STUDY OF MECHANICAL AND METALLURGICAL PROPERTIES OF FRICTION STIR WELDED ALUMINIUM ALLOYS (AA2014 & AA6082) BY ADDITION THE TIO_2 NANOPARTICLES AND ITS SIMULATION ANLYSIS

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ABSTRACT

The present work investigates the mechanical and metallurgical properties of friction stir welded aluminium alloys AA2014 & AA6082 by the addition titanium dioxide nanoparticles and its simulation analysis by ansys software. The hexagonal tool pin is used for FSW of dissimilar aluminium alloys and TiO_2 nanoparticles were inserted during welding process. The maximum peak stress obtained was 151.16 MPa at 900RPM, welding speed of 16mm/min and tilt angle of 1.5^{o} . The maximum Izod impact obtained was 10.5 joules and Maximum Vickers Micro hardness obtained as 95.3 VH. The microstructure results show that the addition of nanoparticles enhanced the grain size in the weld size. It is concluded from study that the experimental results obtained are in agreement with the values obtained by simulation analysis.

Keywords: TIO_2 nanoparticles, Aluminium alloys AA 6082 & AA2014, SEM, Friction Stir welding, modified Tool, Microstructure and Mechanical properties, Micro hardness, stimulation analysis in ansys.

I. INTRODUCTION

Friction stir welding is a solid-condition welding technique and very accurate method for joining of non-ferrous materials like Magnesium alloys, aluminium alloys, copper, bronze, brass, titanium etc. and now also even advanced to join the ferrous materials like steel. FSW is a fairly new type of joining technology these were improved and patented in December 1991 through the welding Institute (TWI) in England. It was initially used for joining low melting point alloys like copper, magnesium, aluminium etc. This is a solid-state welding procedure which is joined by using a non-consumable tool which moves over the surface of the metals to be joined, without melting the material. The temperature is produced due to friction between the rotating tool and work piece materials, which softens and fuses the material to form the joint. Friction stir welding process produces the welded zone which has excellent mechanical properties compared with the conventional welding, making it more commonly used in many welding applications.

Friction stir welding process produces weld joints of extremely high in quality and which gives very high strength and less defects. FSW is capable of joining the magnesium alloys, aluminium alloys, mild steel, copper alloys, titanium alloys, and stainless steel. Most recently, it was successful used to weld polymers. Welding of dissimilar metals has been successfully presented by many researchers in recent times by friction stir welding.

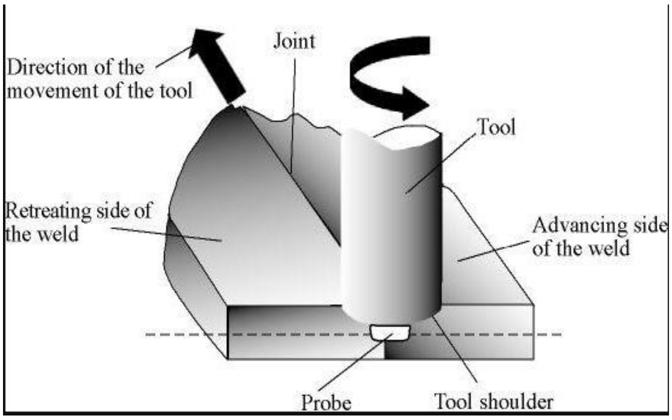


Figure 1.1: Friction stir welding

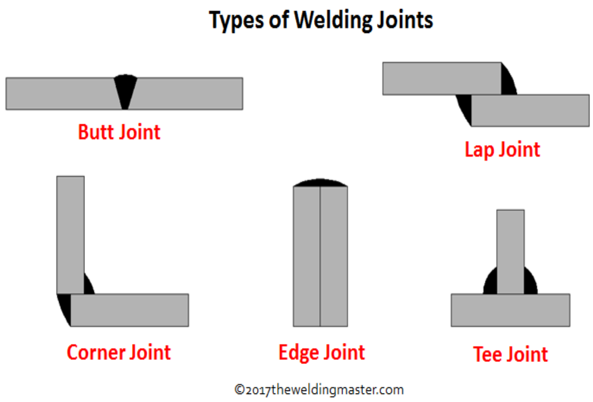


Figure 1.2: type of welding joints

The main advantages in FSW are that it doesn't produce fumes & flames during welding process and is energy efficient. FSW do not require filter material as required to conventional welding process and is relatively easy to carry out the operation of weld performed. However the work piece mounted on the milling machine should rigidity clamped and higher welding speeds should be maintained in order to avoid defect like porosity for non-ferrous and ferrous materials.

Various types of friction stir welding joints

FSW was carried out initially for butt weld possibilities. But after, rigorous testing and research in friction stir welding field different types of joining process were established. The various weld joint are includes- butt joints, lap joints, edge joints, spot joints, corner joints, T-joint fig- 1.2.

FSW was develop into a practical and reliable fabrication component, especially in aeronautics or aerospace applications and for launch vehicles relating aluminum alloys since reported by Hejazi et al. Malarvizhi et al. absorbed out that tool shoulder diameter has been significant role in temperature generation and material run throughout the process. In this subject, the weld joints produced by a most favorable shoulder diameter represented higher tensile strength evaluated to its counterparts. Naga Prasad et al. performed in his project cutting tool taper is designed for the FSW of two dissimilar materials Aluminium alloy 5083 and aluminium alloy 6061. Structural and modal analysis is performed on the circular and taper tool to validate the deformation and stresses. The results show that stresses produced are decreased with circular tool. Two plates of the AA5083 and AA6061 are welded experimentally on a vertical CNC machine using 700rpm speed for circular cutting tool. The ultimate tensile strength was found to be decreasing by increased and hardness test results, the yield stress value was 51.43MPa. Ankur Vasava et al. presented the advantages of FSW that has low distortion, shrinkages, fuller metal, low HAZ, less porosity etc compared to fusion welding. Vivekananda et al. investigated the microstructure and hardness of AA6035 and AA8011 alloy at rotation speed of 550rpm & welding speed of 40-90 mm per minute. The results show that maximum tensile strength 50N/mm^2 was obtained at welding speed 60mm/minute and maximum hardness of 91HV at the weld centre. Naveen Kumar et al. reported FSW of AA7475 &AA6061 at 750rpm by using two type of pins one is round screw threaded pin and other one is circular pin. Here stress values were increasing and hardness decrease with increase in speed, and maximum impact test strength obtained is 32 joules. Prasanna et al. performed FSW on AA6061 by using a vertical axis CNC milling machine & results show that the brinell hardness test value was maximum in weld region.

In recent years, few researchers have studied the effect of nanoparticles and microparticles addition during joining of similar and dissimilar metals by friction stir welding process. The addition of reinforcements during friction stir processing yielded improved properties was also been reported by many researchers. Bahrami et al. examined the influences of SiC nanoparticles using on the mechanical properties of AA7075 similar alloys weld joint. They reported a substantial raise in tensile strength and elongation which were attributed to the pinning effect, higher nucleation sites and contravention of primary grains connected with strengthening nanoparticles. Tabasi et al. performed AZ31 and AA7075 dissimilar joints on FSW by insertion the SiC nanoparticles and carried out that the pinning outcome take place in SZ. They obtained out that the intermixing of 2 alloys was growing by raising the rotation rate and decreasing the journey speed. Mirjavadi et al.studied the effects of TiO_2 nanoparticles addition on microstructure and tribological, mechanical properties of AA5083 aluminium alloy FSW butt joints. They affirmed that the augmentation of mechanical and wear properties was chiefly owing to the reduced grain size. Baridula et al., also reported the influence of reinforcements on the mechanical properties and microstructure of friction stir welded joints.

