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# Investigation of Mechanical Properties of AA6063-T6 Metal Welded by using HCHCr Tool in Friction Stir Welding (FSW) Method

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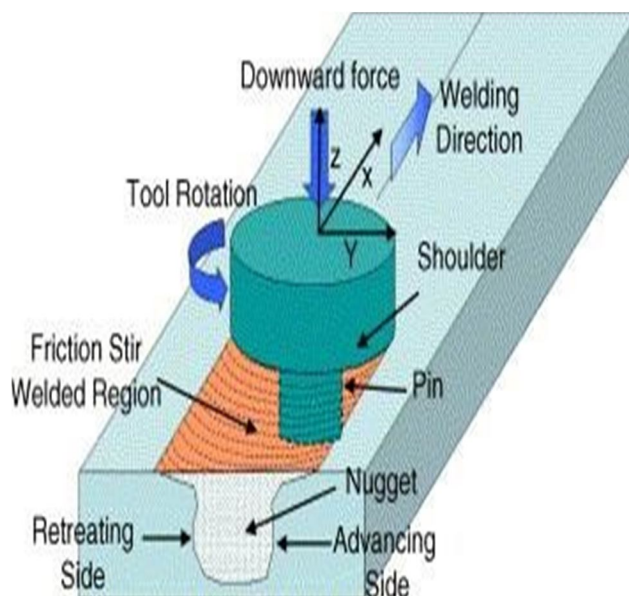
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**Abstract:** This study is to investigate the mechanical properties of AA6063-T6 material welded by friction stir welding process. The material that used for this study was Aluminium Alloy 6063-T6 with the thickness of 4mm HCHCr tool is used in this process. There are two set of parameters speed 700rpm and 900rpm feed 10mm/min and 20mm/min. However the welding for AA6063-T6 find the suitable parameters range and mechanical properties of welded material by use of FSW method. The aim of this study is to analysis the mechanical properties like tensile, Hardness, Bending.

## I. INTRODUCTION

Friction Stir Welding (FSW) is a solid state joining process that was invented and patented by The Welding Institute (TWI) UK. This invention is a big success for joining aluminium as well as low melting temperature materials. Recently, FSW has been proven as an alternative joining technique for high melting materials such as steels, titanium, and so on. The applications of FSW can be found in marine, aerospace, automotive, rail and construction industries. Nowadays FSW is gradually being introduced to oil and gas industries such as offshore structure. In FSW, the parameters that influence the quality of weld joint categorized into primary and secondary parameters. The primary parameters are traverse speed, rotational speed, and tool geometry. Meanwhile the secondary parameters are thickness of the work piece, work piece material, welding tool material, and pin profile. In the last decade many researches have been done on various FSW parameters. Among them, there are some studies that concentrated on pin profiles. In order obtain the best and optimum pin profiles, the geometry of pin will be evaluated with other parameters such as rotation and traverse speeds, and force. They investigated the influence of pin profile and rotational speed, traversing speed, shoulder diameter, and axial force on the formation of friction stir processing. Furthermore, there are many other researchers who investigated the influence of pin profiles on micro structural and mechanical properties of the weld joint.



## II. LITRATURE REVIEW

Thomas (1991) of The Welding Institute (TWI) focuses on this study the relatively new joining technology, friction stir welding (FSW). His first attempt on this welding was to overcome the problems of fusion welding of aluminium alloys. He observed that friction stir welding could overcome the presence of surface oxides and it can be used to join many aluminium alloys.

Thus friction stir welding came into focus on automotive vehicles, rail, and marine and aerospace transportation industries. Lohwasser (2009) suggested that there are two types of material flow in FSW i.e. pin driven flow and shoulder driven flow.

Both the flows coalesce to form a firm joint but leave a key hole at the end of the process. In FSW, as the tool moves in the direction of the pin, the material is transferred from the leading edge of the pin to the trailing edge of the pin through stirring action.

The tool shoulder action breaks up the oxides on the faying surfaces which helps in clean and firm bonding of the materials. The working temperature of the FS welding will always be 0.6 to 0.9 times the melting temperature of the materials to be welded. This technique can be applied to produce butt, corner, lap, T, spot and fillet joints.

### A. Material Used

The process is primarily used on aluminium most often extruded aluminium. This procedure can also be exploited on structures that require superior weld strength without heat treatment after the weld is complete. Aluminium or aluminium is a chemical element with symbol Al and atomic number 13. It is a silvery-white, soft, nonmagnetic, ductile metal in the boron group. By mass, aluminium makes up about 8% of the Earth's crust; it is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, though it is less common in the mantle below. The chief ore of aluminium is bauxite. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments.

