Study of Friction Welding on Conventional Lathes Machine

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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in partial fulfilment of the requirement for the
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May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(GOVINDERJIT SINGH)

ABSTRACT

Friction welding process has been extensively used in the manufacturing industry whereby it's used in the aerospace industry to join two different materials together to create a good joint while retaining the parent material properties after welding. The main objectives that was hoped to be achieved in this research was whether the two pieces of metal can be welded together on the conventional lathes machine and if it could be done what was the rotational speed value (RPM).

Due to the high cost of purchasing a friction welding machine, it was decided to attempt to create the weld joint using conventional lathes machine. Various sources of journals gave different values of good RPM rates but however this could not be taken lightly as it depended on the material that was being chosen.

The scope that was taken was the varying rotational speed which was 855RPM, 1325RPM and 2000RPM. The material of choice was AA 6063(T5).

Research was conducted throughout the after the project was undertaken by the author. A mini experiment was carried in FYP 1 term and more tests were conducted during the concurring semester. Micro – hardness and microstructure were the two choice of testing that was to be carried out.

For the findings, the material had a layering problem whereby it creates a film that protects it from being welded together properly. Furthermore, poor machine conditions created multiple unsuccessful joints whereby the welded parts were incomplete.

More research must be conducted in order to understand the process better and whether it can be applied on different types of machinery such as the common conventional lathes machine.

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INTRODUCTION

1.1 Background of Study

Friction welding has been around us for centuries but it was not optimized until the last decade where patents were drawn up to protect manufacturer rights. Since the ages of men where forging was created to produce weapons, friction welding was not use extensively as it was more towards fabricating using quenching. However, nobody paid much attention to the part where two piece of molten steel being hammered together against one another. Commercially, friction welding was not a good option as it was very expensive due to machine equipments. Today, friction welding is exclusively used for space engineering whereby two piece of metal are joined due to the extensive hard strength of the joint on itself alone. Friction welding is also used in Truck Banjo Axles.

1.2 Problem Statement

Throughout the ages of men, new ways to join two parent materials were being created as to industrial revelation began and how two pieces of material can be welded. New ways and new method bought the birth of Friction Welding whereby two materials could be manufactured without the need of a heat source.

However due to the high cost and multiple rotational speeds used on friction welding machine, a study was carried out on whether friction welding could be achieved a regular conventional lathes machine. The rotational speed was also being analyzed on the conventional lathes machine to achieve a successful joint.

1.3 Significance of Research

Various studies on the how to carry out friction welding on different types of material has been done over the years. Significant results in types of materials that can be used to joint have also increased as two different types of materials can be joined easily for example, aluminum and mild steel joints has been done around the world. The usage of friction welding machine has been extensively pushed to its limits with different material, shapes, varying rotational speed and applied pressure has been used to create a successful joint.

By using a conventional machining process combining it with a high end welding technique, this research will be very helpful to those who wish to learn more about how friction welding can be done conventional lathes machine using the basic tools. Furthermore, this project will also provide knowledge on what are the capabilities and limits of a conventional lathes machine when carrying out friction welding fabrication process on conventional lathes. For material wise, knowledge on material characteristics and properties will be gained as to how the material (aluminum) reacts when friction welding is being done.

1.4 Objectives

The objective of this research is

a) To determine whether friction welding can be achieved on the conventional lathes machine.
b) If it can be achieved, determining the best rotating speed (RPM) to create a good joint will be the next step.
c) To study the relationship of rotational speed against the pressure being applied to the tool stock.
d) To study the physical properties of aluminum alloy (specifically 6063 – T5) in relations to melting point.

