

AN EXPERIMENTAL INVESTIGATION ON EFFECTS OF WELDING PARAMETERS ON FRICTION STIR WELDING OF ALUMINUM ALLOY

Dhruv patel, Satish Shah, H. G. Katariya

Mechanical. Engineering department., BVM Engineering Collage, Vallabh Vidhyanagar, Gujarat, India

ABSTRACT

Friction stir welding is solid state welding process which can be used to produce better welds between similar and dissimilar materials. Dissimilar welds which include welds between the different series of aluminum alloys, aluminum to magnesium alloys, steel and titanium has been successfully produced by friction stir welding. In this study alloy which is used for FSW is Al6082, joint by various welding parameters of friction stir welding. The present study includes the effect of various friction stir welding parameters on FSW and tensile strength and macro testing has been examined of welded joints.

KEYWORDS: Friction stir welding (FSW), welding parameters, Mechanical properties, Macro testing

I. INTRODUCTION

Friction stir welding (FSW) is a solid-state joining technique that uses a non-consumable tool to join two facing work pieces without melting of work piece material. Heat is generated by friction between the rotating tool's shoulder and the work piece material, which leads to a softened region near the FSW tool and faces of material. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and creates the hot and softened metal by the mechanical pressure and tool rotation, much like joining clay, or dough.

Principle of operation: A rotating cylindrical tool with a profiled pin is feed into a butt joint between two clamped workpieces, until the shoulder, which has a higher diameter than the pin, this shoulder touches the surface of the workpieces.

II. EXPERIMENTAL PROCEDURE

2.1 Selection of material for joint

Friction stir welding is the better joining technique for high melting materials such as titanium, zinc steels and for an alloys of various materials .Aluminum alloys and other material is being used in marine, aerospace, automotive, rail and construction industries. Aluminum alloys are majorly used for friction stir welding for its properties. The stiffness to weight ratio, low density, high damping capacity etc. is some of them. These properties had enabled them to become a major part of automotive industry. A reduction of 20- 70% of total weight of the components can be achieved. Aluminum alloys are characterized with less melting point, higher thermal expansion and therefore welding of Al alloys using conventional methods will lead to cracks.

There for alloys which is used for the friction stir welding experiment is Al6082 having composition of alloys

(1)Al6082:

Mg	Si	Fe	Cu	Mn	Cr	Zn	Other elements	Al	Ti
0.6-1.2%	0.7-1.3%	0.5%	0.10%	0.40-1.0%	0.25%	0.20%	0.05-0.15% of total	95.2-98.3%	0.10%

2.2 Selection of welding parameter

Friction stir welding is mostly affected by the following 3 parameter,

- (1) Tool rotational speed
- (2) Welding speed
- (3) Tool tilt angle

Tool rotational speed

For getting the highest tensile strength which is up to 80% of the base material strength, the rotational speed for the experiment should be nearer to 1000 rpm. The available rotational speed for vertical milling machine are 180, 250, 355, 580, 765, 1070, 1500 rpm. So, three speeds for experiment would be 765, 1070 and 1500.

Welding speed

A best quality weld joints are obtained up to speed of 50mm/min. However, at increase in speed up to 200mm/min, a groove –like defects is observed in FSW joint. Such defects can seriously decrease the mechanical properties of weld joint. Increasing the welding speed will effect on tensile properties. The available welding of vertical milling machine is, 14, 20, 31.5, 50, 80, 112, 160, 224, 315, 450, 630 mm/min. The welding speed for experiment 20mm/min,31.5 mm/min and 50 mm/min so that we can get good quality joints.

Tool tilt angle

Various tool tilt angle available for friction stir welding are 1to 5 Available tool tilt angle for milling machine are 0to 6 .And the selected angles 1, 2 and 3.

2.3 Selection of material for tool

Welding tool design is critical in FSW processes Optimizing tool geometry will generate more heat there by breaking the oxide layer, higher welding speeds etc. Tool material should having high hardness at elevated temperatures and should maintain that hardness till the end of the FSW process.

H13 tool steel is usually used for FSW. For friction stir welding number of materials is used, H13 steel, High carbon steel, Nickel alloys, Tungsten carbide and cobalt materials

Tool material	Suitable weld material
Tool steels	Al alloys, aluminum matrix composites and copper alloys, Mg alloys
WC-Co	Mg alloys, mild steels
NI alloys	copper alloys
WC composites	Al alloys and low alloys steel Mg alloys, Ti alloys
W alloys	Ti alloys and stainless steel alloys

Among the all of above material H13 steel material is used for experiment.

Composition of H13 steel

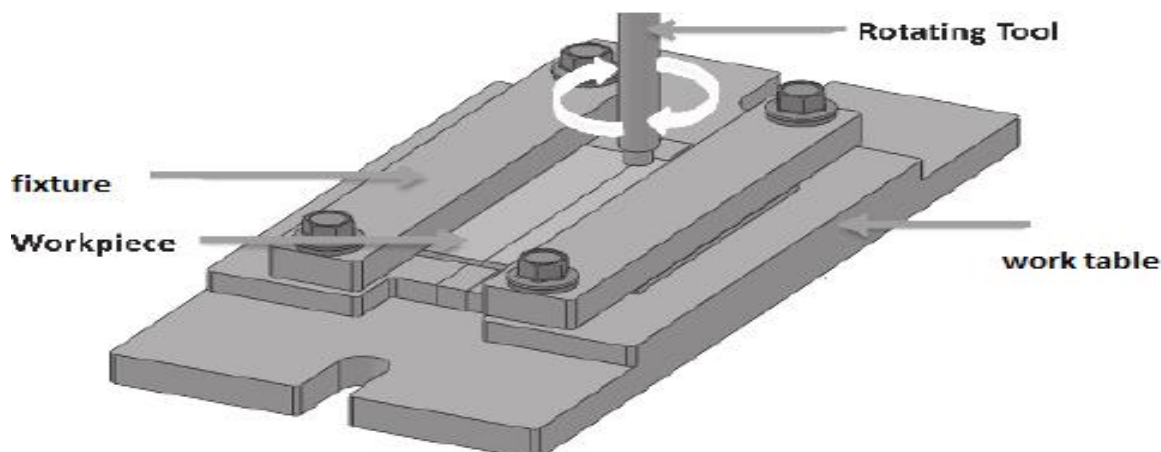
C	Si	Cr	Mo	Vanadium
0.40%	1%	5.30%	1.4%	1.0%

