**Burn off Length (L) in mm**	**Weld time in sec.**	**Max.Temp.in ^{0}Centigrade**
1	1600	.7	21	105
2	1600	.6	17	96
3	1600	.5	18	89
4	1800	.4	16	101
5	1800	.6	21	106
6	1800	.5	20	101
7	2000	.4	21	103
8	2000	.3	19	93

Table 2.5- Test Matrix for Temperature Measurement

No. of Experiment	Parameters			
	RPM (R)	**Burn off Length (L) in mm**	**Weld time in sec.**	**Max.Temp.in ^{0}Centigrade**
1	1600	.7	21	105
2	1600	.6	17	96
3	1600	.5	18	89
4	1800	.4	16	101
5	1800	.6	21	106
6	1800	.5	20	101
7	2000	.4	21	103
8	2000	.3	19	93

III. Results

A. MACROSCOPIC BEHAVIOUR

a) Tensile Result and discussion:

Sr. No.	Parameter			UTM result	
	RPM (R)	Burn Off Length(L) in mm	Weld time in sec.	UTS(N/mm^{2})	UTL(KN)
1	1600	.7	21	135	24.4
2	1600	.6	17	130	28.6

3	1600	.5	18	104	26.2
4	1800	.4	16	110	26.2
5	1800	.6	21	108	25.4
6	1800	.5	20	112	24.8
7	2000	.4	21	131	26.4
8	2000	.3	19	136	27.8

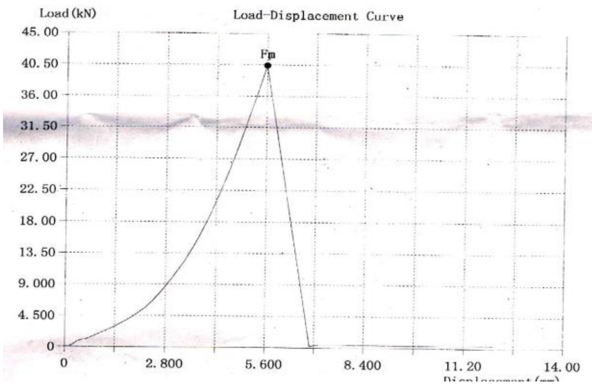

Figure 3.1 Graph of Load Vs Displacement

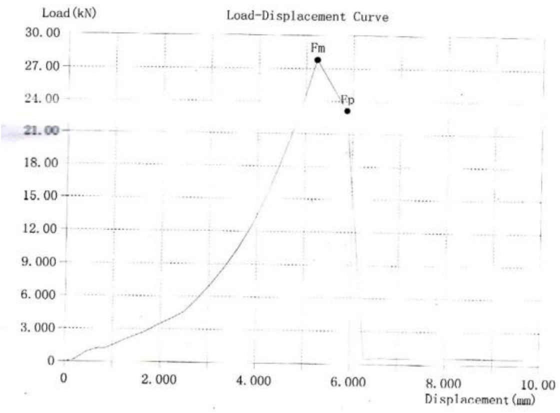

Figure 3.2 Graph of Load Vs Displacement

TEMPERATURE PROFILES

VARIATION OF TEMPERATURE WITH RESPECT TO FRICTION TIME (FIG.3.7-3.14).