1.5 Scope of Study

Below are the scopes that will be analyzed during the fabrication process :

a) Finding a good rotational spindle speed which would is between 855RPM and 2000RPM. This was determined due to lower rotational speed below than 855RPM were not sufficient enough to generate heat for the material to reach its melting point.

b) Due to limitations of the tool stock diameter, the material's overall diameter had to be below 1.5cm or 15 mm. Material was procured at 1.9cm and was than lathed to smaller diameters which were, 0.8cm, 1.2cm and 1.5cm.

c) Using aluminum (6063 – T5) as the joining material. This material was chosen due to its low which is 616 – 654 °C.

1.6 Relevancy of This Project

This project will focus on the problem at hand which is whether a successful joint can be created using conventional lathes machine by using the friction welding process. Furthermore, finding the optimum RPM will also be taken into consideration if the joint can be achieved. However, priority will be given to the successful joint fabrication. This topic is related to the course of Manufacturing Systems and Operation plus with the knowledge of Engineering Material was also needed in order to carry out the research. From a general perspective, this topic is fully related to the mechanical engineering student which covers areas such as manufacturing process and techniques using metals.

Chapter 2

LITERATURE REVIEW

2.1 Introduction to Welding

2.1.1 History

Welding has been around for millenniums even from the Sumerians centuries which date back to almost 6000 years of history. However, back than it was not a full welding process as it was more towards combining two metal pieces together. This was a more of a forging process rather than a welding process. Throughout the centuries, welding has been perfected time after time. Today, there is no need of conventional usage of furnace and a blowpipe like the older days, when a regular arc welding can join two materials together without any hassle.

It started with the Sumerians developing the forging process using blowpipes and furnaces. Around 3000B.C, the soldering process had been developed by the same people. These techniques had led on to the Egyptians when they developed their own process. The Egyptian heated iron ore in charcoal fire to reduce it to sponge iron, the particle were then welded together by hammering. This pressure or solid-phase welding was the first ever welding to be recorded.

Between the modern age and 19th century, mankind had made more discoveries and new techniques being develop in order to help perfecting the welding process. They are stated as below :

- In 1540, Vannoccio Biringuccio published "The Pirotechnia" describing arts of welding in terms of forging operations.
- In the year of 1836, Edmund Davy from England had made the discovery of acetylene in welding.
- In 1881, French scientist Auguste De Meritens had succeeded in fusing lead plates against one another by using the heat generated from an arc
- The blow pipe or torch using gases acetylene and liquefied air or oxygen was developed by Thomas Fletcher in 1887.
- Automatic welding was first introduced in 1920 by P.O. Nobel. He had designed automatic welding to use arc voltage and bare electrode wires. It was used for repairing and moulding metals together.
- In 1932, Russian Konstantin Khrenov successfully implemented the first underwater electric arc welding.
- Gas tungsten arc welding (GTAW) had been designed by C.L. Coffin. His idea was to weld in a non – oxidizing gas atmosphere, which he patented in 1890. The concept was further engineered in the late 1920s by H.M.Hobart, who used helium for shielding, and P.K. Devers, who used argon.
- The first high-tech welding system was recorded in 1984 which was using laser beam welding in industrial series production.

2.1.2 Types of Welding

There six types of basic welding stated as below :

a) Arc Welding or SMAW
b) Gas or Oxy – Acetylene Welding
c) Gas Metal Arc Welding or GMAW (also known as MIG)
d) Tungsten Inert Gas Welding (better known as TIG)
e) Laser Welding
f) Friction Welding (Stir and Pure Friction)

2.2 Friction Welding

2.2.1 History

According to the American Welding Society, the origins of friction welding date back to 1891, when the first patent on the process was issued in the USA. More work progressed throughout Europe as more patents were issued from 1920 to 1944, and in the USSR in 1956. In the 1960's, friction welding was further developed in the USA by AMF, Caterpillar, and Rockwell International. Rockwell built its own machines to weld spindles to truck differential housings, AMF produced machines to weld steering worm shafts, and Caterpillar's machines welded turbochargers and hydraulic cylinders

Across the ocean in United Kingdom, a family business was started in Black Country in 1834 several decades before the Industrial Revolution began. Former coal miner, William Thompson began a small boiler making business using friction welding method in Bilston. The business was so successful that it took up other engineering capabilities such as in areas of automotive components and metal window frames. By 1969, it had already developed its own engineering capabilities of friction welding systems.