From this literature examination, it is clear that the authority of reinforcement nanoparticles addition influences the mechanical properties, micro structural characteristics of welded joint. Thus the present study aims to understand the behavior of TiO_2 nanoparticles addition and its influence on mechanical properties and microstructure during joining of AA2014 & AA6082 dissimilar alloy joints by FSW which was not studied adequately.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

This chapter includes the details of the experiments that were carried out to fulfill the objective of this investigation by using friction stir welding process. The welding tool used in the welding process has hexagonal pin which was specially designed to improve the material flow in the weld zone.The titanium nano particles were inserted in to the groove of size 2mm × 5mm during the welding process. The welded joints are obtained by different process parameters by moving the welding tool over the work pieces. The mechanical properties like tension test, impact izod test, micro hardness test and microstructure of the welded joints were studied. The temperature distribution during FSW have been recorded and are validated by using Ansys software 18.1 are also discussed.

2.1. Materials

The material of AA2014 & AA6082 aluminium alloys 100X50X6mm thickness plates are used in this study purchased from Nakoda metals and Special Steel & Alloys Fathe Nagar, Hyd. Their chemical compositions and mechanical properties are shown in Tables 2.1 and 2.2, respectively.Titanium dioxide nanoparticles supplied to addition into the weld samples by nano research laboratory from Jamshedpur. Table 2.3 and Fig 2.1 show the chemical composition and TIO_2 nanopowder properties and scanning electron microscopy (SEM) micrograph of the as-received TiO_2 nanoparticles, respectively.Welding Tool has hexagonal pin profile and is made tool steel H13. H13 tool steel consists of chromium & molybdenum and vanadium and is identified for its high hardness and good toughness. Below table 2.4 & 2.5 explain the chemical composition and properties.

Table2.1 Chemical composition of AA2014

Element	Cr	Cu	Fe	Mg	Mn	Si	Ti	Ti+Zn	Zn	Other	Al
Percentage (%)	0.0-0.1	3.9-5.0	0.0-0.5	0.2-0.8	0.4-1.2	0.5-0.9	0.0-0.15	0.0-0.2	0.0-0.25	0.05-0.15	90.25-92.5

Table 2.2 Chemical composition of AA6082

Element	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Other	Al

Percentage (%)	0.0-0.25	0.0-0.10	0.0-0.50	0.60-1.20	0.40-1.00	0.70-1.30	0.0-0.10	0.0-0.20	0.0-0.15	95.2-98.3

Table 2.3 TIO_2 powder properties

Properties	**Values**
Density	4.23 g/cm^3
Melting point	1843 ^{o}C
Boiling point	2972 ^{o}C
Solubility in water	insoluble
Band gap	3.05 eV
Magnetic susceptibility	5.9x10^{-6} cm^3/mol.

Table 2.4 chemical composition of H13 metal.

Element	C	Ch	Mn	P	Si	S	V
Percentages (%)	0.32-0.45	4.75 - 5.5	0.20-0.50	0.0-0.03	0.8-1.2	0.0-0.03	0.8-1.2

Table 2.5 Physical properties of H13 material

Properties of H13	**Values**	**Properties of H13**	**Values**
Density	7.80 g/cm^3	Tensile strength, ultimate (@20°C)	1200 - 1590 MPa
Melting point	1427 ^{o}C	Modulus of elasticity (@20°C/68°F)	215 GPa
Thermal expansion	10.4 x 10^{-6}/°C	Reduction of area (@20°C/68°F)	50.00%
Thermal conductivity	28.6 W/mK	Tensile strength, yield (@20°C)	1000 - 1380 MPa.

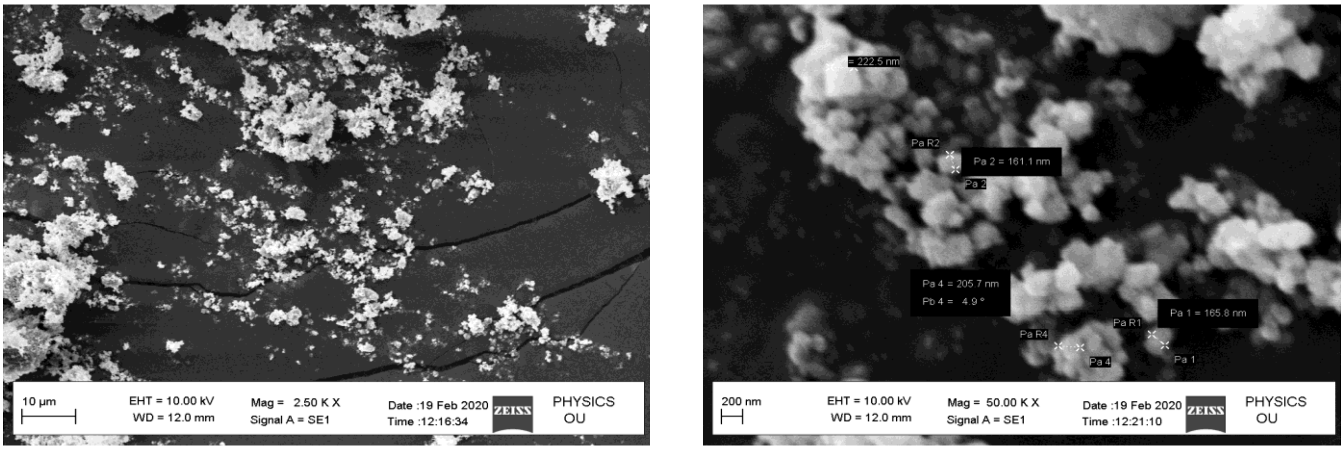


Figure 2.1 SEM of TIO_2 nanoparticles

2.2 Experimental Procedure

2.2 Groove design

Assign the cad model in solid work software by designing the shape of the grooves for inserting the titanium dioxide nanoparticles. The width of the groove is 1mm width 5mm depth from each plate drawing shown below the figure.

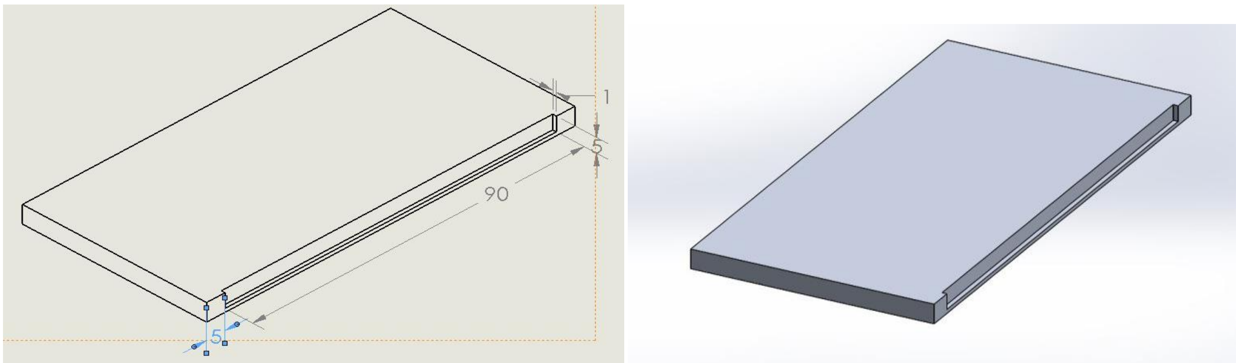


Figure 2.2 2D drawing & CAD model for inserting powder insert in the groove

Figure 2.3 work pieces after cutting the groove

2.3 Tool design

Tool geometry depends on probe length, shoulder size and pin shape which influences the heat generation and material flow in the solid state. The shoulder produces maximum heat which plasticizes the material and the welded joint is formed effectively in the solid state. Many researchers have studied the influence of tool profile on the mechanical properties and microstructure of friction stir welded joints.