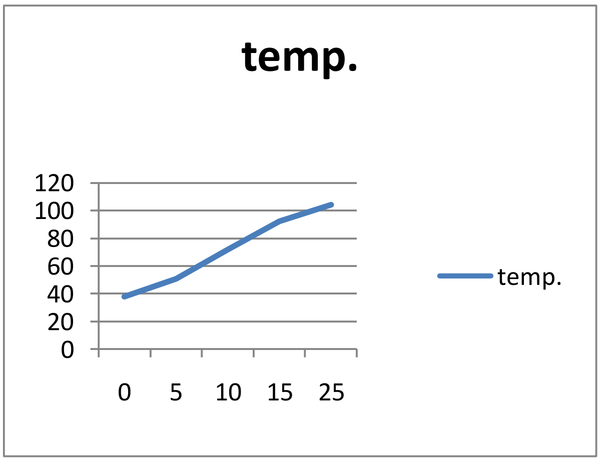

Figure 3.7 Sample no.1

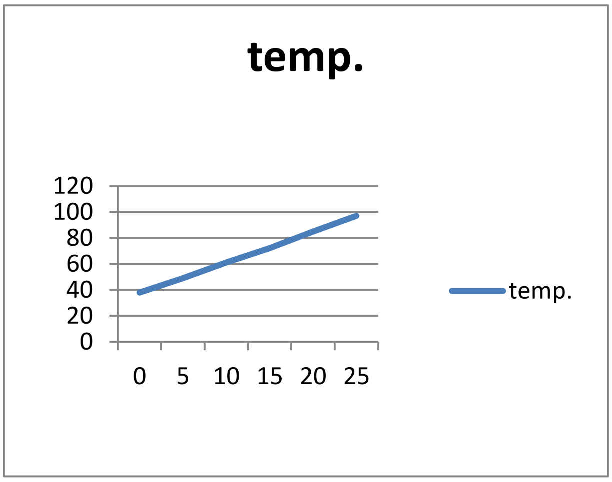

Figure 3.8 Sample no.2

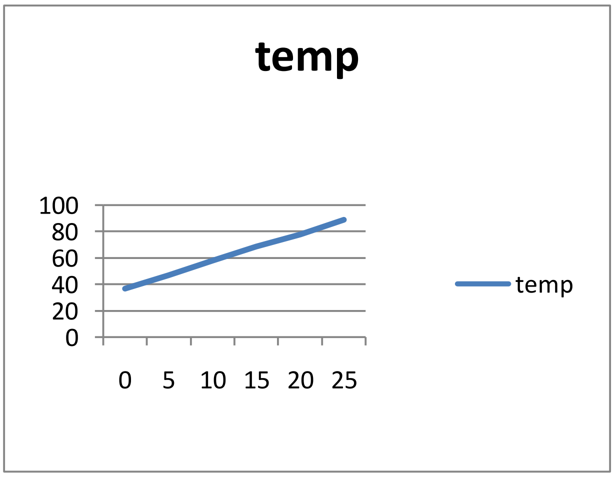

Figure 3.9 Sample no. 3

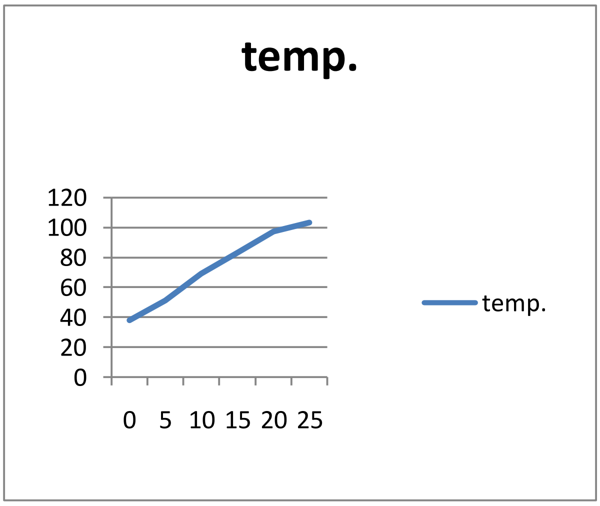

Figure 3.10 Sample no. 4

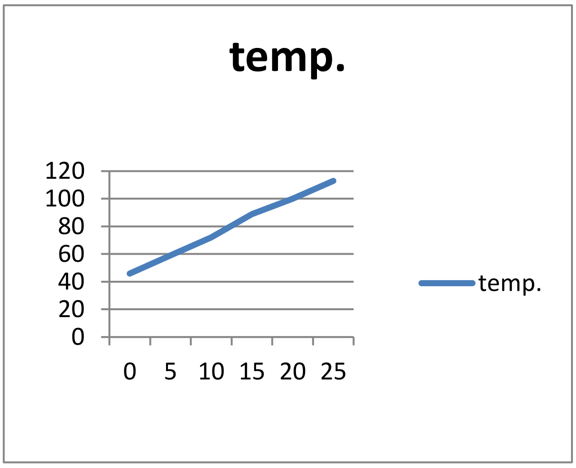

Figure 3.11 Sample no. 5

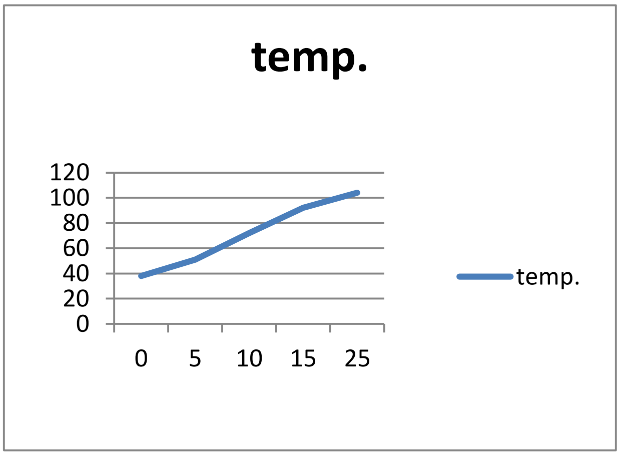

Figure 3.13 Sample no. 7

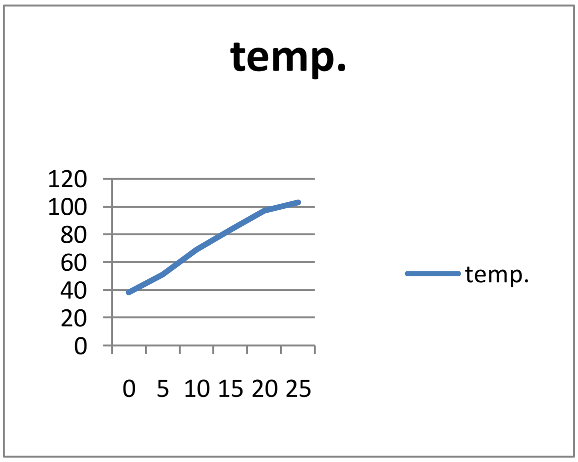

Figure 3.12 Sample no. 6

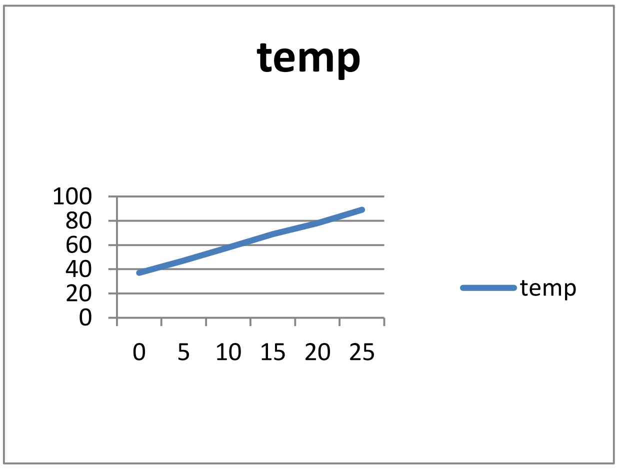

Figure 3.14 Sample no. 8

Table 3.2 Test matrix for Temperature Measurement

No. of Experiment	Parameters			
	RPM (R)	Burn off Length (L) in mm	Weld time in sec.	Temperature
1	1600	.7	21	105
2	1600	.6	17	96
3	1600	.5	18	89
4	1800	.4	16	101
5	1800	.6	21	106
6	1800	.5	20	101
7	2000	.4	21	103
8	2000	.3	19	93

3.2.1 MICROSCOPIC BEHAVIOUR

3.2.1 Microstructure Examination of Friction Welded Joints

On MS -Microstructure on Mild Steel side, On both MS Microstructure near interface on Mild Steel side.