Despite all those early ages, a British patent was only issued in 1969 describing a linear reciprocating mechanism for welding mild steel, although no further information was ever published. However in the early 1980s, TWI demonstrated the viability of the LFW technique for metals using modified equipment. The design and build of a prototype of electro – mechanical machine with a linear reciprocating mechanism followed in the mid 1980s. The LFW has been used successful to join a range of materials including steel, inter – metallic materials, aluminum, nickel, copper and titanium alloys.

APCI's LFW Technology has paved the way to use LFW across a variety of industries due to its exponentially lower equipment and maintenance costs, reliability and quality of the weld.

2.2.2 Types of Friction Welding

Friction welding is carried out by moving one of the components relative to the other along a common interface, while applying compressive force between the joint. The heat generated from the extreme friction at the interface tends to soften both components. When both components become plasticized, the interface material is extruded out of the edges of the joint in order to have more clean material from each component is left along the original interface. The relative motion is than stopped, and a higher compressive force is applied before the joint is allowed to be cooled. The key to friction welding is that the molten metal that is generated does not leave the work piece as it sticks to it when carrying out the process, before it is allowed to be cooled. Once the solid state has been achieved, the excess material is than removed

Rotary

In this method, one of the component is rotated against the other, is the most commonly used in manufacturing vehicle axles and sub-axles. The process can also be used to fabricate suspension rods, steering columns, gear box forks and driveshaft's as well as engine valves.

Linear

Based on the name, this method is used to join blades onto discs in the aircraft engines. Newer and lower costing methods are being developed such as brake discs and wheels rims also engine parts.

2.2.3 Friction Welding Process

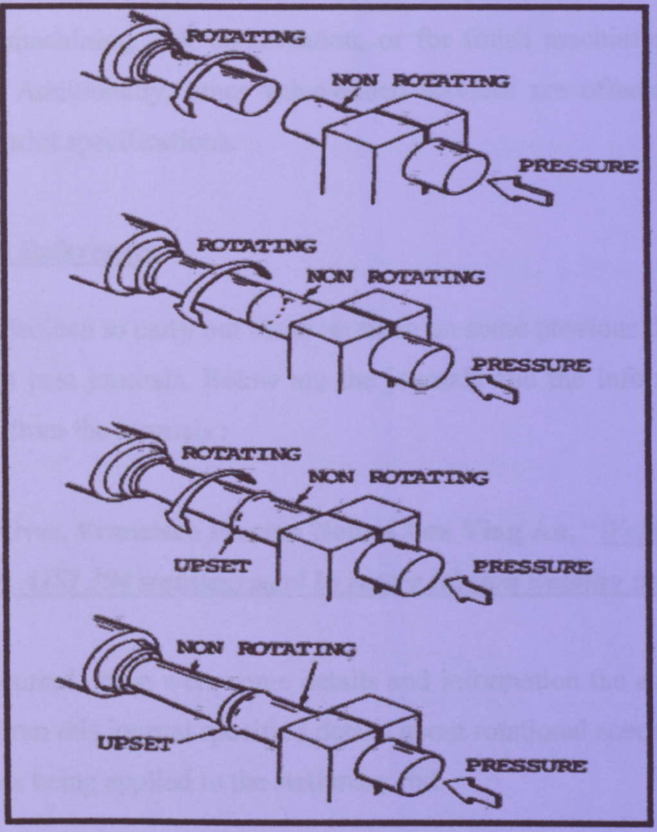

Figure 2.2.3 : Friction Welding Process

Rotary friction welding has four basic steps in order to create the joint. Below are the steps :

<u>Step 1</u>

One component is loaded into a rotational "head" chuck and the other component is loaded into a fixed "tail" stock. The head is accelerated to a preset speed.

