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Experimental Analysis of AA7075 and AA6061 Stir Welded Joints with Dissimilar Friction

[1]N.Sandeep Kumar, [2]K.Suresh, [3]M.Surender, [4]Musthala Parushuram
[1,2,3]Assistant Professor, [4]UG Student, [1,2,3,4]Department of Mechanical Engineering, Kasireddy Narayanareddy College of Engineering and Research, Hyderabad, Telangana

ABSTRACT
Since its creation, friction stir welding (FSW) has swiftly gained popularity and found use in a variety of industries, including shipbuilding, railroads, aircraft, and notably the manufacturing of aluminium alloys. A spinning, non-consumable tool is used in the operation to create frictional heat in the work piece. Because to the simultaneous impacts of extreme plastic deformation and frictional heating during welding, FSW had an impact on both the aluminium matrix and the reinforcing particles. Moreover, the development, dissolution, and re-precipitation of hardening precipitates are all impacted by frictional heating. The quality of the weld is determined by FSW process variables such tool revolution, transverse speed, and tilt angle. Aircraft engines, automobile parts, and energy saving strategies in general have promoted the interest and research in the field of lightweight materials, typically on alloys based on aluminum. Aluminum AL6061-T6 isa common alloy which is used for many purposes since it has the superior mechanical properties such as hardness and weld ability. It is commonly usedin aircraft, automotive and packaging food industries. In the present investigation work, friction stir welding of 6061 aluminum alloy and 7075 aluminum alloy and effect of process parameters rotational speed, transverse speed , and tilt angle were investigated. The main objectives of the present investigation are to study; i) the friction stir welding of 6061 and 7075 aluminium alloys. ii) Mechanical properties were evaluated by the tensile test on UTM, Hardness test on Brinell hardness tester (Rockwell).
Key words: Friction stir welding (FSW), Aluminum AL6061-T6, 7075 aluminum alloy, UTM, Brinell hardness tester (Rockwell),

INTRODUCTION:

The development of surface and bulk reinforcement MMCs using FRICTION STIR WELDING (FSW), a relatively new technique, is possible with aluminium alloys from the 7000 range, particularly 7075. For academics and technicians, refining aluminium and its alloys has long been a significant difficulty. Because of its low density and excellent strength to weight ratio, aluminium and its alloys are primarily employed in the automotive and aerospace sectors. When traditional metals and alloys reach their limitations of growth, metal-matrix composites (MMCs) are a new class of structural materials that, with correct processing, may produce MMC with dramatically better features including reduced density, greater specific modulus, and higher specific strength. The addition of ceramics reinforcements (SiC) raise performance limits of the aluminum alloy 7075 and however the presence of reinforcements in matrix makes it brittle. Instead of bulk reinforcements, if the ceramic particle would be added it could improve the wear resistance and hardness. **R.S.Mishra et al.** demonstrated that the FSW is a versatile technique with a compressivefunction for the fabrication, processing and synthesis of materials. The microstructure and mechanical properties of processed zone can be controlled by optimizing the tool design and FSW parameters. The depth of the processed zone can be adjusted by changing the length of the tool pin, and large volume of materials can be produced by multiple passages. The effect of particle refining, mixing and consolidation of powder mixtures provided by FSW can be investigated without the interference of reaction between reinforcement and matrix. **Adem Kurt et al.[1]** It has been demonstrated that FSW was an appropriate method to modify the microstructure and mechanical properties of Alalloy. In general, FSW decreased the grain size and increased the hardness of processed material. Increased rotation speed and low travelling speeds caused more heat input whichaffects the thickness of the surface layer, grain size and distribution of the precipitates and reinforcement particles. A good dispersion of SiC can be obtained for the composite layer produced by ω=1200rpm and v=20mm/min. Good interfacial conditions between particle and base metal can be formed during this solidstate process which avoids the chemical reactions on the interface. The microhardness of the plain surface of aluminum increased significantly with increasing travelling speeds. With further research efforts and increasedunderstanding, FSW could be conducted for mechanical behavior of these composites, like fatigue and creep response and new tool design for uniform distribution of reinforcement particles into the matrix materials. **Ning sun et al.** reported that friction stir processing (FSP) is a recent outgrowth of the friction stir welding (FSW) process and relies on solid state deformation to modify the surface of the working a surface/material. This is to eliminate casting defects and refine the microstructure to improve their mechanical properties and enhance corrosion resistance. Such improvements have important implications for manufactured components for a variety of automotive and other industrial applications.