2.4 Design of Experiment

- Design of experiment as per taguchi method
 No of factors:03 with levels of :03
 Tool rotational speed (A)-765, 1070 and 1500 rpm
 Welding speed (B)-20, 31.5 and 50 mm/min
 Tool tilt angle(C)-1, 2, 3

Experiment No.	A(tool rotational speed)	B(welding speed)	C(tool tilt angle)
1	765	20	1
2	765	31.5	3
3	765	50	2
4	1070	20	3
5	1070	31.5	2
6	1070	50	1
7	1500	50	2
8	1500	20	1
9	1500	31.5	3

III. EXPERIMENTAL DETAILS

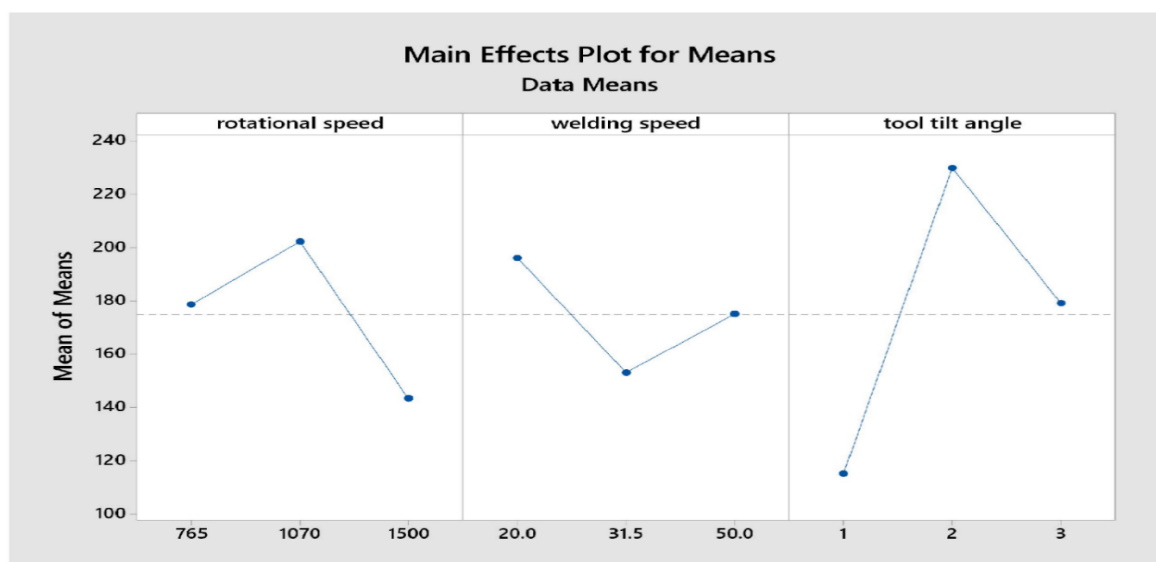


The figure shows the experimental setup for friction stir welding. As shown in fig. the material is placed in fixture and friction is generated by the rotating of tool so that weld has been generated.

IV. RESULTS & DISCUSSION

4.1 Result analysis:

1) Mean of mean for tensile strength:



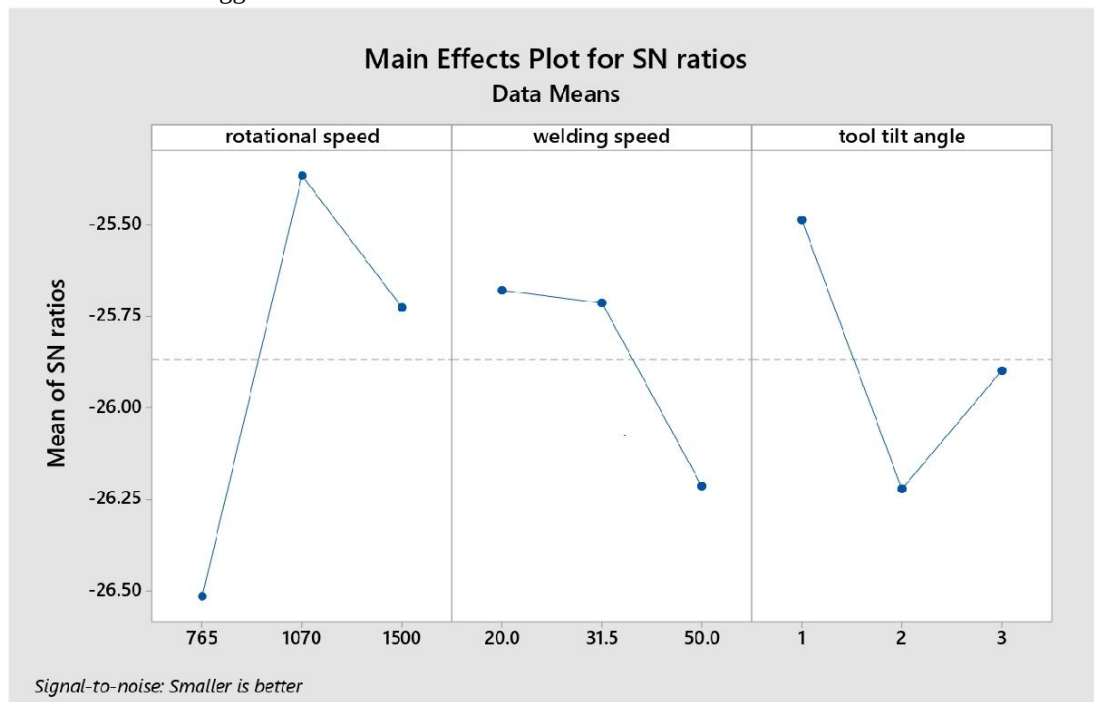
2) SN ratio for tensile strength:



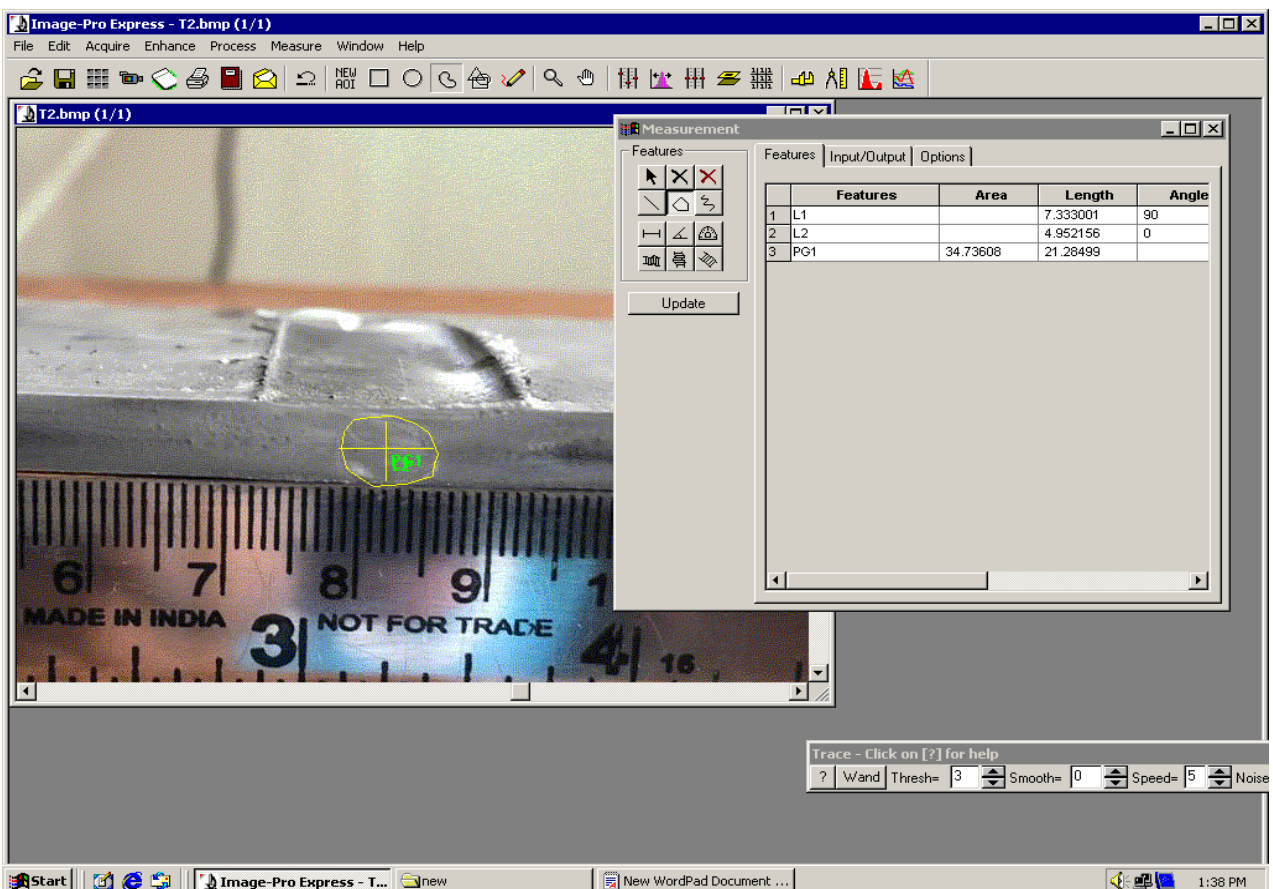
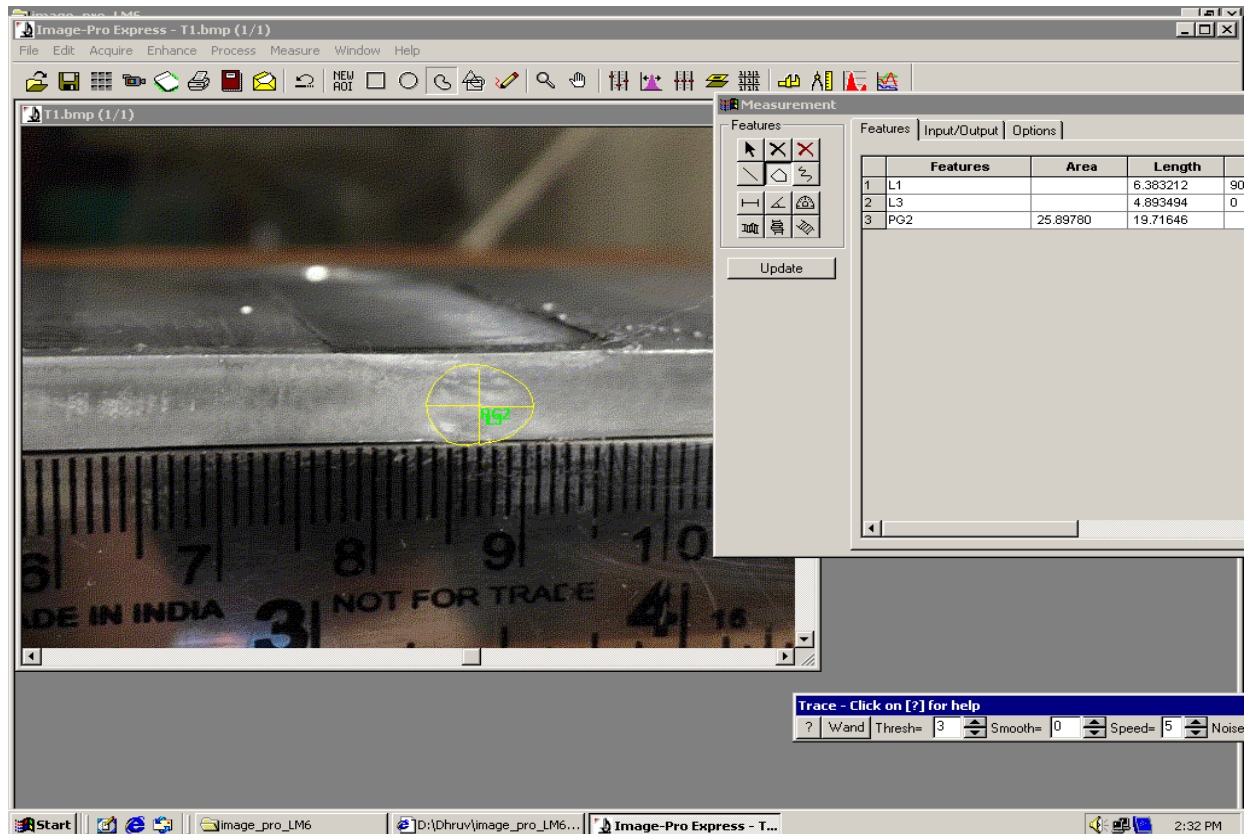
3) Mean to mean ratio for weld nugget area:

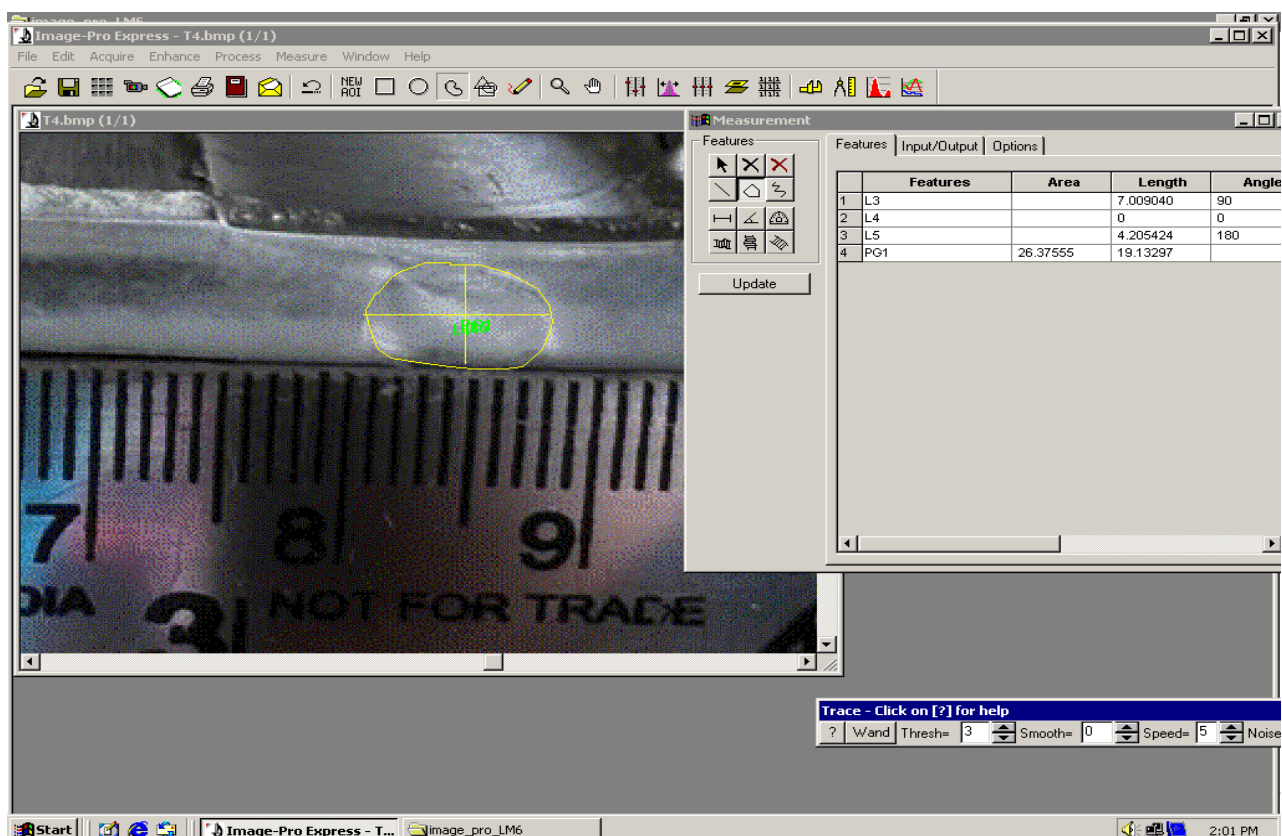
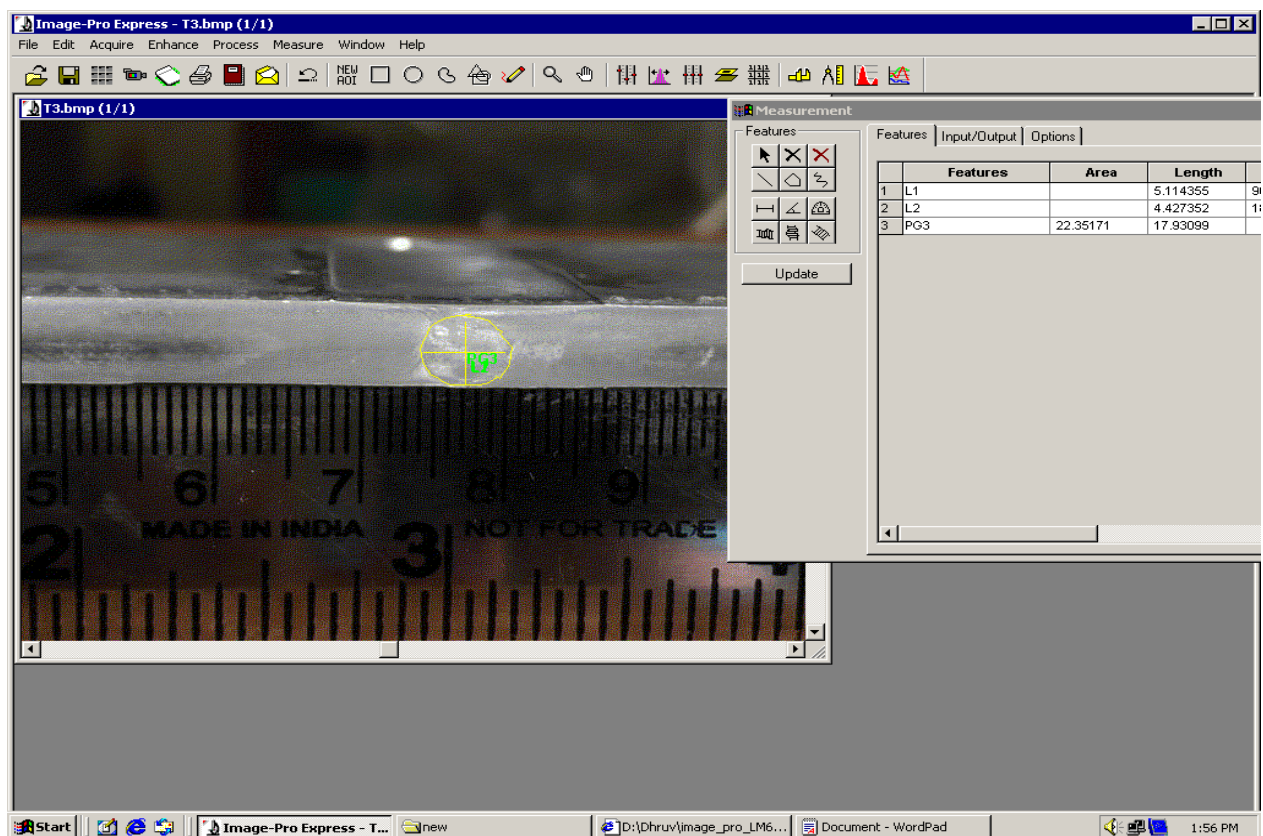