<u>Step 2</u>

The rotating "head" component or the fixed "tail" stock (depending on machine style and desired pressure) is then forced against the remaining component.

<u>Step 3</u>

Rotation stops and forge pressure completes the welding cycle. The result is a clean, strong, and full interface weld every time.

Step 4

CNC machining is then performed for removal of difficult or hardened flash (if desired), rough machining, cell optimization, or for finish machining to provide a completed part. Additionally, other value-added services are offered to finish the project to exact print specifications.

2.3 Journal References

The author had decided to carry out some research on some previous friction welding research through past journals. Below are the journals and the information that the author obtained from the journals :

Eder Paduan Alves, Francisco Piorino Neto, Chen Ying An, "*Welding of AA1050 aluminium with AISI 304 stainless steel by rotary friction welding process*", 2010

Based on this journal, there were some details and information the author had found very useful as from this journal specified details about rotational speed and amount of pressure that was being applied to the stationary rod.

From here, the author acknowledged that there was a need for added pressure when trying to conduct friction welding. This welding process was carried out on friction welding machine itself. This had made the process easier due to a hydraulic system being available. The author had come to a conclusion that some improvisations needed to be made due to the friction welding will be carried out on a lathes machine and not on a friction welding machine.

Below are the details of the materials used by the journal :

AA1050 aluminum	Elements (wt %)							
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
	0.07	0.26	<0.001	-	<0.001	-	<0.002	<0.007
AISI 304 stainless steel	Si	S	P	Mn	C	Cr	Ni	-
	0.38	0.024	0.036	1.67	0.054	18.2	8.0	-

Figure 2.3.1 : Material Properties of the Rods – Journal 1

Material	Mechanical properties				
	Strenght σ (MPa)		Elongation ε (%)		Modulus of elasticity E (GPa)
	Yield	Maximum	Maximum	Fracture	
AA1050 aluminum	44.70	78.48	21	43	59.12
AISI 304 stainless steel	354.69	643.79	48	63	177.10

Figure 2.3.2 : Mechanical Properties of the Rods – Journal 1

Hazman Seli, Ahmad Izani Md. Ismail, Endri Rachman, Zainal Arifin Ahmad, "*Mechanical evaluation and thermal modelling of friction welding of mild steel and aluminium*", 2010

From this journal, the author had learned that there might be a chance that the parent material properties might not be the same as it had been hoped for as before due to the fact of thermal energy generated by the extensive friction force while carrying out the friction welding process.

	Composition (wt%)												
	C	Si	P	S	Cr	Mn	Ni	Al	Cu	Fe	Mg	Zn	Bal
Mild steel	0.30	0.22	0.02	0.02	0.12	0.78	0.10	–	0.44	98	–	–	<0.01
Aluminium	–	0.59	–	–	–	0.09	0.01	98	0.25	0.22	0.85	0.03	<0.01

Figure 2.3.3 : Material Properties of the Rods – Journal 2

In conclusion, the author had learned that the extreme friction might alter the parent material properties of the welded joint if two different types of materials are being used. This could be one of the limitations when welding with different types of material using friction welding method.

N. Ozdemir, "*__Investigation of the mechanical properties of friction-welded joints between AISI 304L and AISI 4340 steel as a function rotational speed__*", 2005

Based on this journal, there were 6 rotational speeds carried out at 200RPM intervals between 1500RPM and 2500RPM. This test was carried out to find the best mechanical properties after the weld had been completed. Below are the properties of the metals used in this research :

Materials	C	Mn	Si	P	S	Cr	Ni	Cu	Fe
MCS	0.18	0.39	0.11	—	0.1	0.02	0.016	0.02	Balance
ASS	0.06	1.38	0.32	0.06	0.1	18.4	8.7	—	Balance

Figure 2.3.4 : Material Properties of Rods (MCS-medium carbon steel & ASS-austenitic stainless steel) – Journal 3

From this journal, the author had concluded that a good rotational speed (RPM) for welding steel against steel would be between 1500RPM and more.