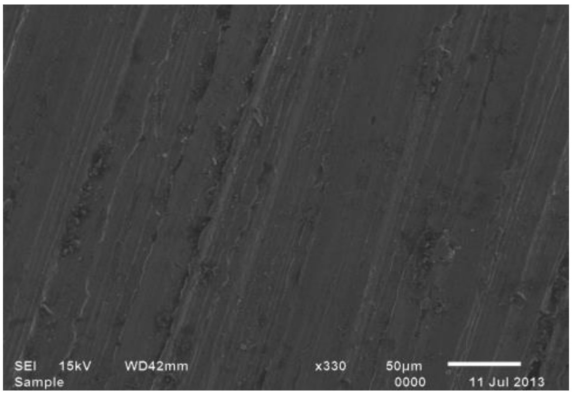

Figure 3.2.1.1 MS/side 1

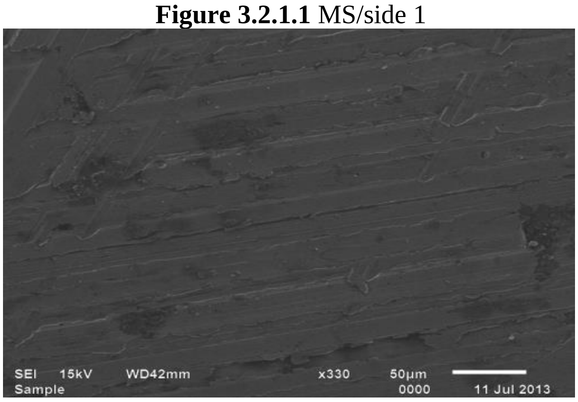

Figure 3.2. 1.2 MS side 2

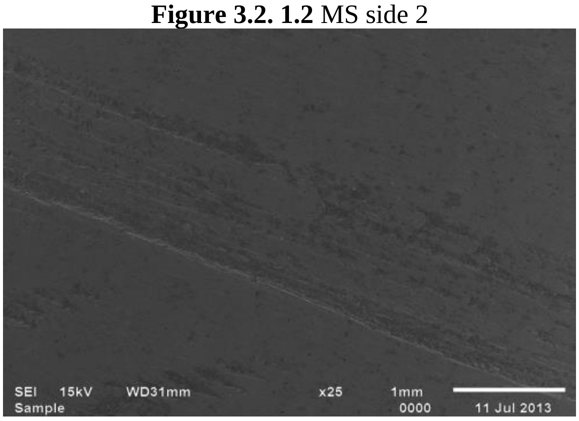

Figure 3.2. 1.3 Joint 1

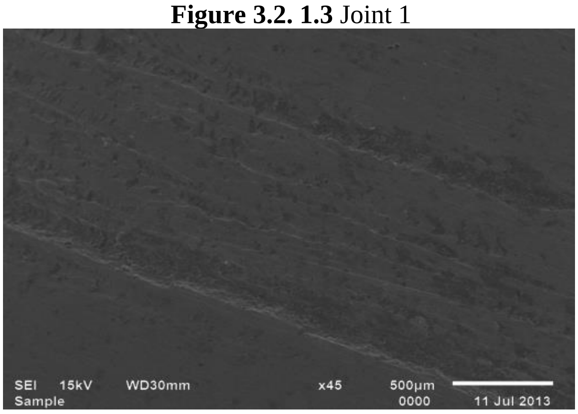

Figure 3.2.1.4 joint 2

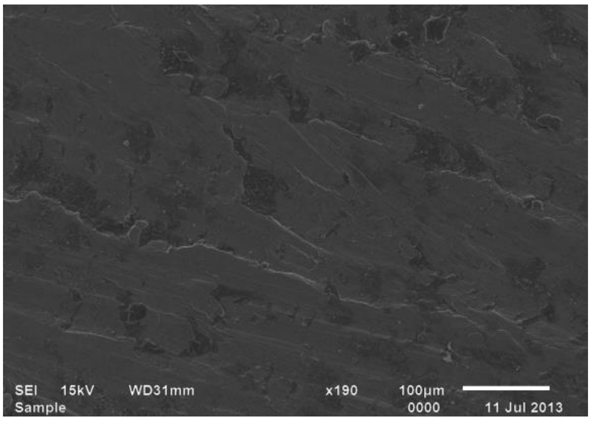

Figure 3.2.1.5 joint 3

3.2.2 Micro hardness Measurements

3.2.2.1 Micro hardness measurement along the weld:

The following are the table showing micro hardness on different specimens along the weld.

Distance from joint along mild steel direction(mm)	Hardness (HRB)
.10	72
.20	68
.30	76
.40	70
.50	71

Table 3.3 Hardness Profile

No. of experiment	Parameters			Micro hardness value		
	RPM (R)	Burn off Length (L) in mm	Weld time in sec.	Mild steel	Interface	Mild steel
1	1600	.7	21	72	43	72
2	1600	.6	17	68	45	68
3	1600	.5	18	76	41	76
4	1800	.4	16	70	42	70
5	1800	.6	21	71	42	71
6	1800	.5	20	73	40	73
7	2000	.4	21	69	38	69
8	2000	.3	19	72	40	72

Figure 3.17 Micro hardness measurement

3.2.3 SEM Examination of Friction Welded Parent Joints

The following are the images taken on SEM machine (Figure 3.18-3.23)

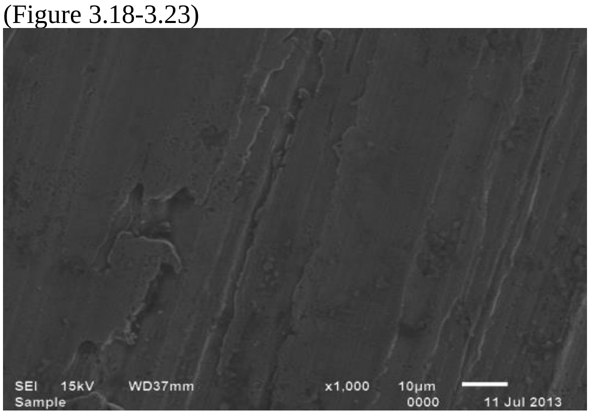

Figure 3.18 SEM measurement for MS side 1.