Table 2.6 Tool materials chart for alloys

S .no.	Alloys name	Metal for tool in FSW
1.	Aluminium alloys	Tool steel (H13).
2.	Magnesium alloys	Tool steel.
3.	Copper and Copper alloys	Tool steel, PBCN, nickel, tungsten.
4.	Titanium alloys	Tungsten.
5.	Stainless steel	PBCN, tungsten alloys.
6.	Low-alloy steel	WC, PBCN.

The commonly used pin profile in friction stir welding more frequently are tapered cylindrical, straight cylindrical, threaded cylindrical, square pin, triangular, hexagonal pin and pentagon pin, etc to be fabricate the joints.

Figure **2.4** Welding tool

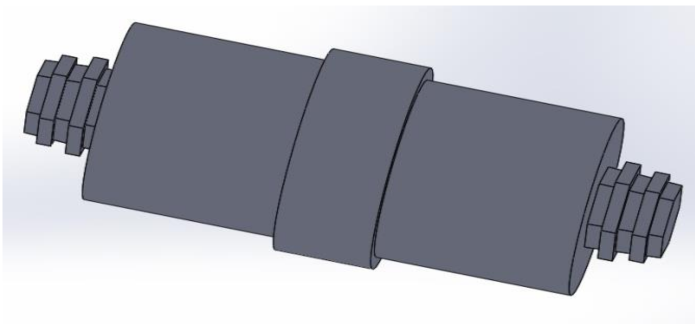


Figure 2.5 Hexagonal pin tool with hexagonal rings

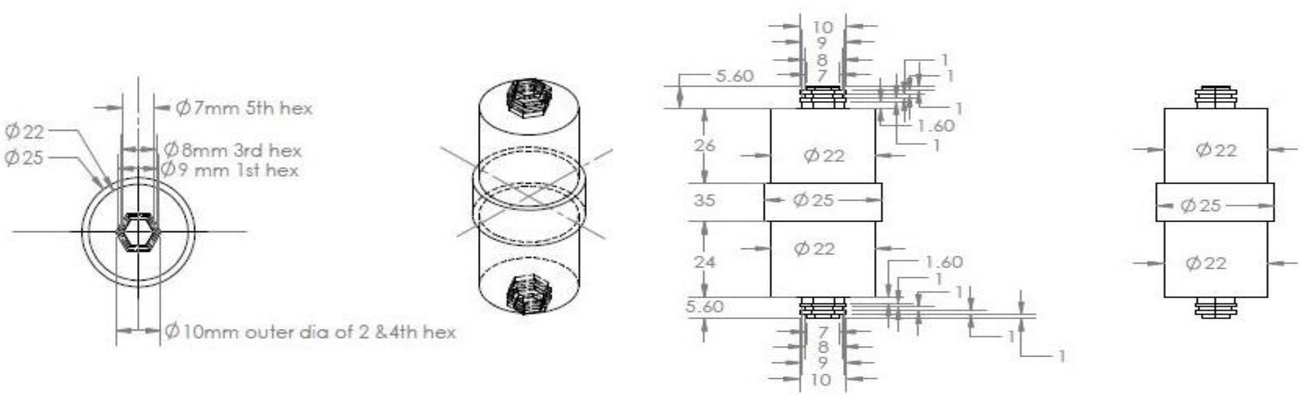
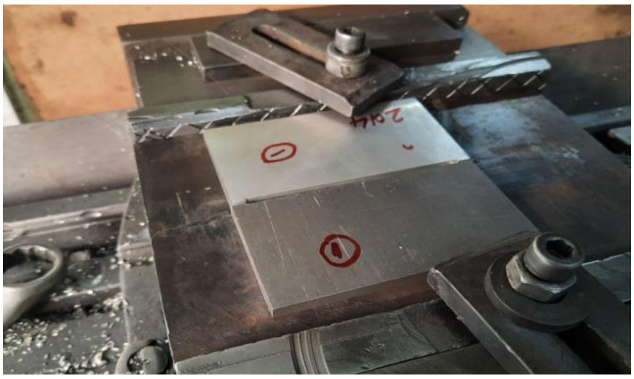


Figure 2.6 Geometry of tool pin

2.4 Mechanical joining of AA2014 and AA6082 by FSW

Friction stir welding is a solid-state welding process with no spark created for welding and commercially used for joining types of alloys of aluminum, magnesium, copper light and heavy load ferrous and non ferrous material. and etc.



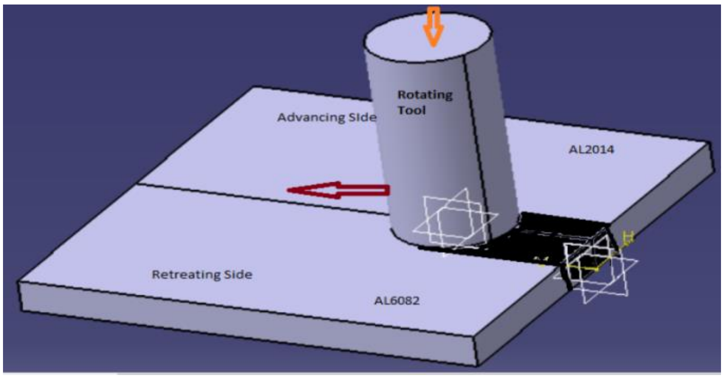


Figure 2.7 plates are placed on milling machine flat and hard tight the clamps, advancing side 2014& 6082 retreating side

Powder inserting in groove between both plates

Tool mounting on joint of both plates edges

Figure 2.8 Show the FSW process

Titanium dioxide nanoparticles are inserted into the groove before the welding process and the welding tool is moved along the edges of dissimilar aluminium alloys AA2014 & AA6082 on semi-automated milling machine to complete the welded joint. Total 2.7 welded joints are obtained with different process parameters.The process parameters used are 900rpm and 1120rpm, welding speed of 16 mm/min and 25mm/mm and tilt angle of 1.5 and 2.0 respectively.

Temperature distribution during FSW process are recorded on the joint edge of both plates **100mm X 50mm** at 10 equal segments 10mm distance between every welded samples. The temperature values are considered exactly at the stirring zone when the Tool running along the weld joint line. The Temperature is noted with help of an Industrial temperature Gun and its having temperature sensor in the gun to absorbing reading of temperature at joint line. The Gun has been finding maximum temperature values of -50^0 C to 550^0 C.