Asghar abasi et al. [8] studied the effect of Reinforcement of TiB2 particles by friction stir welding. In this work friction stir processing was utilized to successfully disperse and embed TiB2 particles with global size of 2.62 μm in Al 7075 increasing the rotational speed caused a more uniform distribution of TiB2 particles micro-hardness of the cross section and tensile test result were also evaluated. The micro- hardness values of produced composite surface raise with increasing the rotational and traverse speed andimproved almost 3 times as compared with base aluminum. Tensile test result shows rising in yield strength by more than two times of base metal. The traverse speed to 20mm/min improves the hardness of surface layer composite. **Marek St. Weglowski et al.** were demonstrated that this technology offers control over shsping the functional properties of materials being processed. FSW consists in heating and plasticizing a material as a result of friction with a tool, provided with a probe, rotating and moving along an element surface subjected to processing. Today's state of FSW/P (Friction stir welding/Friction stir processing) research by Z.Y.Ma et al.[5],[6] and M.Shamanian et al.[7] Hardness is high for FSP materials. The primary research on friction stir processing focuses on aluminum alloys. Applying this technology for processing other alloys and materials including vanadium alloy joining and processing. One is the tool wear in processing reinforced composite materials. The other challenge is hoe to increase the joining strength and improve the fatigue property of FSW composite materials.

EXPERIMENTATION

Material selection: It includes the selection of aluminium alloys of 6061 & 7075; required dimensions are taken 150*100*6 mm^3.

Chemical Composition of Al6061-T6

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others	Al
6061-T6	0.4-0.8	0.7	0.4	0.15	0.8-1.2	0.35	0.25	0.15	0.05	95.8 -98.6
7075-T6	0.40	0.50	1.2-2.0	0.30	2.1-2.9	0.28	5.1-6	0 .20	0.05	87.1 -91.4

EXPERIMENTAL SETUP

A friction stir welding machine was used for friction stir welding (FSW) of aluminium alloy. The machine was a maximum speed of 1800rpm and 5.5 kW/rpm. The materials used in thiswork are commercial Al 7075 alloy and Al 6061 (tempered condition) rolled plates with nominal composition as shown in table. The surface plates were grinded at the place welding to be performed before processing. Work pieces were prepared with respective length, width, thickness. The alloy plates are fitted in the machine rigidly. A hardened HSS tool was used that consists of a shoulder with diameter of 16mm, pin with a tapper diameter of (2 x 3)mm and length 2mm respectively. This tool is fitted into the tool holder and work piece is rigidlyclamped to machine table using fixtures.

SPECIFICATIONS:

DESCRIPTION	DEMENSIONS
Machine type	Semi automatic(FN2 V)
Overall Dimensions (LxW)	1520 x 310 mm
Clamping Length (LxW)	1350 x 310 mm
Power operated table tranverse	800 mm
Power operated table longitudinal	400 mm
Power operated table cross vertical	265 mm
Number of speeds	18
Speed range	35.5 – 1800
Main motor	5.5/1500 kW/rpm
Feed motor	1.5/1500 kW/rpm
Space required (LxBxH)	255 x196 x197 mm

Welding:

The welding processed here is friction stir welding. **Friction stir welding** (**FSW**) is solid- state joining process that uses a non-consumable tool to join two facing work pieces without melting the work piece material. Heat is generated by friction between the rotating tool and the work piece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes thetwo pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool, much like joining clay, or dough. It is primarily used on wrought or extruded aluminium and particularly for structures which need very high weld strength. FSW is also found in modern shipbuilding, trains, and aerospace applications.