Base Metal	Aluminium Alloy 6063-T6
Tool	HCHCr

### B. Properties Of Aluminium

Property	Value
Atomic Number	13
Atomic Weight	26.98g/mol
Melting Point	615°C
Boiling Point	2480°C
Density	2.698 g/cm <sup>3</sup>
Modulus of Elasticity	68.3 GPa
Poisson's Ratio	0.33

Table 1: Properties of AA6063-T6



Fig 1.1 Aluminium Alloy 6063-T6 PROPERTIES OF HCHCr:

Property	Value
Tensile Strength	640-2000 MPa
Atomic Weight	26.98g/mol
Melting Point	1426°C
Hardness (HRC)	58
Density	$7.7 \times 10^3 \text{ kg/m}^3$
Modulus of Elasticity	190-210 GPa
Poisson's Ratio	0.27-0.30

Table 2: Properties of HCHCr TOOL USED IN HCHCr: (D2 Alloy Steel):

Alloy produces D2 Alloy Steel round rods, D2 Alloy Steel forging, sheet, coil and profiled strip, Deformed steel, flat steel, forging, steel to hot and cold rolling process, heat treatment, etc., we have the control of professional engineers. We have advanced precision machining equipment, according to the requirements of users machining. In order to achieve the most satisfied with the user requirements.

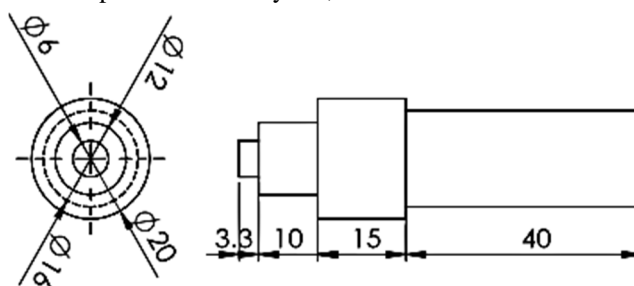


Fig 1.2 HCHCr Tool

### C. Tool Characteristics

To produce a high quality FSW joint, it is a requirement that the tool material selection is done properly.

- 1) Resistance to wear,
- 2) No harmful reactions with the Weld metal,
- 3) Good strength, dimensional Stability and creep resistance at ambient and elevated temperature,
- 4) Good thermal fatigue strength to resist repeated thermal cycles,



All dimension are in mm

Fig.1.3 Tool Geometry



### III. FRICTION STIR WELDING METHOD

Today, the machine commonly used to perform FSW, industrially and in laboratories, are dedicated SW machine, modified milling machine, serial and parallel kinematics robots. WORKING METHOD:

#### A. Modified Milling Machine

Milling and FSW machine have the same general characteristics spindle rotation, travel speed and CNC control process necessary to perform FSW welds. They generally offer high stiffness and a good accuracy. The biggest disadvantage of most the milling machine is unavailability to propose a force controlled operation. But, new milling machines technologies can offer a mold, steel wire, have all specifications. With production experience, strict control D2 Alloy Steel chemical composition and D2 Alloy Steel mechanical properties. From casting, force controlled process.

#### B. FSW Dedicated Machine

FSW dedicated machine allows a force control operation and generally the possibility to weld with the three tool technologies, conventional, retracting and bobbin tool. Each machine is designed to weld, 2- or 3-dimensional and has a predefined workspace. The main advantages of these machines are their high payload capacity due to high framework stiffness. They generally offer large workspace. The disadvantages of this kind of equipment is its high investments cost and the poor accessibility of the tool.

##### 1) FSW Machine Specification

Spindle Tapper	ISO 40
Spindle Speed	3000rpm
Spindle Tilt Angle	+/- 5deg
Z-axis thrust force	30KN(max)
Z-axis Travel	300mm
X-axis Travel	300mm
Y-axis Travel	100mm (optional: Servo)
Table to Spindle nose Min/Max	100mm/400mm

Table 3: FSW Machine Specification STANDARD FEATURES:

- a) Ideal for high productivity
- b) Ideal for multi spindle and single spindle drilling
- c) Built in cylinder
- d) High rapid drilling advance and retract speed
- e) Adjustable rapid and feed travel length
- 2) Optional Features
  - 1) Peck drilling attachment
  - 2) Coolant system
  - 3) Auto coolant system
  - 4) Rotary table attachment
  - 5) Part holding jig and fixture
- 3) Classification
  - a) Rotational Friction Welding:
    - i) Direct Drive Friction Welding
    - ii) Inertia Friction Welding
      - b) Friction Stir Welding
      - c) Linear Friction Welding or Linear Vibration Welding
      - d) Orbital Friction Welding
      - e) Radial Friction Welding

- 4) *Working Principle Of Friction Stir Welding*: Friction Stir Welding features have led to the application of leaders for micro joining of electronic components, but the process is also being applied to the fabrication of automotive components and precision machine tool parts in heavy section steel. It is schematically represented in and actual working diagram in at first, the sheets or plates are abutted along edge to be welded and the rotating pin is sunken into the sheets/plates until the tool shoulder is in full contact with the sheets or plates surface. Once the pin is completely inserted, it is moved with a small notating angle in the welding direction.