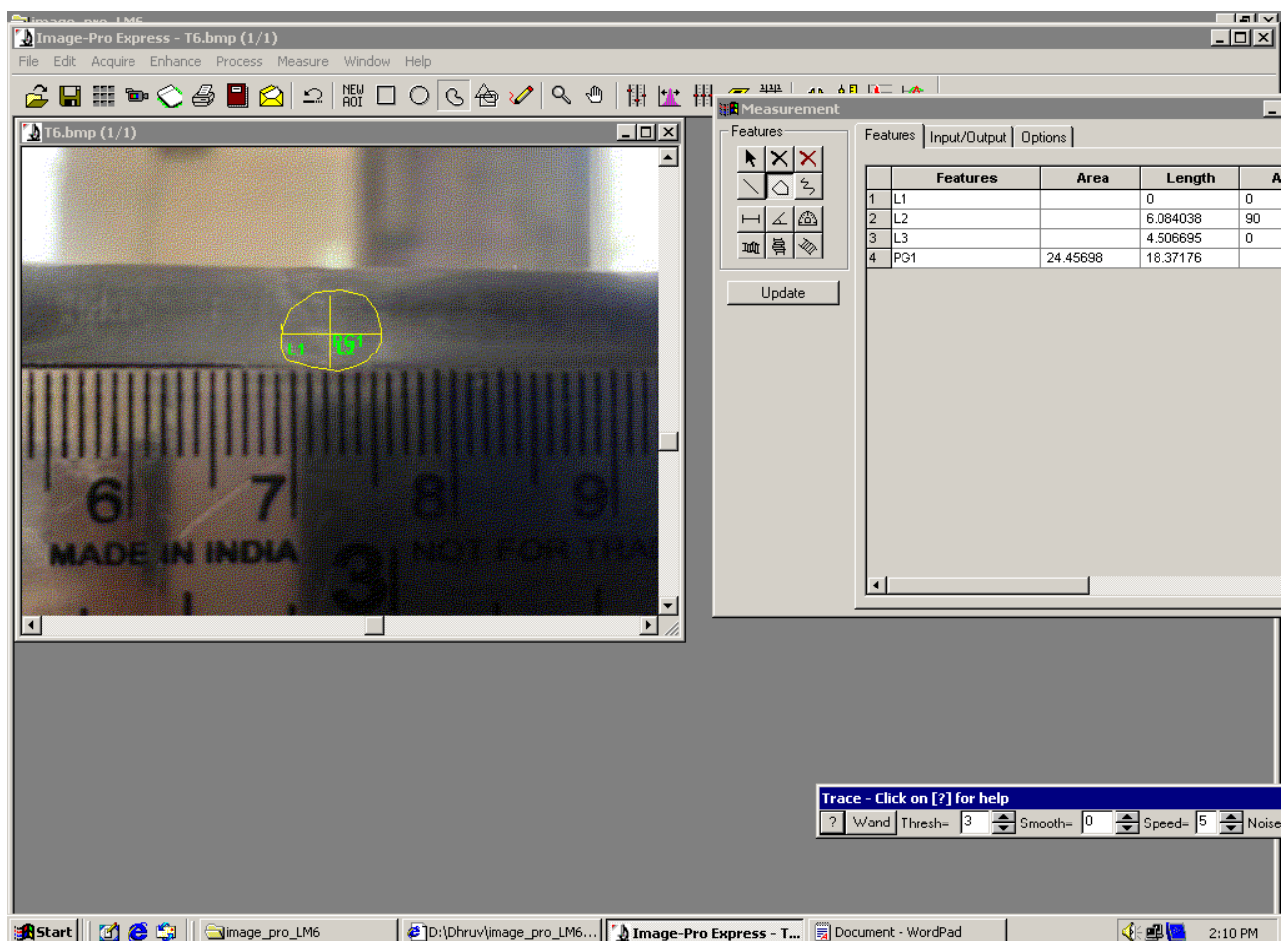
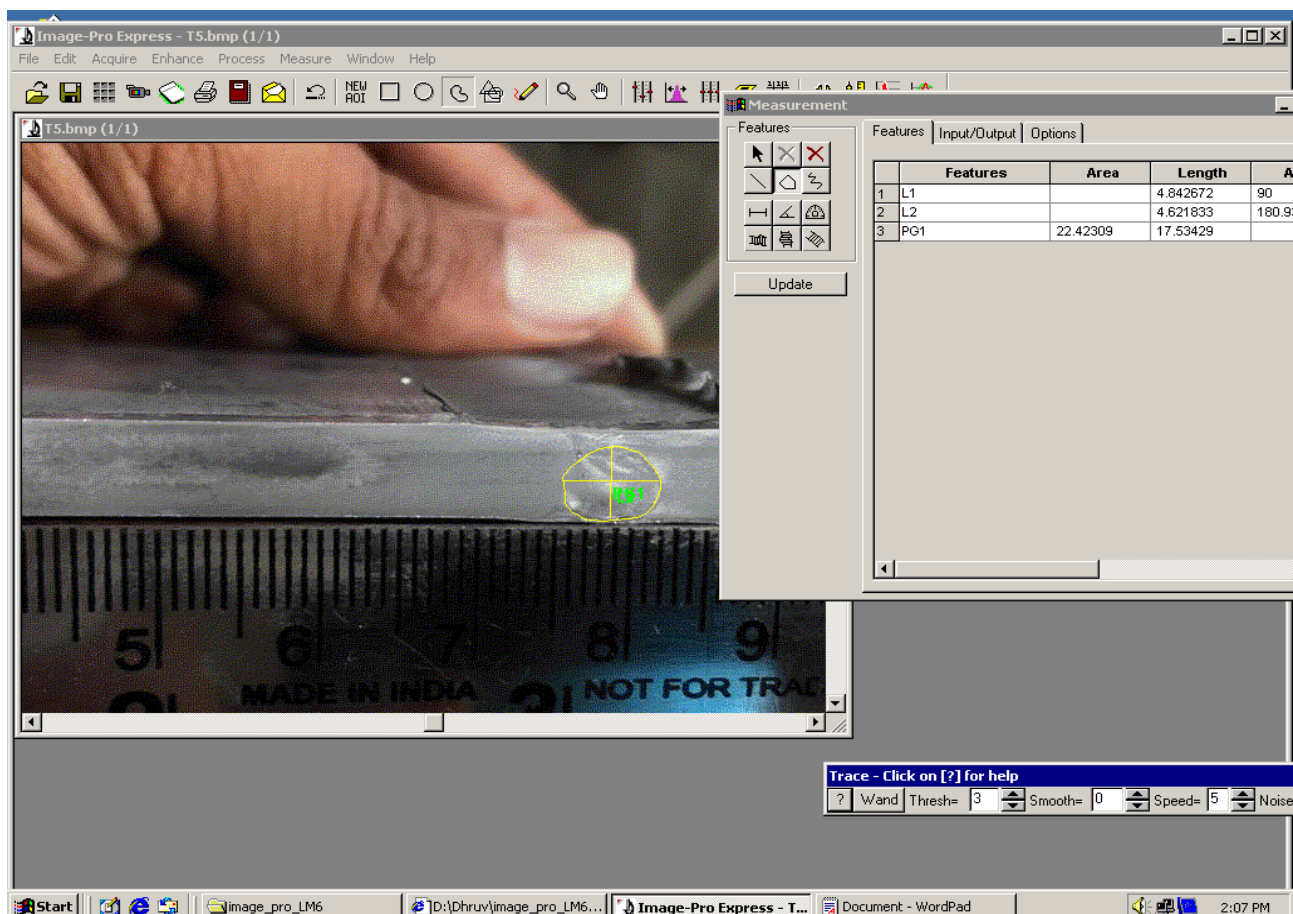
4) SN ratio for weld nugget area:

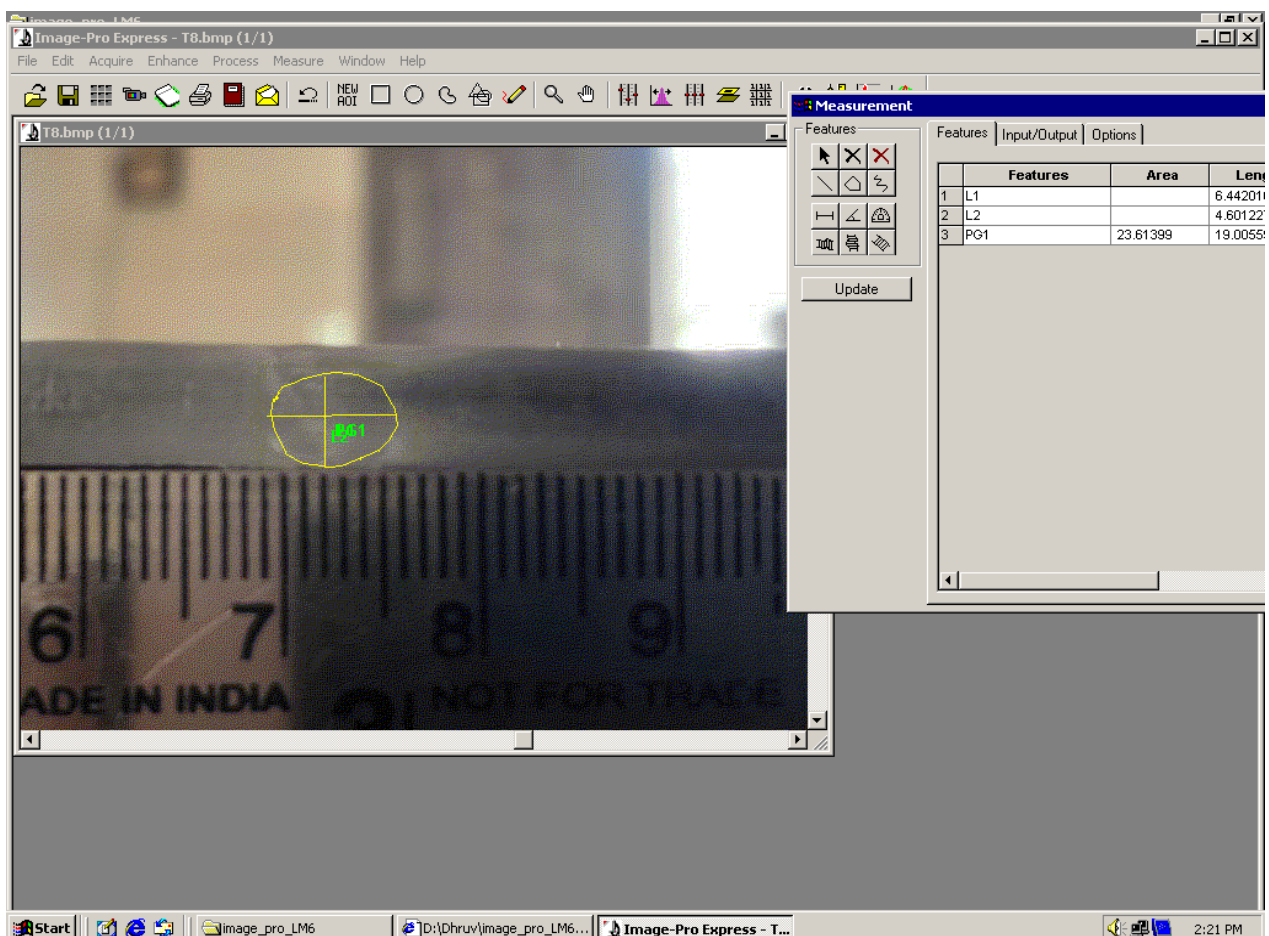
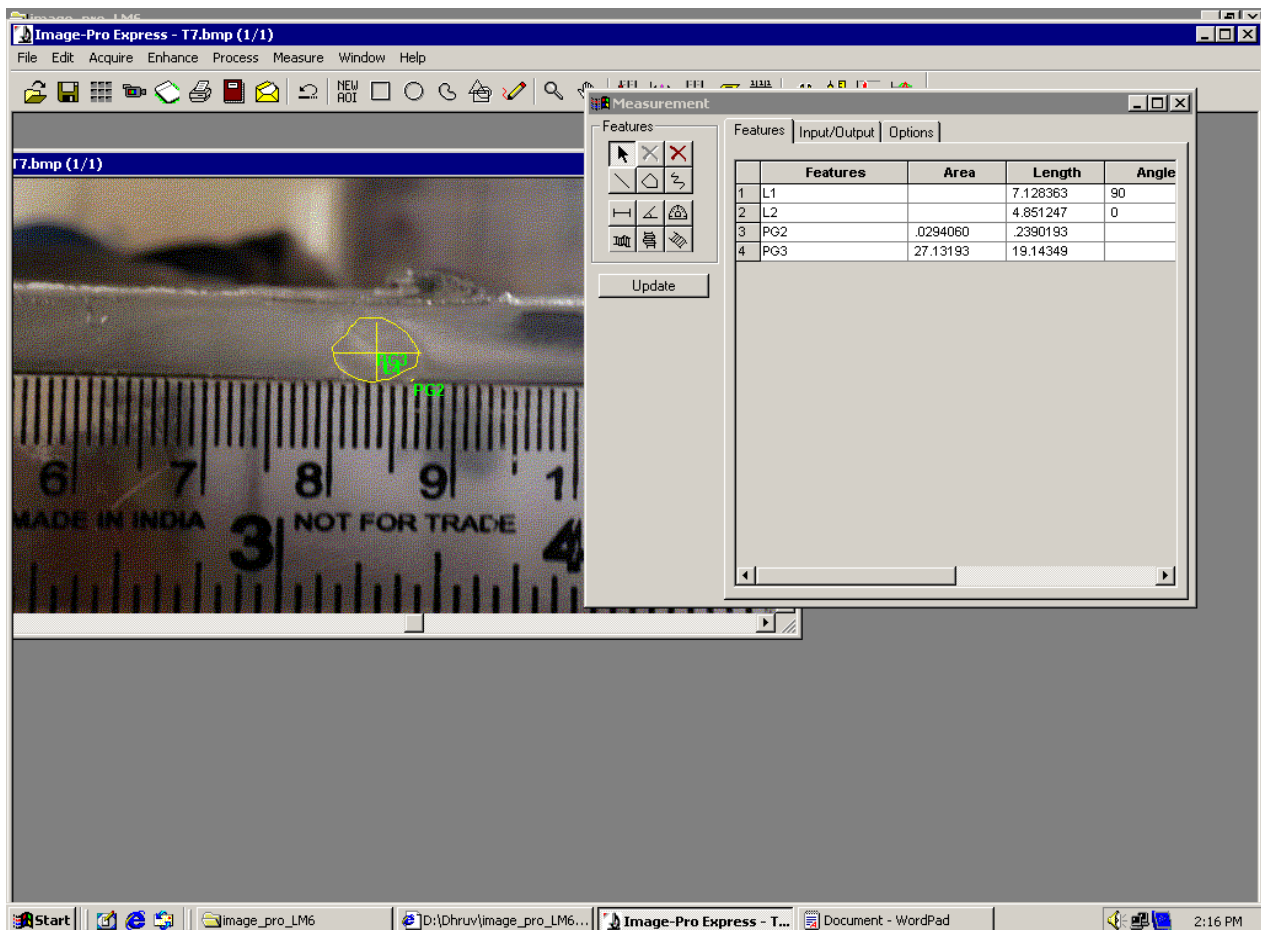


