EXPERIMENTAL AND ANALYTICAL INVESTIGATIONS OF FRICTION STIR WELDING OF VARIOUS ALUMINIUM ALLOYS

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Abstract - *FEA analysis will be performed for friction stir welding of aluminum 6061 and aluminum 7475 at different speeds using ANSYS. Coupled field analysis, thermal and structural will be performed. A parametric model with the weld plates and cutting tool will be done in Pro/Engineer. The speeds are 800rpm, 650 rpm and 450rpm.*

The effects of different tool pin profiles on the friction stir welding will also be considered for analysis. Tool pin profiles are circular.

In this thesis, the static analysis is to determine the deformation, stress and strain at different speeds (800,650& 450rpm) of the cutting tool. And thermal analysis is to determine the heat flux and temperature distribution. The two process parameters i.e. Circular pin profile and rotational speed. It is found that the joint fabricated using round screw thread pin exhibits superior tensile properties, impact and hardness.

Key words - Finite element analysis, speed, tensile test, impact and hardness test.

I. INTRODUCTION

Friction Stir Welding is the most recent upgrade to the Space Shuttle's gigantic External Tank, the largest element of the Space Shuttle and the only element not reusable. The new welding technique—being marketed to industry—utilizes frictional heating combined with forging pressure to produce high-strength bonds virtually free of defects. Friction Stir Welding transforms the metals from a solid state into a "plastic-like" state, and then mechanically stirs the materials together under pressure to form a welded joint. Invented and patented by The Welding Institute, a British research and technology organization, the process is applicable to aerospace, shipbuilding, aircraft and automotive industries. One of the key benefits of this new technology is that it allows welds to be made on aluminum alloys that cannot be readily fusion arc welded, the traditional method of welding. In 1993, NASA challenged Lockheed Martin Laboratories in Baltimore, Md., to develop a high-strength, low-density, lighter-weight replacement for aluminum alloy Al 2219–used on the original Space Shuttle External Tank. Lockheed Martin, Reynolds Aluminum and the labs at Marshall Space Flight Center in Huntsville, Ala., were successful in developing a new alloy known as Aluminum Lithium Al-Li 2195, which reduced the weight of the External Tank by 7,500 pounds (3,402 kilograms). Today, the External Tank project uses the new alloy to build the Shuttle's Super Lightweight Tanks. The lithium in the new lighter-weight material—aluminum lithium alloys Al-Li 2195—made the initial welds of the External Tank far more complex.

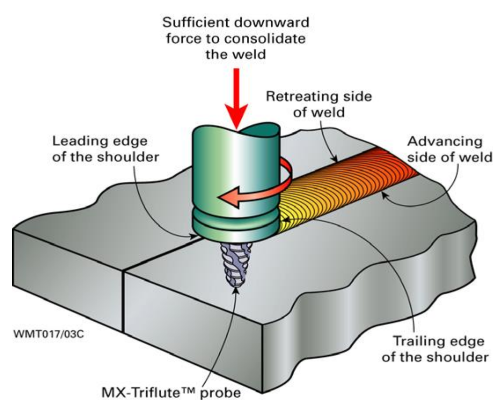


Fig1. Fsw process

The principle of Friction Stir Welding

By keeping the tool rotating and moving it along the seam to be joined, the softened material is literally stirred together forming a weld without melting. These welds require low energy input and are without the use of filler materials and distortion. Initially developed for non-ferrous materials such as aluminium, by using suitable tool materials the use of the process has been extended to harder and higher melting point materials such as steels titanium alloys and aluminum. Since its conception in 1991 there have been considerable advances in process technology and there are now over 135 licensees of the process and over 1500 subsidiary patents have been filed. This paper will concentrate on improvements for tooling for the friction stir welding of aluminium alloys.