Fig 1.4 FSW Machine

#### IV. METHODOLOGY

In Friction Stir Welding, a cylindrical shouldered tool with a profiled probe is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together. The parts have to be firmly clamped onto the worktable in a manner that prevents the joint faces from being forced apart. Frictional heat is generated between the wear resistant welding tool and the material of the work piece as shown in Fig. 4.4(b). This heat causes the latter to soften without reaching the melting point and allows passing of the tool along the weld line as shown in Fig. 4.4(c). The plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged by the intimate contact of the tool shoulder and the pin profile. It leaves a solid phase bond between the two pieces.

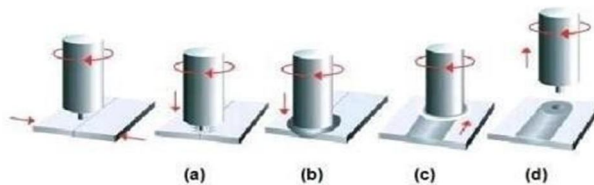


Fig.1.5 Working of FSW Methodology

A significant benefit of Friction Stir Welding is that it has significantly fewer process elements to control. In a Fusion weld, there are many process factors that must be controlled—such as purge gas, voltage and amperage, wire feed, travel speed, shield gas, arc gap. However, in Friction Stir Weld there are only three process variables to control: rotation speed, travel speed and pressure, all of which are easily controlled. The increase in joint strength combined with the reduction in process variability provides for an increased safety margin and high degree of reliability for the External Tank. Friction Stir Welding works as first a dowel is rotated between 700 to 900 revolutions per minute, depending on the thickness of the material. The pin tip of the dowel is forced into the material under 5,000 to 10,000 pounds per square inch (775 to 1550 pounds per square centimeter) of force. The pin continues rotating and moves forward at a rate of 10 to 20 millimeter per minute (1.0 to 2.0 centimeters per minute). As the pin rotates, friction heats the surrounding material and rapidly produces a softened "plasticized" area around the pin.

##### A. *Process Parameters Affecting The Fsw Process Quality*

The FSW experimentation can be based on many process parameters. Some parameters were fixed and the others were not. The different process parameters were listed as below:

- 1) Material
- 2) Alloy composition
- 3) Thickness
- 4) Tool rotation speed

## V. TESTING METHOD

### A. Tensile Test

Tensile testing is also known as tension testing is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area.

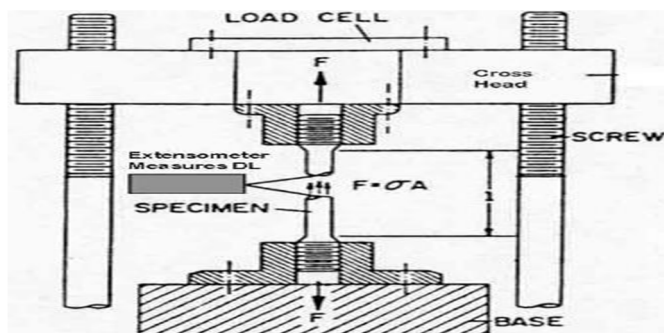


Fig.1.6 Tensile Test Machine



Fig.1.7 Tensile Test Specimen

Speed	Width	Length	Thickness	Area	Ultimate Force	Ultimate Stress	Total Elongation
rpm	mm	mm	mm	mm <sup>2</sup>	N	N/mm <sup>2</sup>	mm
700	20	50	4	549	2240	59.83	2.184
900	20	50	4	593	2620	69.81	2.365