Table 2.7: Shows The Temperature Readings taken during FSW process

Weld specimen no.	Tool speed RPM	Feed rate mm/min	Tilt angle ^{o}	T1 ^{0}C	T2 ^{0}C	T3 ^{0}C	T4 ^{0}C	T5 ^{0}C	T6 ^{0}C	T7 ^{0}C	T8 ^{0}C	T9 ^{0}C	T10 ^{0}C
1	900	16	1.5	34	56	78	130	172	176	178	160	141	140
2	900	25	1.5	60	74	96	112	126	121	118	114	113	110
3	1120	16	1.5	92	99	119	125	131	145	157	181	172	166
4	1120	25	1.5	101	111	120	127	130	137	139	152	168	173
5	900	16	2	76	96	110	117	145	152	132	144	134	131
6	900	25	2	100	111	123	154	152	150	147	138	142	147
7	1120	16	2	110	123	135	146	157	149	138	134	133	134
8	1120	25	2	103	111	121	126	132	138	143	144	146	164

Figure 2.9 Welded Specimens From 01-08.

The tensile test was conducted on UTM-Universal Testing Machine as require the work piece is of ASTM E8 is obtained by EDM wire cut machine. ASTM E8 Tensile test specimen (Dog Bone Shape) was obtained from the FS welded specimen having thickness of 6mm, Gauge length as 40mm, Fillet radius as 12mm and shoulder length 30mm as shown in the Figure 2.10. The friction stir welded tensile test specimens are shown in the figure 2.11.

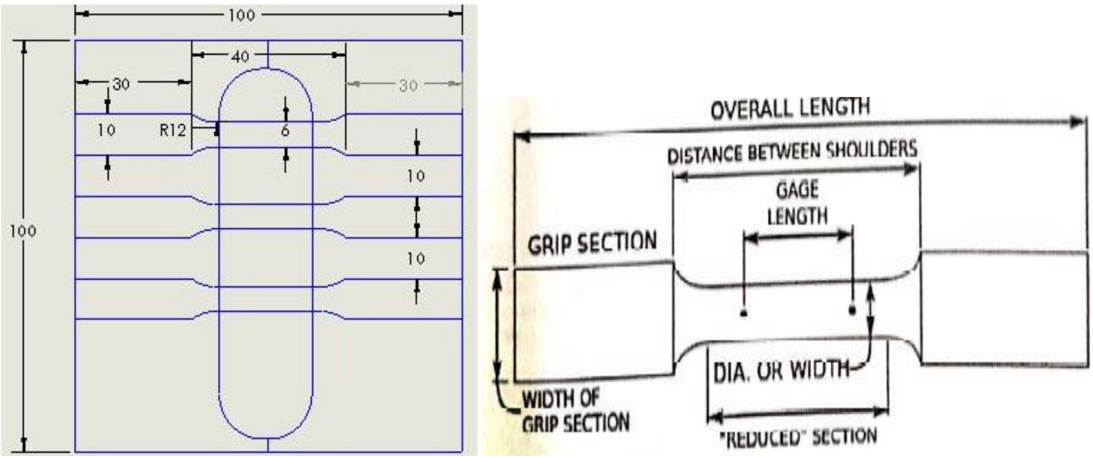


Figure 2.10: CAD model of dog bone shape based on ASTM E8 standard for tensile test

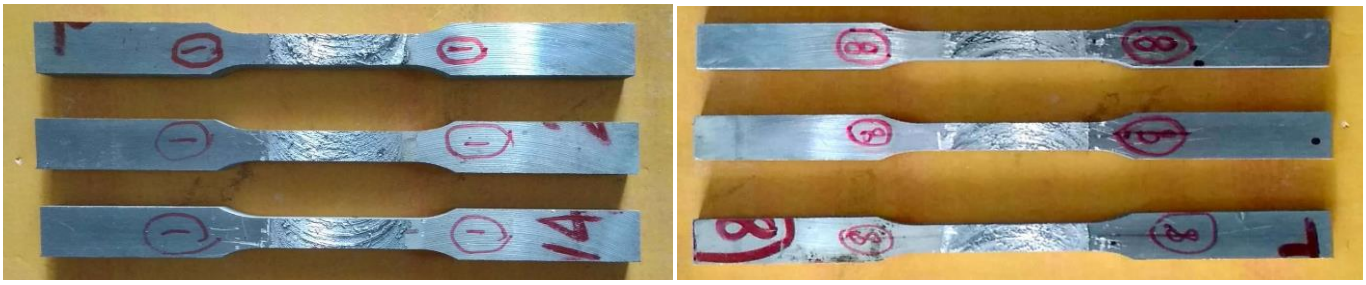


Figure2.11: ASTM E8 Tensile test samples

The Izod impact test was conducted by using impact testing machine, the test specimen are shown in the figure 2.12 and 2.13. The energy engrossed by the weld piece is calculated from the height the arm swings to after striking the sample. A notched job is commonly used to conclude impact energy and notch sensitivity. The ASTM D256 specimen is having dimensions of 6X10X55mm.

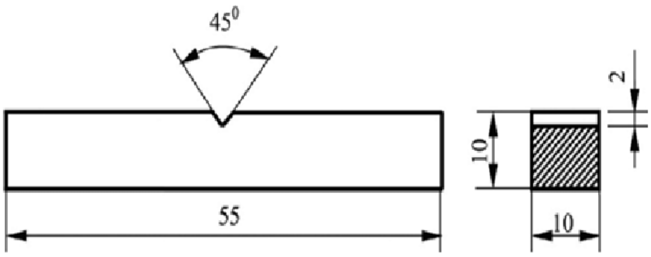


Figure 2.12: ASTM D256 standard for Izod test

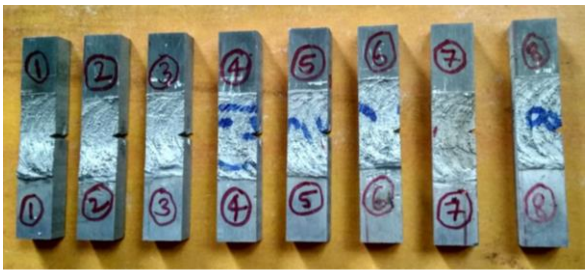


Figure2.13: Izod impact test samples after EDM wire cut based on ASTM D256

Similarly the Micro hardness test is conducted by Vickers hardness testing machine as shown in the figure 2.14. The specimen with smooth surface finish was prepared properly for microhardness test.

Figure2.14: Micro hardness testing machine

2.7 Microstructure test

Microstructure study has been done by metallurgical microscope and the samples of size 40mm length and width 10mm are obtained by EDM wire cut machine. The welded sample are trimmed or machined based on the required dimension for conducting the Metallographic test to study microstructure. The polished samples were etched with Keller's Etching agent used for Aluminium to reveal microstructure. These different zone in specimen study were primarily characterized into (a)Weld zone or Nugget Zone and b) TMAZ c) HAZ zone and finally the parent material Zone. The microstructure samples are shown in the figure 2.15.

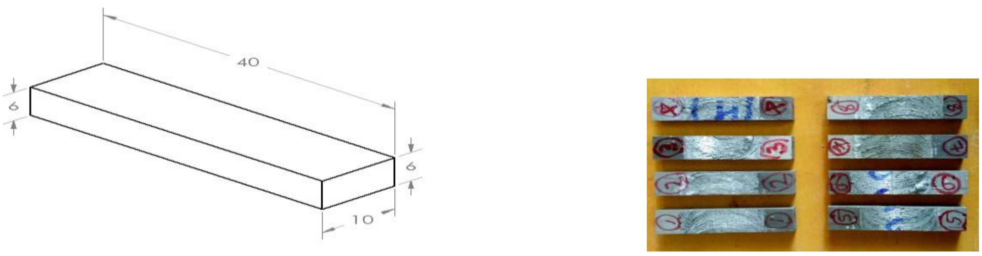


Figure 2.15: CAD model for EDM wire cut and microstructure specimens for test

III. RESULTS AND DISCUSSION

In the present investigation the results of friction stir welded aluminium alloys by the addition of reinforcements are given below along with the simulation analysis. It has been observed that the process parameters plays an important role during of metals by FSW process.