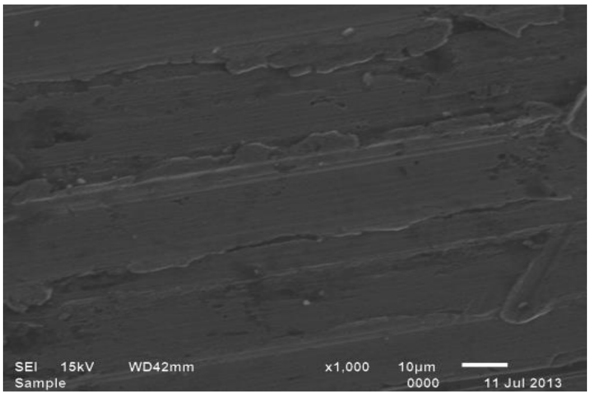

Figure 3.19 SEM measurement for MS side 2

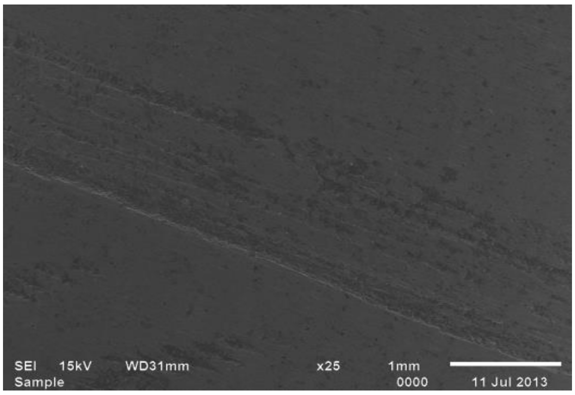

Figure 3.20 SEM measurement for MS/MS Joint

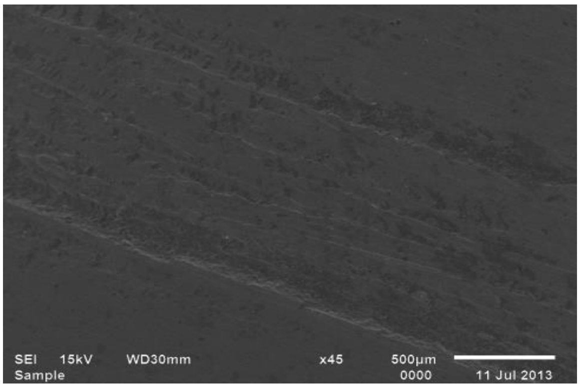

Figure 3.21SEM measurement for MS/MS Joint

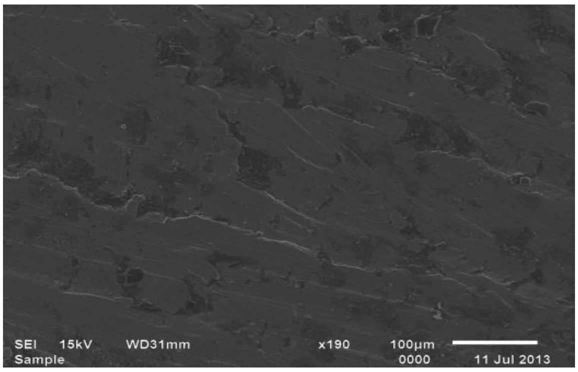

Figure 3.22 SEM measurement for MS/MS Joint

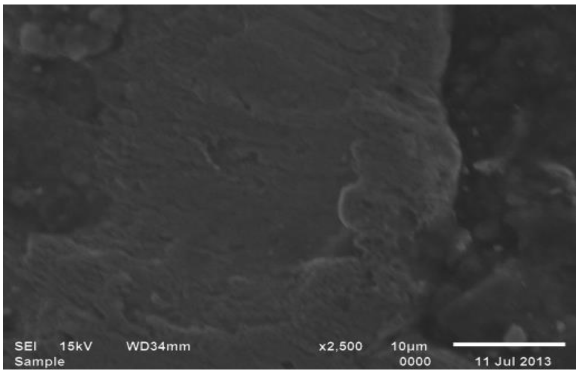

Figure 3.23 SEM measurement for MS/MS Joint

IV. DISCUSSION

Tensile Strength: The Diameter of the each Specimen is 12 mm so that the effects of various parameters on the strength of the joints were examined in welding. From Table 5.1, It shows that maximum Ultimate Tensile Strength was observed for welded sample no.8 i.e. 136 N/mm2 and Ultimate Tensile Load 27.8 KN. Lowest Ultimate Tensile Strength for sample no. 3 i.e. 104N/mm2 and UTL 26.2 KN. Load Vs Displacement variation is shown in Fig.5.1-5.2. Since the friction welding process is characterized by a fast applied thermal and stress/strain cycle causing micro structural changes, the mechanical properties of the mild steel is quite same. It would be expected that the mechanical properties of welded joints would be quite different from those of bimetallic materials.

Temperature profile: The temperature for every weld is clearly shown in Table 3.2 and Fig. 3.3-3.10.The measurement of temperature for every specimen is observed by the help of non contactable temperature gun from the distance of 40 mm. The highest temperature reading is 106 degree Celsius and lowest is 89 degree Celsius as per shown in the table 5.2. When temperature is measured from the distance of 40 to 50 mm, maximum temperature observed is 106 degree Celsius for sample no.5 and Lowest temperature is 89 degree Celsius for specimen no.3. It is observed that when friction force is increased and other parameters remain constant , there is increase in temperatures.

Chemical composition: The element percentage composition, Interface and mild steel regions of friction welded joints. Mild steel combine with another mild steel at the interface, the percentage of Fe is then being 98.47% and 98.47% respectively. Then at the interface resulting from friction welding joint the percentage of Fe will be 91.65. So that the percentage of Fe in mild steel is decreased at the interface due to the elemental diffusion takes place between two metals. Similarly it is observed that the percentage Si, Mn, C, S, P decrease the percentage in mild steel at the interface due to the elemental diffusion of the metals. In all the cases diffusion takes place in the interface.