PRINCIPLE OF OPERATION

A rotating cylindrical tool with a profiled probe is fed into a butt joint between two clamped work pieces, until the shoulder, which has a larger diameter than the pin, touches the surfaceof the work pieces. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. After a short dwell time, the tool is moved forward along the joint line at the pre-set welding speed. Frictional heat is generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the tool is moved forward,a special profile on the probe forces plasticized material from the leading faceto the rear, where the high forces assist in a forged consolidation of the weld. This process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

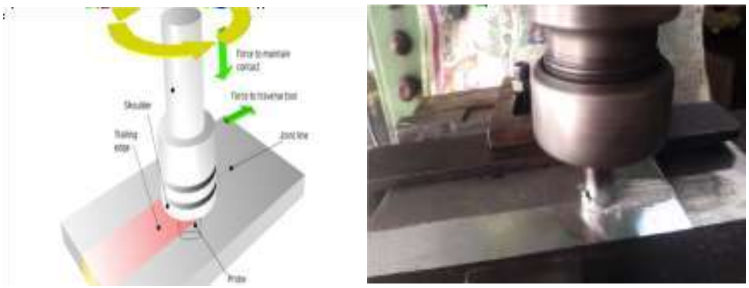


Fig. 1 Friction Stir Welding

FRICTION STIR WELDING PROCEDURE

TOOL: HIGH SPEED STEEL MATERIAL : Al 6061-T6 &Al7075-T6

The process of friction stir welding is done on the RETROFITTED LATHE. After removing a small layer of the work piece at the borders of Al 7075 & Al 6061.then the work pieces are ready for the machining process. These work pieces are taken that a piece of Al 7075 &and a piece of alAl6061 are placed side by side on the machining table and these pieces are clamped tightly by the clamps that, not to slide or move while welding is done. The cylindrical tool with probe is fitted to the head of the lathe. Then switch on the machine thenthe tool is start rotating, with the help of mechanical drives lift the lathe table towards the tooland the while tool is rotating insert the tip of the tool into the plates that, the probe of the toolis placed to the half of Al 6061 and Al7075 plates.

OBSERVATIONS

S. no.	Speed (rpm)	Feed(mm/min)	Tilt Angle
1	560	20	10
2	560	30	20
3	560	30	30
4	1120	30	20
5	1120	30	30
6	1120	40	10
7	1400	20	30
8	1400	30	10
9	1400	40	20

MECHANICAL TESTING

BRINNEL HARDNESS TEST-INTRODUCTION:

For Metallurgists, Hardness Testing is a collection of different methods formeasuringa definite characteristic of metallic materials, namely:

a) The resistance to penetration of a specific Indenter (defined by fixed form andproperties),

b) Under the application of a certain static force

c) For a definite time,

d) Using precise measuring procedures.

The result, usually expressed by a number or by a range of numbers, must be qualified by anaccepted convention indicating exactly by which one of the possible methods such result wasobtained. Hardness so defined is not an intrinsic property of any material, (likedensity or melting point), it is rather a characteristic deriving from the composition, the thermal and mechanical history of the material, and essentially from the structure (or more properly the microstructure) of the specimen involved. The variety of methods and conditions developed for hardness testing is a consequence of the fact that no single method can cover all the possible degrees of this characteristic. All the methods employed are empirical, in the sense that they were developed by trial and error to satisfya need, and that they knew their enormousdiffusion due to their intrinsic usefulness.

BRINELL HARDNESS TEST

One of the most popular hardness testing methods, Brinell Hardness Number is obtained using a perfectly spherical hardened steel ball of 10 mm pressed against the testsurface using a static force of 3000 kg (=29.42 kilo Newton) for at least 10 seconds for steel and measuring the diameters of the indentation left on the surface by means of a graduated low power microscope. The result is either Calculated using a given formula (see at the end of this section) or looked up on prepared Tables. The equipment generally consists of a manually operated hydraulic press holding the test piece on a sturdy table and forcing a properly held ball indenter into the surface while avoiding impact. Simple as it looks; it is a precise testing method giving repeatable and meaningful results but only when applied correctly. The theory and practice of the method are presented in the most complete way in the current Standard: ASTM E 10, Standard Test Method for Brinell Hardness of Metallic Materials. This Standard is prepared and maintained by the American Society for Testing and Materials.