3.1 Tensile test

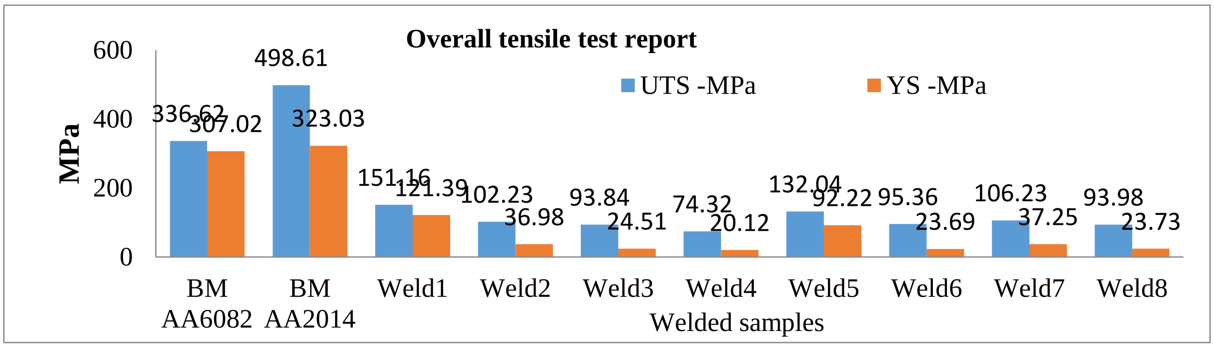
Tensile test was conducted by using UTM and the results are given in following table 3.1. The parameter range of tool rotational speed 900 rpm and welding speed of 16 mm/min and tilt angle 1.5 can gives the high range of Tensile Strength than other parameters. The tensile samples after the test are shown in the figure below.

The reading obtained while performing the tensile test are shown below in table3.1

Table 3.1: Showing Reading Recorded while the tensile test

Identification of the Sample	Tool rotation speed RPM	Weld speed mm/min	Tilt angle °	TENSILE TEST RESULTS					
				C/S Area (mm²)	Ultimate Load(KN)	UTS (MPa)	Yield Strength (MPa)	%Elongation	Results/ Remarks
Weld '1'	900	16	1.5	34.93	5.28	151.16	121.39	10.4	Broken in Weld Zone
Weld '2'	900	25	1.5	36.78	3.76	102.23	36.98	9.72	
Weld '3'	1120	16	1.5	36.66	3.44	93.84	24.51	10.06	
Weld '4'	1120	25	1.5	36.60	2.72	74.32	20.12	8.48	
Weld '5'	900	16	2.0	38.17	5.04	132.04	92.22	10.68	
Weld '6'	900	25	2.0	38.17	3.64	95.36	23.69	12.96	
Weld '7'	1120	16	2.0	36.90	3.92	106.23	37.25	10.56	
Weld '8'	1120	25	2.0	37.03	3.48	93.98	23.73	8.16	

Figure 3.1: Tensile Test specimen after Break.



Graph 3.1: Overall tensile test report

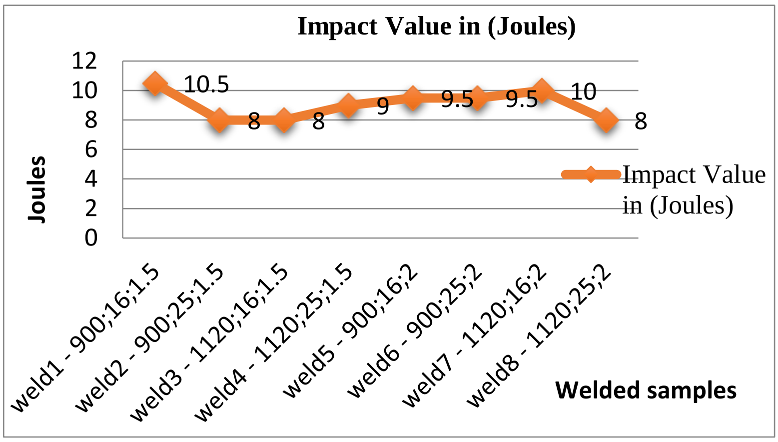
From the above data we can clearly notice that Highest peak stress is 151.16 MPa for Hexagonal Tool pin profile at 900 rpm , 16mm/min weld speed, 1.5 tilt angle on UTM.

3.2 Izod Impact Test

Izod impact test was conducted by using impact tester machine and the results are given in following table 3.2. The parameter range of tool rotational speed 900 rpm and welding speed of 16 mm/min and tilt angle 1.5 etc. can gives the high range of impact value than other parameters. The impact samples after the test are shown in the figure 3.2.

The reading obtained while performing the Izod impact test are shown below in table:

Table 3.2: Showing Reading Recorded while the Izod impact test



graph 3.2: Observed Impact Value in (Joules) while test

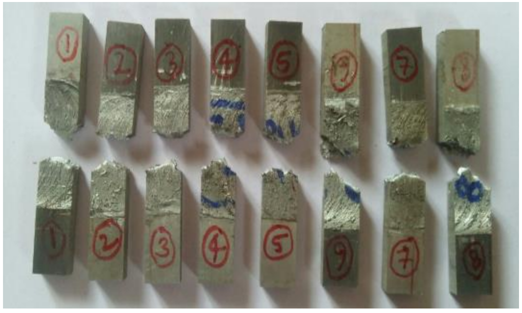


Figure 3.2: Izode impact test specimen after break

3.3 Micro hardness test

The micro hardness test conducted on Vickers hardness tester to the welded specimen was measured using diamond intender for various welded specimens with varying rotational speed and transfer speed were prepared and tested. Hardness values consider under micro scale. Form the Vickers hardness test the welding speed of 16 mm/min and the tool rotational speed of 900 RPM & tilt angle 1.5^{o} is given good range of hardness value 96.6 HV. Micro hardness test is carried in six different zones to dissimilar material:

a.) Weld zone or Nugget Zone b) TMAZ c) HAZ zone and finally the parent material Zone.

Locations / Specimen No	Parameters			Hardness (HV0.1)						
	Tool rotation speed RPM	Weld speed Mm/min	Tilt angle °	BM@ AA6082	HAZ@ AA6082	TMAZ@ AA6082	WELD ZONE	TMAZ@ AA2014	HAZ@ AA2014	BM@ AA2014
WELD '1'	900	16	1.5	123.3	82.1	66.8	**95.3**	57.6	63.9	96.9

WELD '2'	900	25	1.5	-	72.2	78.6	72.9	53.8	66.9	-
WELD '3'	1120	16	1.5	-	72.5	71.3	62.1	53.5	58.8	-
WELD '4'	1120	25	1.5	-	70.6	69.6	70.9	56.8	56.3	-
WELD '5'	900	16	2.0	-	83.2	64.1	71.6	51.3	60.7	-
WELD '6'	900	25	2.0	-	93.1	74.5	80.8	68.9	64.1	-
WELD '7'	1120	16	2.0	-	79.8	70.9	63.9	59.7	57.2	-
WELD '8'	1120	25	2.0	-	83.3	69.6	76.1	57.0	61.8	-

Table 3.3: Reading is recorded while the micro hardness tester specimens from SNO: 01-08.