Table 4. Tensile Test

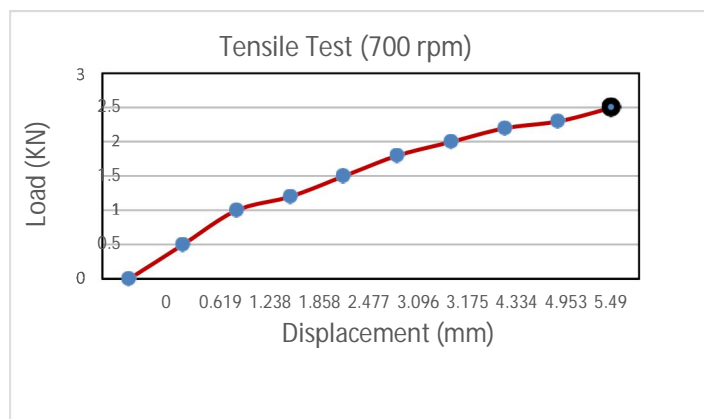


Fig.1.8 Tensile Test Graph (700rpm)

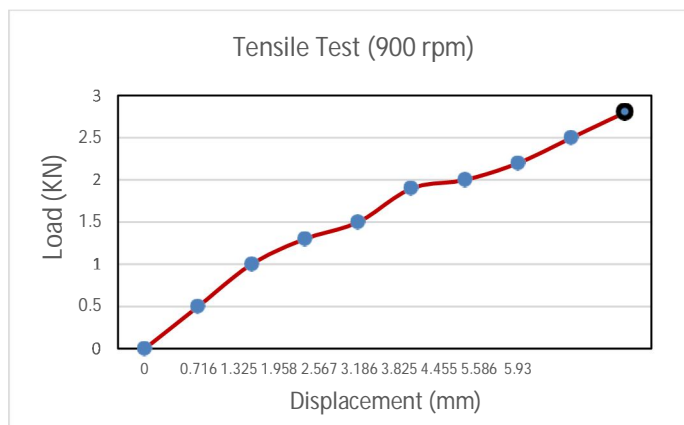


Fig.1.9 Tensile Test Graph (900rpm)



Fig.1.10 Tensile Test

### B. Rockwell Hardness Test

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load  $F_0$  usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration. When equilibrium has again been reached, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

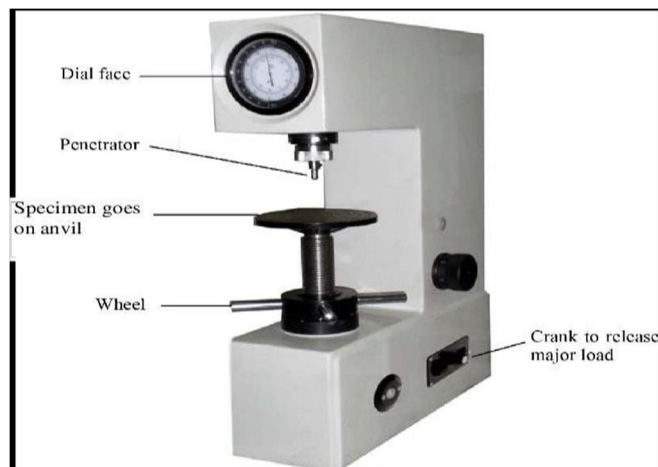


Fig.1.11 HARDNESS TEST MACHINE



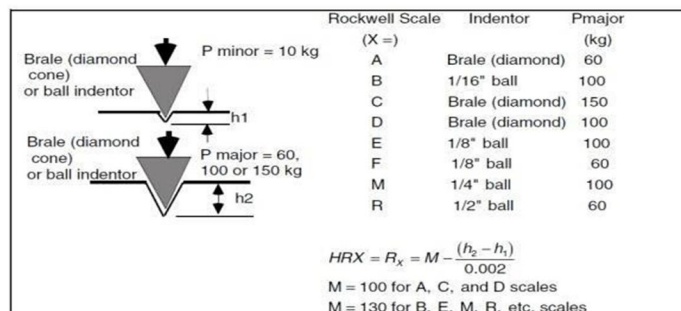


Fig.1.12 Rockwell Hardness Test

There are several considerations for Rockwell hardness test

- 1) Require clean and well positioned indenter and anvil
- 2) The test sample should be clean, dry, smooth and oxide- free surface. The surface should be flat and perpendicular to the indenter