Note: Links to the Sources ASTM and ISO can be found at the end of this publication. An International standard, issued by ISO – International Standards Organization, available onthis subject is: ISO 6506-1 Metallic Materials - Brinell

Hardness Test. Standards requirements cannot be overemphasized. It is also strongly recommended to study with attention the Operating Manual of the equipment on hand and to take care of maintenance operations as advised by the Manufacturer. Brinell Hardness Test is most often applied on iron and steel castings where its usefulness is most advantageous as the results represents a sort of average surface hardness because these materials are not uniform on the microscopic scale. It can also be successfully applied to steel bars and plates, and to normalized forgings, that is to forgings which were submitted to a homogenizing heat treatment, or to fully heat treated ones. Assuming that the surface is representative of sound metal, for ease of reading the indentation diameters one should have it cleaned from paint, oil or grease, and lightly ground with abrasive paper (180grit). The principal purpose of hardness test is to determine the suitability of a material for a given application. The ease with which the hardness test is performed has made it the most common method of inspection for metals and alloys.

PRINCIPLE

Rockwell cum Brinell tests consists of forcing an indenter (Diamond or Ball) into the surface of a test piece in two steps i.e. first with preliminary test force and thereafter with additional test force and then measuring depth of indentation after removal of additional test force (Remaining preliminary test force active) for measurement of hardness value. RASNE series machines are suitable for Rockwell, Rockwell superficial & Rockwell cum Brinell tests. These are motorized digital Hardness testers having LCD display for easy hardness measurement. The results are displayed in 0.1 Rockwell unit for more accurate measurement. The results obtained, even when the test was performed with utmost care, could be wrong: If the surface is not flat If the surface is covered with a thick scale If the tested material is too thin (less than 9.6 mm or 3/8 ") so that a mark appears on the opposite side If the tested material is too hard (more than 450 HBS for steel ball or more than 650 HBW for tungsten carbide ball). The letters HBS stand for Hardness Brinell with Steel ball, (HBW for tungsten carbide ball) but the qualification should be completed by indicating also the ball diameter (10 mm) and The applied force (load) (3000 kg). The complete and meaningful designation is therefore expressed as: 450 HBS10/3000 or 450 HBS10/3000. Note: ASTM Standardization News of February 2000 announces that in the next future a change will take place, whereby steel balls for indenters will be substituted by tungsten carbide balls for all the ranges, in a movement that will align ASTM E 10 with ISO 6506. Ingeneral one should not attempt to establish a Brinell hardness Number if the diameter of the indentation is smaller than 2.4 mm (24%) or larger than 6 mm (60% of a 10 mm diameter ball). One of the most useful features of Brinell Hardness Test derives from the observation that if the ratio of ForceF (in kg) to the square of Ball Diameter D (in mm) is kept constant, one obtains an approximation of the same BHN (Brinell hardness number) as measured with the standard parameters (10 mm ball and 3000 kg). Therefore, with available equipment of special design, one can use the method With the following pairs of Force and Ball Diameter for $F/D2 = 30$: The application of these different parameters enlarges the scope of the method for thinner or more delicate machine elements. Until now applications were described for ferrous metals. But the usability is extended to softer materials like copper or aluminum alloys with the only condition of establishing a different ratio for F/D2, like 15, 5, 2.5, 1.25, 1. It is evident that, to be understood, the test so performed Must be qualified with the indication of force and of ball diameter. According to the above mentioned ASTM Standard E 10 the following ratios should be usedfor the materials indicated: For hard copper and aluminum alloys: $F/D2 = 15$ For soft copper and aluminum alloys $F/D2 = 5$ For lead and other soft alloys: any one of the smaller values. Although most of Brinell testing is performed with machines firmly standing on the floor, there are a few portable instruments which have proven their usefulness, Permitting to take the test to very large and heavy raw metal parts. This type of portable instrument performs the regular test and the results are therefore perfectly acceptable as if they were obtained withthe original equipment. Other instruments though are based upon different physical principlesand showa translation of the value using some correspondence table which at best is approximate: one should always beware of optimistic affirmations of manufacturers becausetranslated results from different instruments are generally not accepted as an alternative fulfillment of contract requirement. The formula used for calculating Brinell hardness numberis as follows:

Where

BHN = P/ π * D/2 *(D-SQRT (D2 - d2))

P = test load in kilograms

D = diameter of ball in millimeters

d = diameter of read impression in millimeters (or average of tworeadings,mutually perpendicular)

SQRT= Square Roo

BHN (Brinell hardness number) metal hardness

Formula & step by step calculation to measure the resistance of solid materials permanent shape change when a compressive force is applied. BHN = 2P/πD (D - & radii ;(D2 - d2)). Load Pin kgf, steel ball diameter D in mm & changed diameter d in mm are the key terms of this calculation

Fig.2 SPECIMEN AFTER CONDUCTING HARDNESS TEST

RESULTS

Machine details

Name : Brinell hardness

Model No/Srl.NoTest detail : 085 TRS

Test procedure : IS 1586:2005

Type of hardness : HRBIndentor : 1/16”

Load applied : 100 Kgs

Sl no	Location	Impression1	Impression2	Impression3	average
1	Sl. no A	51	48	50	49.67
2	Sl. no B	57	46	55	52.67
3	Sl. no C	60	62	58	60.00
4	Sl. no D	58	56	54	56.00
5	Sl. no E	60	60	64	61.33
6	Sl. no F	65	63	65	64.33
7	Sl. no G	64	62	64	63.33
8	Sl. no H	60	64	66	63.33
9	Sl. no I	36	62	52	50.00

TENSILE TEST:

Effectiveness and quality of materials used in manufacturing play a crucial role in bringing about marketplace success. Tensile tests help determine the effectiveness and behavior of a material when a stretching force acts on it. These tests are done under optimum temperature and pressure conditions and determine the maximum strength or load that the material can withstand. Tensile properties of the weld joints namely yield and ultimate strength and ductility (%age elongation, %age reduction in area) can be obtained either in ambient condition or in special environment (low temperature, high temperature, corrosion etc.) depending upon the requirement of the application using tensile test which is usually conducted at constant strain rate (ranging from 0.0001 to 10000 mm/min). Tensile properties of the weld joint are obtainedin two ways a) taking specimen from transverse direction of weld joint consisting base metal heat affected zone. Schematic of tensile specimens from a) transverse section of weld joints and b) all weld specimen Tensile test results must be supported by respective engineering stress and strain diagram indicating modulus of elasticity, elongation at fracture, yield and Ultimate strength Tests results must include information on following point about test conditions .Type of sample (transverse weld, all weld specimens). Strain rate (mm/min).Temperature or any other environment in which test was conducted. Rate of increase of specimen length is uniform with time (the load measuringmechanism moves a negligibledistance). Rate of increase of the load is uniform with time and rate of extension is dependent onthe load-elongation characteristics of the specimen. Pulling one clamp at a uniform rate and the load is applied through the other clamp.This moves appreciably to actuate a load measuring mechanism so that the rate of increase of either load orelongation is usually not constant.

TESTING EQUIPMENT:
This type of physical weld testing is used to measure the strength of a welded joint. A portionof a to locate the welded plate is locate the weld midway between the jaws of the testing machine

Fig : Universal Testing Machine with specimens

The tensile physical weld testing specimen is then mounted in a machine that will exert enough pull on the piece to break the specimen. The testing machining may be either a stationary or a portable type. A machine of the portable type, operating onthe hydraulic principle and capable of pulling as well as bending test specimens, is shown. As the specimen is being tested in this machine, the load in Newton's is registered on the gauge. In the stationary types, the load applied may be registered ona balancing beam. In either case, the load at the point of breaking is recorded. Test specimens broken by the tensile strength test areshown.
Machine details Name : FIE/UTN 40
Test procedure : ASTM B 557:2006
Material specification : Al alloy 6061 & AA 7075
Experimental results