3.4 Microstructure

Microstructure test performed from the micrographs, it can be indirect that the weld section of all the joints invariably contain uniformly circulated. However, the size of the particles is diverse, and it is found to be influenced by the tool rotation speed. Total 8 welded specimen Micro structural studies was carried out in different zones like 1) Nugget zone NZ 2) TMAZ 3) HAZ 4) Interface Zone 5) Base metal as shown in the figure 3.3.

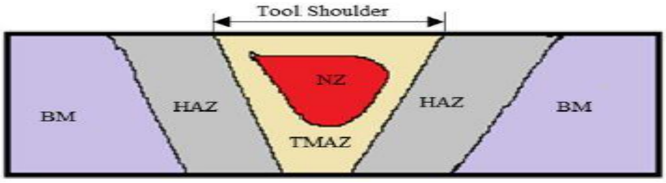
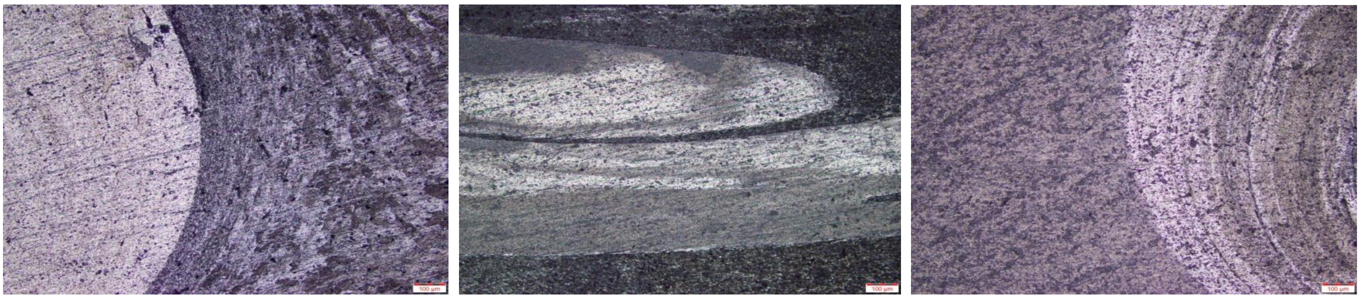


Figure 3.3: Figure showing the different zones of FSW.

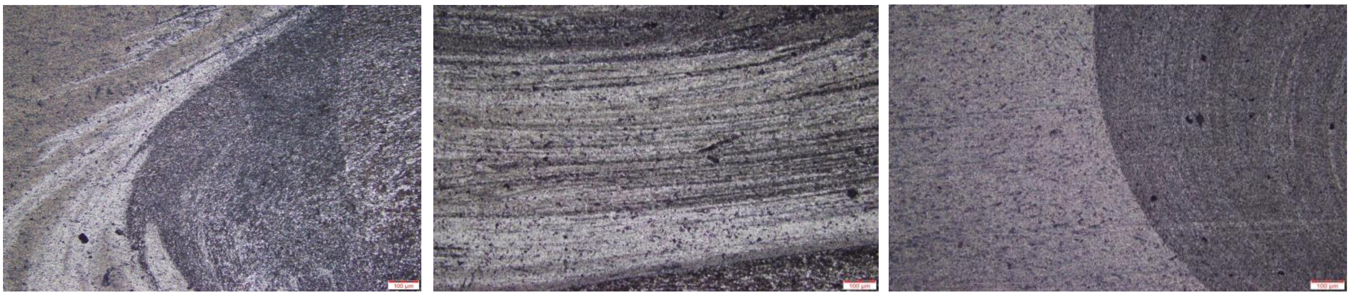


HAZ@2014 **(100X)** TMAZ@2014 NZ (100X) TMAZ@6082 **(100X)** HAZ@6082

Figure 3.4 Microstructure Welded Specimen No: 01 at 900rpm; 16 mm/min weld speed; 1.5 tilt angle

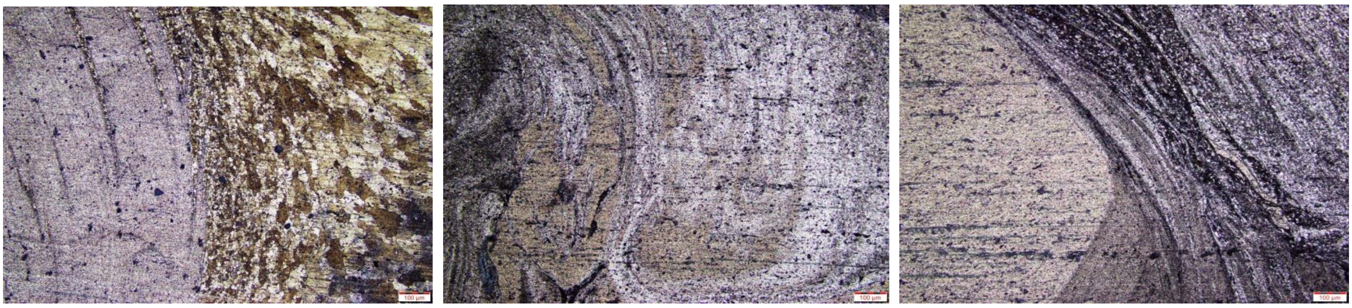
HAZ@2014 **(100X)** TMAZ@2014 NZ (100X) TMAZ@6082 **(100X)** HAZ@6082

Figure 3.5 Microstructure of Welded Specimen No: 02 at 900rpm ;25 mm/min weld speed ;1.5 tilt angle



HAZ@2014 **(100X)** TMAZ@2014 NZ (100X) TMAZ@6082 **(100X)** HAZ@6082

Figure 3.6 Microstructure of Welded Specimen No: 03 at 1120rpm; 16 mm/min weld speed; 1.5 tilt angle



HAZ@2014 **(100X)** TMAZ@2014 NZ (100X) TMAZ@6082 **(100X)** HAZ@6082

Figure 3.7 Microstructure of Welded Specimen No: 04 at 1120rpm; 25 mm/min weld speed; 1.5 tilt angles

The microstructures of the welded samples from 1 to 4 with different regions are shown in the figure 3.4 to 3.7. The microstructure of the optimum weld which has the highest UTS of 151.16 Mpa was obtained for weld 1 and **74.32** MPa was obtained for weld 4 by the addition of TiO_2 powder during welding between the plates. The amount of the temperature generated in FSW usually depends on three parameters: distance of the shoulder and the grouping of the welding speeds and tilt angle.

3.5 Simulation of Friction stir Welded joint

3.5.1 Stimulation analysis of tensile test

The ANSYS Software was used for the simulation of friction stir welded joint. The simulation analysis performed was tensile test and moving heat source. The readings obtained in tensile test in Ansys software 18.1 are shown in table 3.4.

Table 3.4: Weld Specimen from 01 to 08 tensile reports from Ansys

Weld Specimen No.	(Input) Tensile Force Applied (KN)	(output) Equivalent Stress Obtained (MPa) max	(output) Total Deformation mm(Max)	Tool rotation speed RPM	Weld speed mm/min	Tilt angle °
1	5.28	157.68	0.123	900	16	1.5
2	3.76	112.63	0.088	900	25	1.5
3	3.44	106.19	0.083	1120	16	1.5
4	2.72	80.44	0.063	1120	25	1.5
5	5.04	138.37	0.108	900	16	2.0
6	3.64	103.62	0.0814	900	25	2.0
7	3.92	119.13	0.0936	1120	16	2.0
8	3.48	101.37	0.0796	1120	25	2.0

The simulation analysis of tensile test of weld 1were obtained by Ansys software as shown in figure 3.8. Also the figure 3.9 shows the comparision between experimental values and simulation analysis.