Microstructure of friction welded joint of AL & MS: The microstructure of mild steel at magnifications of 1000X. The structure consists of fine grains. The microstructures of Mild steel base at magnification 1000X. The large austenitic grains are clearly visible in the microstructure. Dendrite and reheat refined grains characterized the near interface region of the weld as shown in figure. The reheat refined region closed to the dendritic boundry develops comparatively coorser grain than the size observed in the reheat refine region away from the dendritic boundry of the interface. Therefore microstructure can be distribute in the weld of three different microstructure regions- Dendritic region at interface (D); Reheat refined coarse grains (RC) and Reheat refine grain region (RF). The coarse grain reheat refined region (RC) primarily contains a mixture of acicular and chunky ferrite.. The microstructure at the different interface regions of weld metal in the friction weld. Thus, it may be concluded that the weld prepared varies within a broad range of coarseness as typically marked.

Micro hardness measurement along the weld: Vickers Micro hardness machine is used to measure the micro hardness. Measurement of Micro hardness was taken at the base metal (mild steel side1), at interface, weld metal (Mild Steel side2). Readings were taken from various location & the average on the behave of these readings was taken for analysis. A maximum micro hardness of 45 has been obtained near the weld interface. Studies on austenitic mild steel joints using friction welding have reported a decrease in micro hardness at the interface zone of the joint. During the welding process oxidation and friction processes took place which result in increase in micro hardness at the welding interface. This explanation was also corroborated by microscopic studies which revealed a plastically deformed zone at the weld interface. The highest micro hardness value found at the weld interface is 45 for sample no.3 and the lowest value at the interface is 38 for sample no.7 as shown clear in above Table 3.5. It is also observed that micro hardness increases at the interface with the increase in friction force. The value of micro hardness was lower for sample 7 and higher for sample no. 3.

ACKNOWLEDGMENT

The author is thankful to all who directly or indirectly contributed in this research work.

REFERENCES

[1] https://www.mech4study.com/2017/04/friction-welding-principle-working-types-application-advantages-and-disadvantages.html.

[2] https://www.mech4study.com/2017/04/friction-welding-principle-working-types-application-advantages-and-disadvantages.html