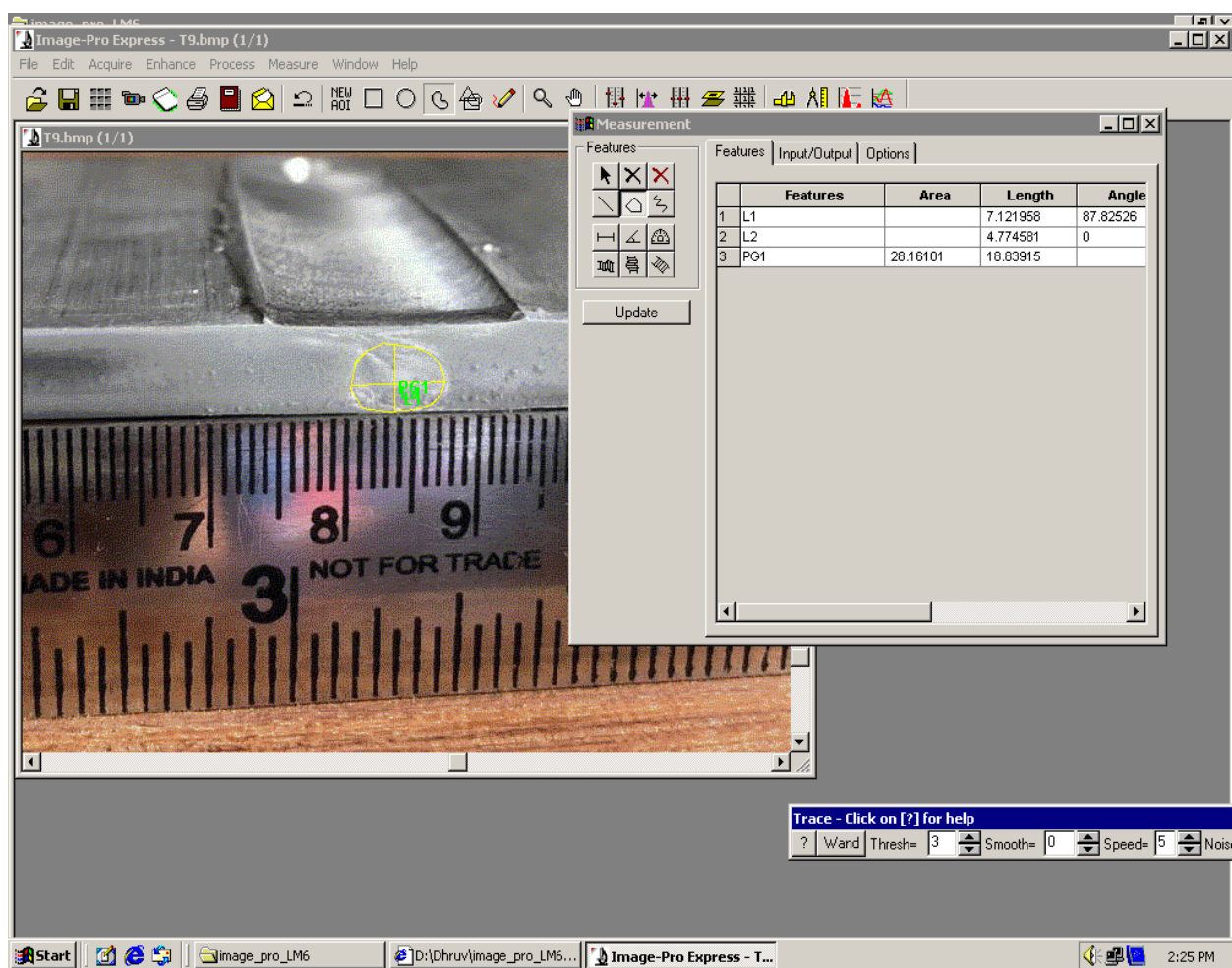
4.2-Macro testing











4.3 Observation from result:

Observations from the results of experimentation carried out,

- 1) Material tested is Al6082.
- 2) Material thickness 6mm.
- 3) The joint which is made by joining of two specimen is Butt joint.
- 4) Total nine specimens are joined using friction stir welding with different combination of parameter of the process, welding speed, tool rotational speed and tool tilt angle.
- 5) Table 6.1 shows the combination of these process variables, as per DOE, Taguchi method, L9 orthogonal array.
- 6) The two output parameters are measured and recorded, namely, the ultimate tensile strength of each specimen and the c/s area of nugget are measured using image analysis software.
- 7) The result are analyzed using MINITAB software and plots are shown in fig 8.4.1 to 8.4.4.

Comments:

- 1) The maximum ultimate tensile strength is found with parameters of 1070 rpm, 20mm/min, and 2 degree. At same time, the c/s area measured was found to be 19.25 mm². The weld joint efficiency, for the same parameters is computed 89.51% which is maximum, among all the combinations.
- 2) The sample has been cracked just after welding operation, the parameter combination is 1500 rpm, 31.5 mm/min, 1 degree.
- 3) The tensile test specimen failure has been studied, in the 5 cases, the failure has been found from the weld as per table and for 4 cases (t2, t4, t7, t9) it has failed from base metal. The cracked specimen has been also tested for UTS as a very small crack has been found after welding in the specimen at the end of the plate, the reason of the crack may be unwarranted condition, while the weld was ended, hence the cracked weld length has been ignored and the remaining good portion has been tested.

Specimen No.	A	B	C	Observation	Failure location
T ₁	765	20	1		From the weld
T ₂	765	31.5	2		From the base metal
T ₃	765	50	3		From the weld
T ₄	1070	20	2		From the base metal
T ₅	1070	31.5	3		From the weld
T ₆	1070	50	1		From the weld
T ₇	1500	20	3		From the base metal
T ₈	1500	31.5	1		From the weld
T ₉	1500	50	2		From the base metal

V. CONCLUSION

- The mechanism of formation of coherence generated frictional heat, which is caused by rotating the pin. As the process started, frictional heating softens (or plasticizes) the metal at joint, facilitating a stirring action of plasticized metal. Further heat is created by the plastic deformation becomes the major sources of heating as the weld progresses.