II. LITERATURE REVIEW

Many investigators have suggested various methods to explain the experimental and numerical investigation of friction stir welding.
Scialpi et al[1],was carried out FSW process shows several advantages, in particular the possibility to weld dissimilar aluminum alloys. In thispaper,thin aluminum alloy 2024-T3 and 6082-T6 sheets, 0.8 mm thick, have been welded in the rolling direction by FSW (FSW for ultra-thin sheets). Both similar and dissimilar joints have been successfully produced and analyzed. Mechanical characterization has been executed through static and uniaxial fatigue tests with constant load amplitude. Finally, micro hardness and residual stress measurements have been executed on welded sheets for each joint typology.

III. PROBLEM DESCRIPTION

The objective of the present research is to develop a finite element simulation with improved capability to predict temperature evolution in aluminum alloys and to determine the optimal weld parameters using trend line equation. Experiments have been conducted on the AA6061 Aluminum alloy in a vertical axis CNC milling machine by programming . The peak temperature attained during Friction stir welding process along the direction of the weld line and the temperature perpendicular to the weld line from maximum temperature point are measured. Comparison is made between theoretical values from ANSYS and experimental values.

METHODOLOGY

•In this work frictional stir welded Aluminium 6061, Pure Aluminium7475 specimens are compared for mechanical properties. In this study FSW specimens are prepared at 11mm/min feed rate and The speeds are 800rpm, 650 rpm and 450pm.feed rate: 11mm/min

•In this experiment plate size of aluminium and copper are same and having 100 mm length, 50 mm width and 5 mm thickness. HCHCr material is used to manufacture the tools. Tool has pin diameter of 2millimetre size.Tool dimensions: Shoulder Diameter-20 mm The Length of Pin4.7mm

•Experiment Design Following are materials and parameters used for experiment Material: Aluminium 6061, Pure Aluminium7475 Thickness: 5mm Tool: Cylindrical Spindle Speed: The speeds are 750rpm, 560 rpm and 410rpm.feed rate: 20 mm/min.

•The 3D modeling of FSW is designed in Pro/Engineer.

•In static analysis, to determine the stress, strain and deformation.

•In thermal analysis, to determine the temperature distribution and heat flux

IV. INTRODUCTION TO CAD/CAE:

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer

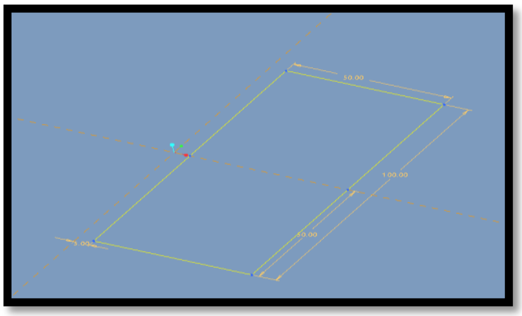
Part design , Assembly, Drawing & Sheet metal.

INTRODUCTION TO FINITE ELEMENT METHOD:

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

V. RESULTS AND DISCUSSIONS:

Models of fsw using pro-e wildfire 5.0:
Plate1 sketch



Extrude part

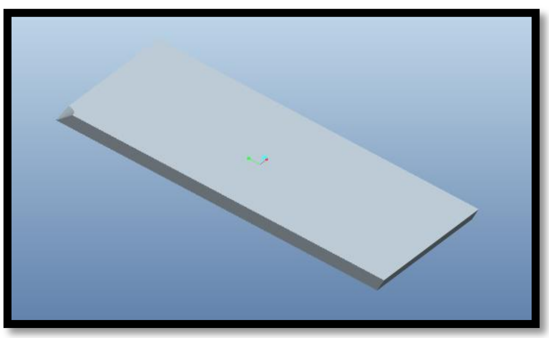
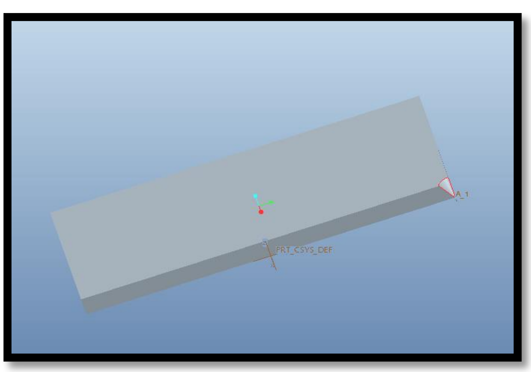
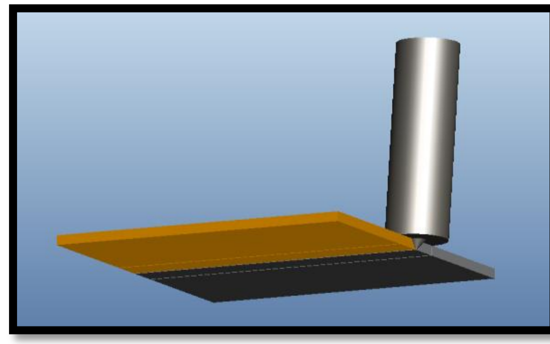


PLATE2



Round tool assembly

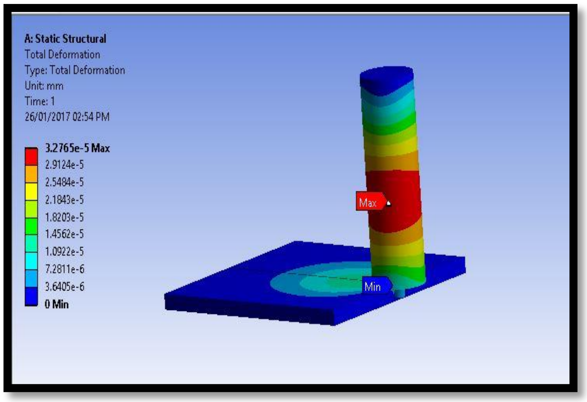


Introduction to FEA

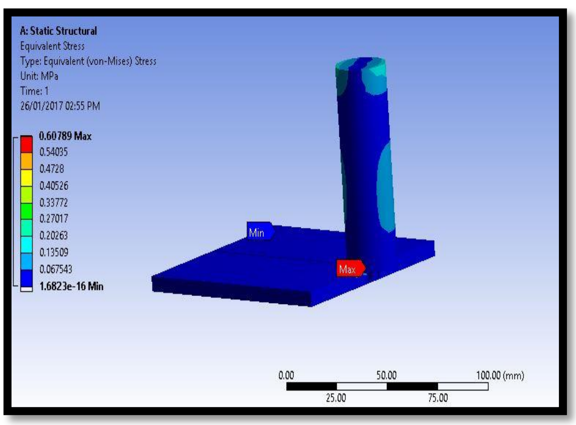
Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".
By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.
FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.
There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