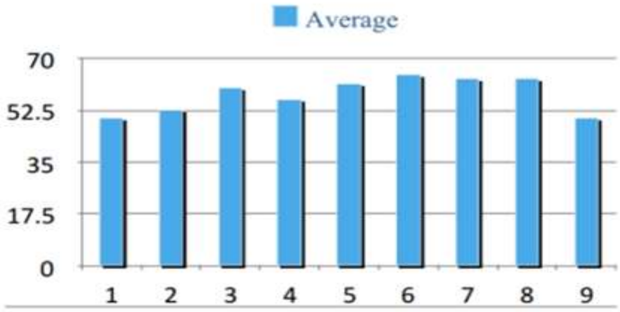
slno	Specimen type	Specimen Width(mm)	Specimen Thickness(mm)	c/s area(mm2)	Original Guage Length (mm)	Final Guage Length(mm)	Results (ultimateload)KN	Ultimate tesile strength (N/ m2)	Elongation (%)	Yield Load(KN)	Yield Stress (N/mm 2)
1	Flat	19.97	6.13	122.416	50	51.79	17.40	142.14	3.580	13.690	114.034
2	Flat	19.92	6.07	120.914	50	51.29	18.08	149.533	2.580	15.960	131.999
3	Flat	20.03	6.16	123.385	50	50.37	18.68	151.402	0.702	14.400	116.713
4	Flat	19.88	6.04	120.075	50	51.71	18.88	157.229	3.420	18.160	151.229
5	Flat	19.95	6.07	121.097	50	50.5	16.72	138.068	1.00	16.280	134.434
6	Flat	20.01	5.97	119.46	50	52.42	17.40	145.655	4.84	15.690	133.601
7	Flat	20.013	6.08	122.39	50	50.82	5.200	124.193	1.640	14.720	120.271
8	Flat	20.087	6.08	122.026	50	51.02	13.60	111.44	2.040	11.600	95.059
9	Flat	20.014	6.03	121.444	50	51.76	20.00	168.314	3.520	14.720	121.212

RESULTS AND CONCLUSIONSHARDNESS TEST RESULTS

Type of hardness : HRBIndentor :
1/16"Load applied : 100Kgs

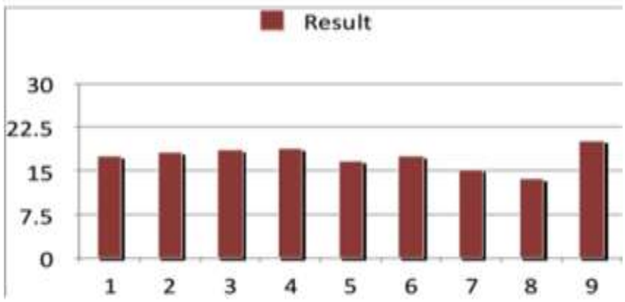
SAMPLE NUMBER VS. AVERAGE

From the above Graph it is Observed that Sample 9 has highest Hardness.



TENSILE TEST RESULTS

Input Parameters for Sample 8:Speed : 1400 pmFeed : 30mm/min
Tilt Angle: 1 Deg



From the above Graph it was observed that Sample 8 elongates less because it has more Tensile Strength. In the present investigation, traverse rates of 50 mm/min, 80 mm/min and 100 mm/min were demonstrated.

However, in order to compete with processes like laser welding which havehigh productivity (although not necessarily better metallurgical properties), faster traverse rates should be achieved. This can be done by optimizing the tool design and further optimization of process conditions. The effect of post heat treatment of FSW joints with different ageing treatments to improve the tensile strength can be studied. Study of dissimilar friction stir welding between copper-brass and aluminum -magnesium can be attempted. More experiments with different tool materials and geometries should be attempted in order to improve the tensile strength and make the process acceptable to the welding industries. Study of heat transfer analysis can be extended to lap friction stir welded joints.

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