- The stir zone represents the region where there is considerable metal flow or stirring due to tool rotation. The heating combined with plastic deformation continually creates very fine grain, a process known as dynamic recrystallization. The fine grain structure associated with stir zone results in excellent mechanical properties. The stir zone microstructure is likely to vary from one side to other since the relative stirring material will be greater in the direction of weld travel. The heat deformation affected zone (HDAZ) is a narrow region surrounding the primary stir zone, which reveal small levels of deformation that occurs at the elevated welding temperatures. HAZ may also form.
- In order to successfully weld material with FSW, it is necessary for the material to flow at an elevated temperature. Therefore, flow stress as a function of temperature can be used to determine the FSW characteristics of a material.
- For Al alloys, temperature above 450° C are needed in order for sufficient metal flow in occur.
- The Al alloy used in the present work is Al 6082-T6, which is an Al-Mg-Si alloy. It is strengthened by precipitation hardening, by forming complex Al-Mg-Si compound fine particles, dispersed in matrix to strength it.
- Hence, while stirring the same heat treated structure is not obtained, but with condition of rotational speed of 1070 rpm, welding speed 20mm/min and tool tilt angle 2 has produced highest strength, with almost similar stir area of 19mm² (range is 18 to 22.5mm²). It implies that, a fine recrystallized structure has been produced in this case, which has created superior mechanical properties.
- Whereas, the other combinations have created almost same area but lower strength, implies that proper temperature distribution and stirring has not taken place, resulting into lower strength. No, significant presence of HDAZ and HAZ has been noticed adjacent to stir areas, as seen in macro examination.
- Also, the tensile specimen, failure has been observed in the base metal, suggesting that, weld zone is stronger. Hence, it is recommended that, combination 1070 rpm, welding speed 20mm/min and tool tilt angle 2, yields better mechanical properties, with reasonable area of bonding and without defects, for welding of Al6082T6. So, these are the FSW characteristics of 6082 T6.

VI. REFERENCES

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