S.NO	SPEED	NORMAL ZONE	WELDING ZONE
1	700 rpm	95,96.5,97	82.5,85,88
2	900 rpm	95,96.5,97	84.5,88.5,91.5

Table 5. ROCKWELL HARDNESS

### Hardness for normal zone (HN)

$$HN = \frac{a + b + c}{3}$$

$$HN = \frac{95 + 96.5 + 97}{3} = 96.16$$

### Hardness for weld zone (HW) (700 rpm)

$$HN = \frac{a + b + c}{3}$$

$$HN = \frac{82.5 + 85 + 88}{3} = 85.16$$

### Hardness for weld zone (HW) (900 rpm)

$$HN = \frac{a + b + c}{3}$$

$$HN = \frac{84.5 + 88.5 + 91.5}{3} = 88.16$$

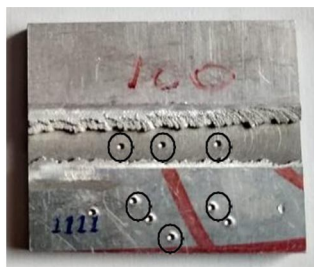


Fig.1.13 700rpm Rockwell Hardness



Fig.1.14 900rpm Rockwell Hardness

### C. Bendingtest

Bending tests are conducted by placing a length of material across a span and pushing down along the span to bend the material until failure. Bending tests reveal the elastic modulus of bending, flexural stress, and flexural strain of a material. 3-Point bending involves placing the material across a span supported on either ends of the material and bringing down a point source to the center of the span and bending the material until failure while recording applied force and crosshead displacement

Speed	Width	Length	Thickn e ss	Angle	Ultima te Force	Result
Rpm	mm	mm	mm	Deg	N	-
700	20	50	4	180°	260	No Break
900	20	50	4	180°	520	No Break

Table 6.BENDING TEST

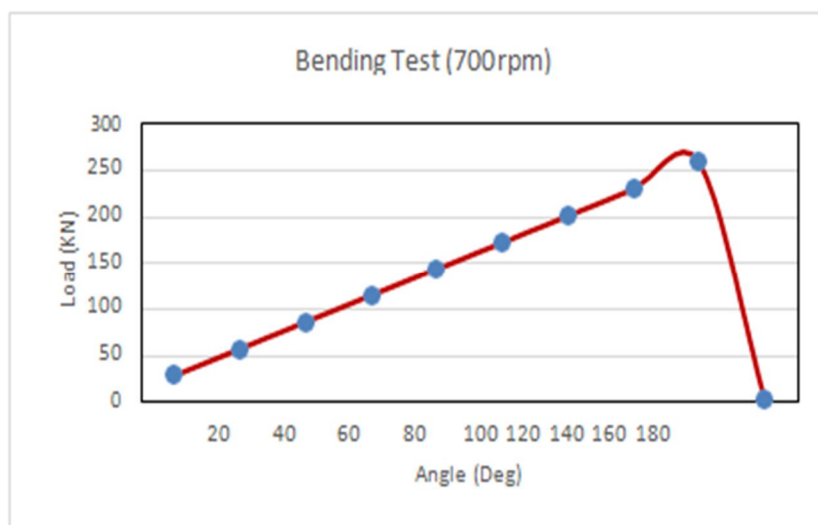


Fig 1.15 Bending Test Graph (700 rpm)

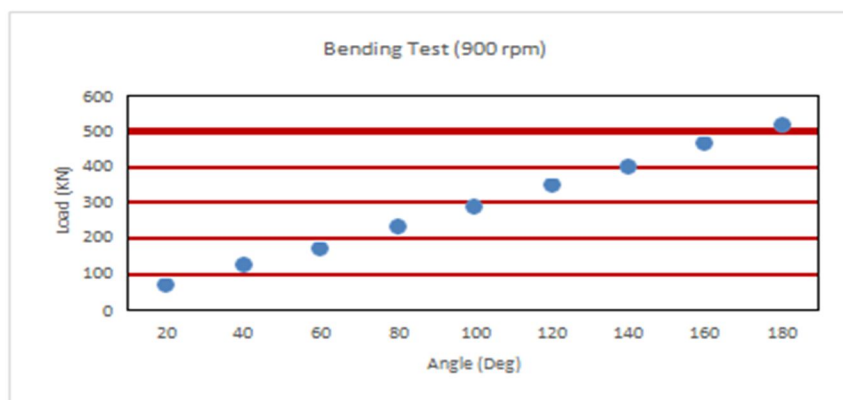


Fig 1.16 Bending Test Graph (900 rpm)



Fig.1.17 Bending Test

## VI. CONCLUSION

Flat plates of aluminium (4 mm thick) were butt welded using Friction Stir Welding. Three pairs of plates were welded under the same operating conditions but with differing Speed and feed. The pin profiles used were cylindrical.

In summary, the main conclusions drawn from this work are

- A. Measured hardness varied through each FSW zone.
- B. The hardness in each zone was higher than that of the parent material.
- C. The strength of aluminium welded zone is higher than normal aluminium zone measured by Rockwell hardness tester.
- D. By comparing the two speed and two feed such as 700rpm, 10mm/min and 900 rpm, 20mm/min
- E. Above tests the 900 rpm speed and 20mm/min provides good strength, hardness then other speed.

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