STRUCTURAL ANALYSIS OF FSW
SPEED AT -450 RPM

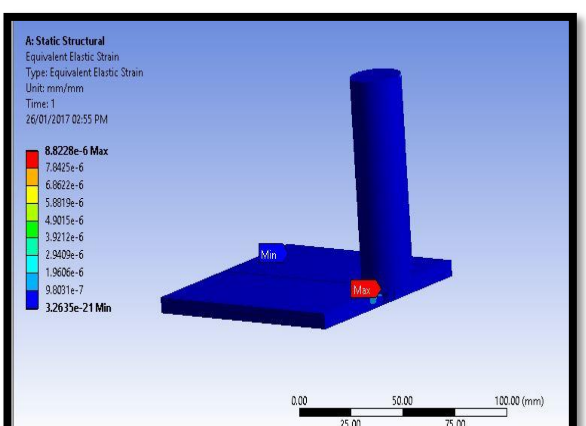
DEFORMATION



STRESS



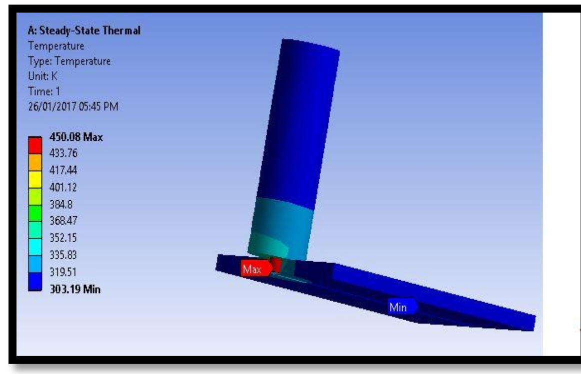
STRAIN



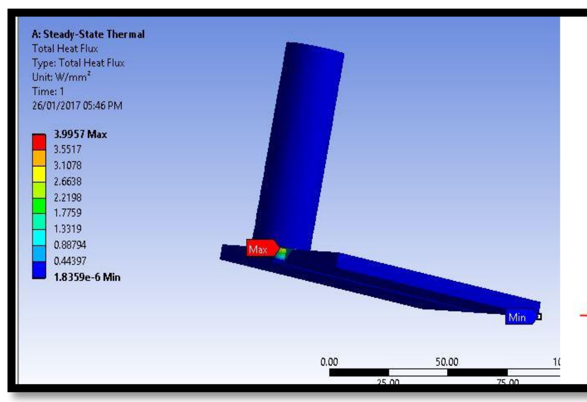
THERMAL ANALYSIS OF FSW

At 180⁰C

Temperature



Heat flux



STATIC RESULT TABEL

SPEED(RPM)	DEFORMATION(mm)	STRESS(N/mm^2)	Strain
750	0.00010961	2.0336	2.9151e-5
560	0.00006119	1.1339	1.6458e-5
410	3.276e-5	0.60789	8.8228e-5

THERMAL ANALYSIS RESULT TABLE

Temperatures input(^{0}C)	Temperature (K)		Heat flux(w/mm^2_
	Min	MAX	
120	303.01	390.5	2.3648
150	303.15	420.07	3.1803
180	303.19	450.08	3.9959

EXPERIMENTAL INVESTIGATION

Experimental investigation is done to verify the mechanical properties of friction stir welding of aluminum alloy 7475 and aluminum 6061. The properties investigated are tensile strength and hardness compared before and after welding.

The welding is done on Vertical CNC machine.

TOOL	SPEED (rpm)
circular	800
	650
	450

In this work, the process was done using a vertical milling machine having automatic feed. The tool rotational speeds and the feeds were set accordingly and the respective experiments were conducted. The tool rotational speeds considered were450,650and 800rpm's and the feed rate considered is 20 mm/min respectively.

Machine used for Friction Stir Welding

Machine Specifications

- Motor Capacity-7.5 HP
- Rotation Speed- 35 to 800RPM
- Feed Rate-16 to 800 mm/min.
- Make –HMT
- Bed length 1000*400*450 mm

The Tool

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion and deformation and their ability to hold a cutting edge at elevated temperatures. As a result tool steels are suited for their use in the shaping of other materials.

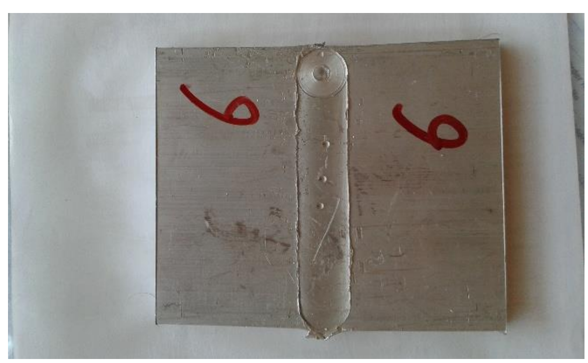
There are six groups of tool steels: water-hardening, cold-work, shock-resisting, high-speed, hot-work, and special purpose. The choice of group to select depends on, cost, working temperature, required surface hardness, strength, shock resistance, and toughness requirements.