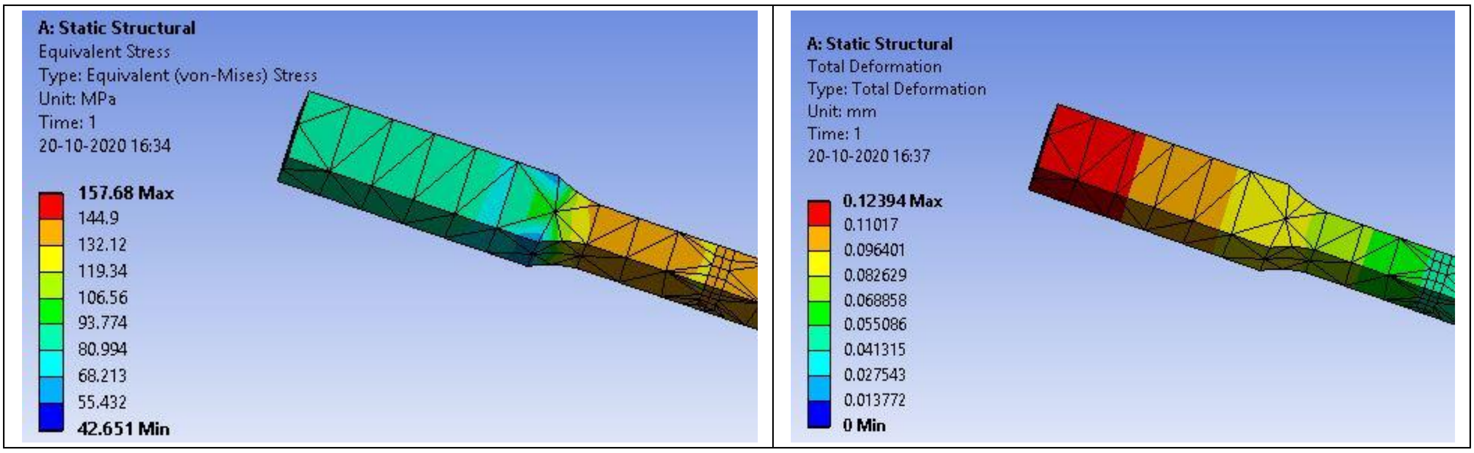


Fig 3.8 Ansys Simulation Analysis tensile test of Specimen No: 01

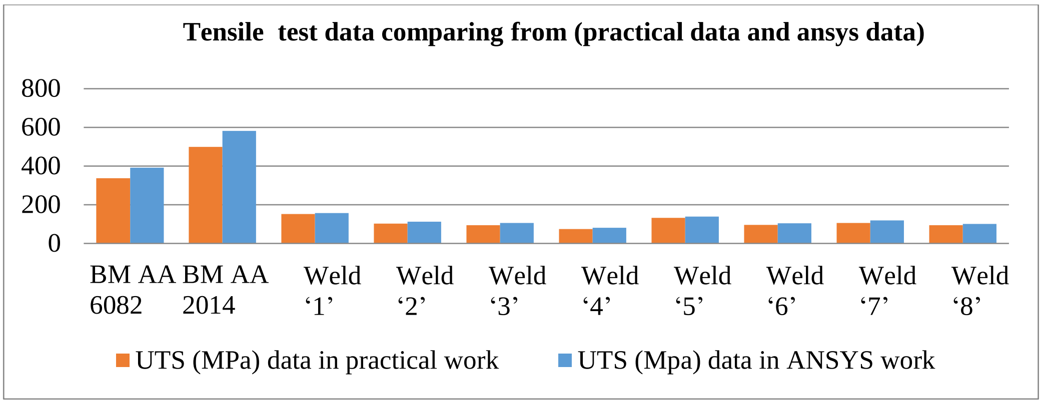


Figure 3.9: Tensile test data are comparison between experimental and ANSYS

3.5.1 Moving Heat Source (MHS)

The concept of Moving heat source is carried in Ansys Software which is similar to thermal analysis. The temperature (heat generated) automatically created by the input given here is initial temperature and the tool RPM and Feed rate & velocity is synchronized with time and the investigation is carried in Transient Thermal analysis. MHS is carried for all the weld specimen. The outputs of the results are shown below for Weld Specimen No: 01 and weld specimen No.02. The table 3.5 and 3.6 show the simulation analysis of moving heat source of friction stir welding process for weld specimen 1 and weld specimen 2.

Table 3.5: MHS data while recorded simulation in ANSYS 18.1 software

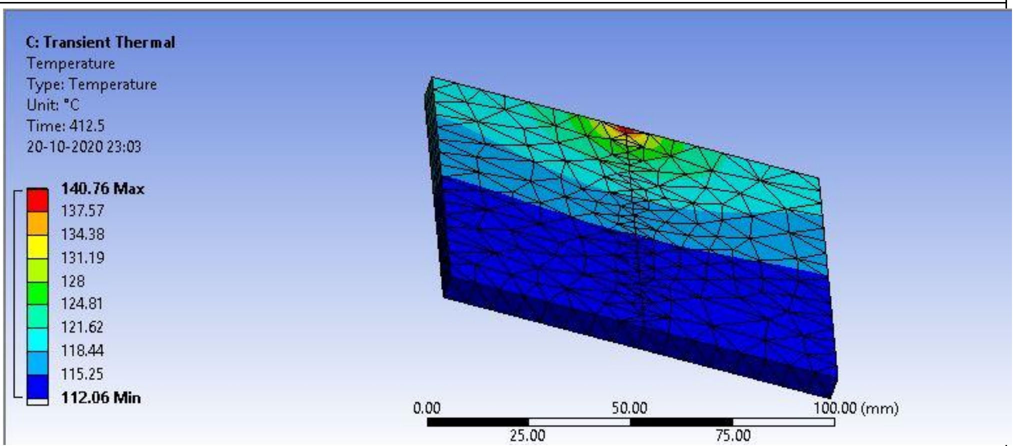
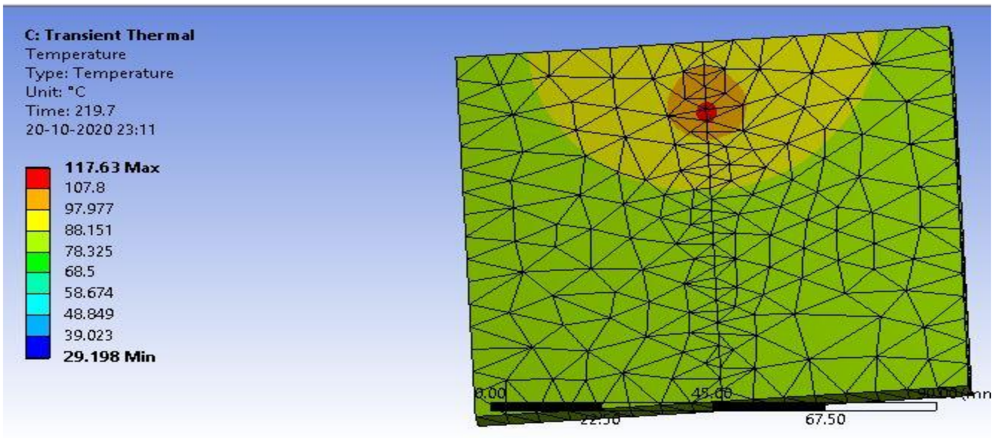
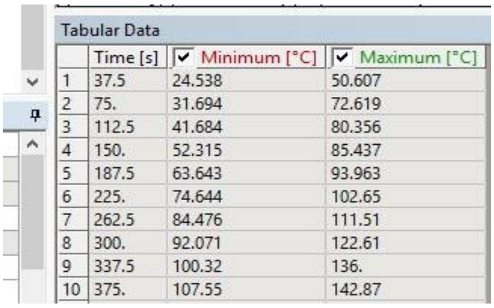
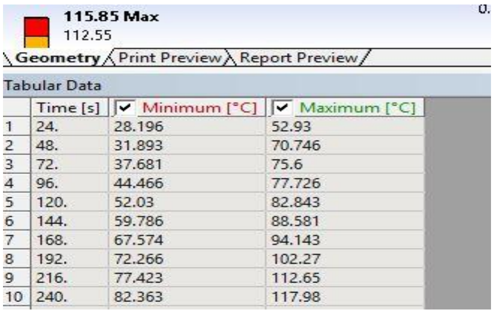
Weld Specimen No.	Temperature (^{o}C)max	moving Heat Source on specified alignment of friction Stir Welding of Aluminium dissimilar metal stimulation by the ANSYS 18.1 software
1	141	
2	116	