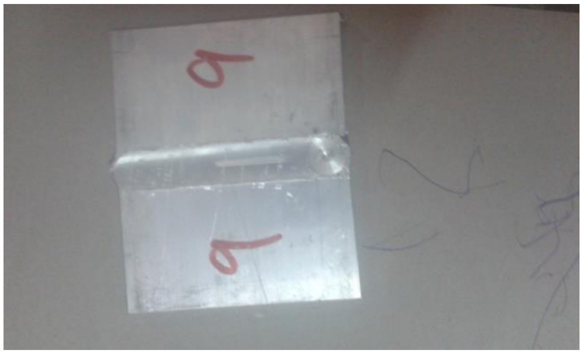
Tool Material taken in this paper is HCHCr (High Carbon High Chromium steel)

- The tool shoulder diameter -20 mm,
- The length of the pin -4.7 mm,
- Diameter of the tip of the tool-2 mm
- Length of the tool-100 mm

Process

The dimensions of the plates taken were 100*50*5 mm. They were cut into the desired size by shearing process. Both plates were clamped to the machine bed. Plunge depth was given by a center bit at the place of joining of the plates and a hole was created for the tool to traverse on the plates to be friction stir welded. After the hole has been created, tool is passed on the intersection of the two plates by applying pressure on the plates by using the tool shoulder. Tool is moved on to the other side of the weld by automatic feeds. After the tool has been inserted, sometime is given for the friction to develop and the material to get heated up to the red hot condition of the plates. This time is called as time of indentation. Generally it is taken as 5 to 8 seconds. After the tool reaches the other side, the plates are said to be friction stir welded.





Friction stir welded plates

Tensile Testing

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined young's modulus, poisons ratio, yield strength and strain-hardening characteristics.

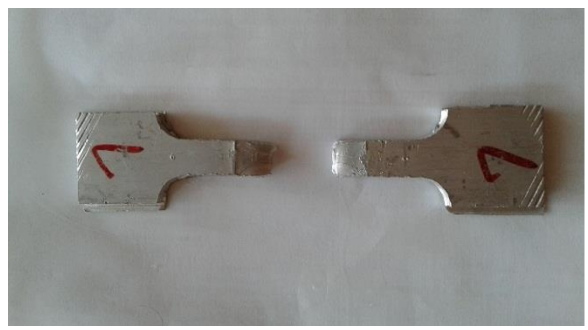
TENSILE TEST

Type of test – Tensile

Machine Model – TUE-C-600

Ultimate tensile testing machine

Specimen Width – 12.3mm
Specimen Thickness – 6mm



HARDNESS TEST
MACHINE DETAILS

Name –HARDNESS

TEST DETAILS

Test Reference – IS 1586:2000

Type of Hardness – HRC

Machine Model – 2008/073, MRB 250

Sample ID – Hardness Test at Weld Zone

CONCLUSION

In this project cutting tool taper is designed for doing Friction Stir Welding of two dissimilar materials Aluminum alloy 7475 and aluminum alloy6061 running at speeds of 410,560 & 750rpm. Modeling is done in Pro/Engineer.

Structural analysis is performed on the circular tool to verify the deformation and stresses.

By observing the results, stresses values are increases by increasing the speeds.

Two plates of the aluminum alloy 7475 and aluminum alloy 6061 are welded experimentally on a vertical CNC machine using 750rpm speed for circular cutting tool. Tensile strength, impact and hardness are evaluated after welding

By observing the tensile test results, ultimate tensile strength values are increases by increasing the speeds.

By observing the hardness test results, when speed will increases than hardness will decreases.

By observing the impact test results the impact more at high speed that is 32 joules.

So it can be concluded the cutting tool speed 750 rpm is the better.

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