Table 3.6: MHS data while recorded simulation in ANSYS 18.1 software

Weld Specimen No	Input Tool RPM	Input feed rate mm in min/ Tilt ^{o} Angle	Temperature flowing at ten segments based time Minimum and maximum temperature

1	900	16mm & 1^o	
2	900	25mm & 1^o	

Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]
1	37.5	24.538	50.607
2	75.	31.694	72.619
3	112.5	41.684	80.356
4	150.	52.315	85.437
5	187.5	63.643	93.963
6	225.	74.644	102.65
7	262.5	84.476	111.51
8	300.	92.071	122.61
9	337.5	100.32	136.
10	375.	107.55	142.87

115.85 Max
112.55
Geometry Print Preview Report Preview
Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]
1	24.	28.196	52.93
2	48.	31.893	70.746
3	72.	37.681	75.6
4	96.	44.466	77.726
5	120.	52.03	82.843
6	144.	59.786	88.581
7	168.	67.574	94.143
8	192.	72.266	102.27
9	216.	77.423	112.65
10	240.	82.363	117.98

The Temperature distribution at different segments was also obtained by simulation analysis for flowing heat during FSW process. It was observed that heat variation was due to FSW parameters like tilt angle, tool speed in RPM, feed rate mm/min during moving of welding tool on welding samples. The table 3.7 show temperature distribution during simulation analysis and figure 3.10 shows the comparision between experimental and simulation analysis.

Table 3.7: Temperature data while recorded simulation in ANSYS 18.1

Weld/Temp	weld1	weld2	weld3	weld4	weld5	weld6	weld7	weld8
T1	50.607	49.05	61.439	81.439	98.5	81.096	115.91	109.78
T2	72.619	66.955	88.593	103.14	109.83	98.543	125.31	115.63
T3	80.356	71.75	98.049	108.99	114.89	103.32	131.54	118.39
T4	85.437	73.94	104.28	111.73	123.25	105.57	141.97	124.62
T5	93.963	79.006	114.77	117.96	131.76	110.61	152.51	131.63
T6	102.65	84.766	125.39	124.96	140.43	116.27	163.15	138.6
T7	111.51	90.445	136.26	131.9	151.26	121.84	176.42	148.59
T8	122.61	98.675	149.99	141.93	164.25	129.9	192.31	161.11
T9	136	109.03	166.42	154.52	170.68	140.05	200.11	167.29
T10	142.87	114.17	174.64	160.76	168.19	145.12	196.91	164.64

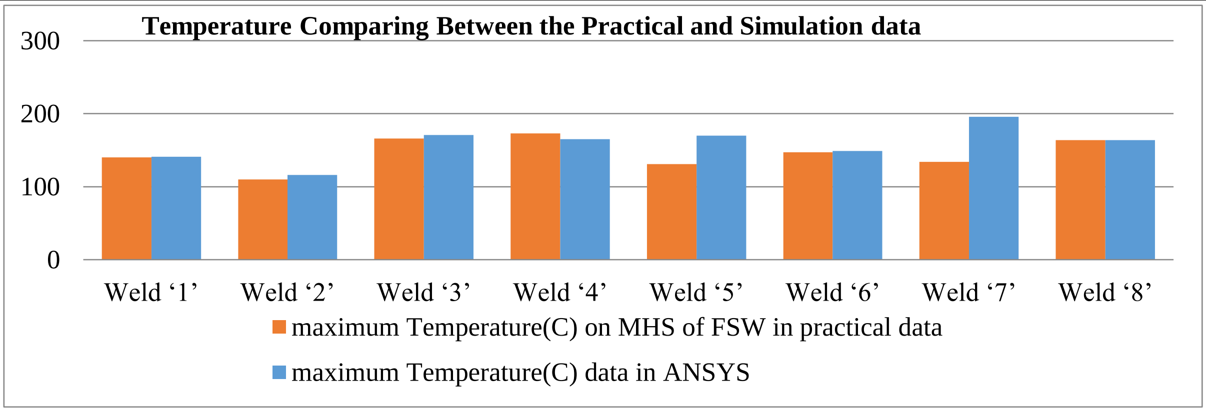


Figure 3.10: Temperature distributing on MHS of friction stir welding

IV. CONCLUSION

The results show that the process parameters influence the mechanical and metallurgical properties of Friction Stir Welded dissimilar aluminium alloys. From the Investigation data and from the Methodology study the values obtained practically were similar to the values obtained through the Ansys Software 18.1. The following data were concluded from the present investigation.

I. From the Tensile Test report the Maximum Peak stress obtained was 151.1MPa on a digitally Automated UTM machine at 900 rpm, 16mm/min and tilt angle of 1.5° by using hexagonal tool pin.

II. From the Tensile Test report the Minimum Peak stress obtained was 74.32MPa at 1120rpm and 25mm/min, tilt angle 1.5°.

III. From Izod Impact Test report the maximum impact value obtained was 10.5 joules on a digitally Automated impact tester machine at weld specimen.01 and 900rpm and 16 mm/min speed using Hexagonal tool pin. And minimum impact values obtained were 8.0 joules on a digitally automated impact test machine at weld2, weld3, weld8 due to same values.

IV. From Microhardness Test is conducted at two point in each location and it is observed that Maximum Hardness is obtained to specimen no: 01 that is FS welded at 900rpm;16 mm/min weld speed and 1.0 tilt angle. The obtained hardness is at HAZ@AA2014-83.9HV and 81.9HV, at TMAZ@AA2014-6.8HV & 68.1HV, at NZ@94.9HV & 96.6HV and at TMAZ@AL6082-55.7HV & 59HV, at HAZ@AA6082-65.8HV & 62.7HV. Lowest Hardness is obtained at Weld specimen no:03 which is welded at 1120rpm ,16mm/min weld speed and 1.5 tilt angle. The obtained Hardness is at NZ is 62.2HV & 60.6HV .

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