2.4 Metals

The compression analysis of concrete-filled steel has been done by few researches. It is crucial information as the application of concrete-filled steel are being widely used by all the industries. It is also one of the best solutions to reinforce any damage or corrode steel. The steel structures do not require any new additional or replacement member, but only being filled with concrete or grout. But, in some part of the structure, member might be under tension stress such as brace member in a frame structure. Thus, reinforcing the member with concrete or grout require verification if improvement in tensile strength can be obtained. Any significant contribution of concrete towards the tensile strength of steel is needed.

Most of the metals and alloys used in the industry can be welded by one or more of the processes. Due to the circumstances of the unavailability of friction welding machine in the university, the metals in consideration would have to undergo a selection process. This section describes the characteristics of metals and their alloys, with particular reference to their significance in welding operations.

All metals would be categorized into 2 main groups which are :

a) Ferrous Metals – metals that contain iron such as mild steel, carbon steel and etc.
b) Non ferrous metals – metals that do not contain iron such as magnesium, aluminum, etc

Physical and mechanical properties play an important role in welding metal. This is to due to the reference of hardness and malleability of the metal. The harder the metal, the more advance and sophisticated process it would need to weld two pieces together. The most important physical properties are :

a) Melting point

   The melting point of a metal is very important with regard to welding. A metal's fusibility is related to its melting point, the temperature at which the metal changes from a solid to molten state. During this process, however, there is absorption of heat during melting and liberation of heat during freezing. The absorption or release of thermal energy when a substance changes it state is called latent heat. Metals having low melting temperatures can be welded with lower temperature heat sources. The soldering and brazing processes utilize low-temperature metals to join metals having higher melting temperatures.

b) Corrosion resistance

   This physical properties is vital in the welding process due to an incomplete weld could lead to structural defect and producing a total failure in terms of the joint. The need to have a corrosion resistance metal will prevent corroding and hold the joint together.

c) Coefficient of linear thermal expansion

Without doubt solid materials expand when they are heated and contract when they are cooled. This coefficient of linear thermal expansion is a measure a measure of how much linear increase per unit length based on the change in temperature of the metal. This expansion is the increase in the dimension of a metal caused by heat. The expansion of a metal in a longitudinal direction is known as the linear expansion. When the metal expands the breadth and thickness also increases along with the size. This is called volumetric expansion. The coefficient of linear and volumetric expansion varies in different types of metals. For example aluminum has the greatest coefficient of expansion, expanding almost twice as much as steel for the same temperature change. This is an important factor for welding aluminum against other types of metals.

2.4.1 Aluminum

This metal is lightweight, soft, low strength which can easily be cast, forged, machined, formed and welded. It is suitable only in low temperature applications, except when it is alloyed with specific elements. Commercial aluminum alloys are classified into two groups, wrought alloys and cast alloys.

For the wrought alloy group, it includes those alloys which are designed for mill products where the final physical form is obtained by working the metal mechanically. On the other hand, for the casting alloy group it includes alloys whose final shapes are obtained by allowing the molten metal to solidify in a mold.

Generally aluminum and aluminum alloys have an excellent heat conductivity and unfairly corrosion resistant. However though, pure aluminum should be used in low temperature applications. Properties of aluminum are as stated below :

i) Pure aluminum

Has a Brinell hardness of number 17 to 27, tensile strength of 6000 to 16 000 psi (41 370 to 110 320 kPa) and a melting point of 1220°F (660°C).

ii) Aluminum alloys

Has a Brinell hardness number of 100 to 120 and tensile strength of 30 000 to 75 000 psi (2 06 850 to 517 125 kPa)

2.4.2 6063 Aluminum Alloy (T5)

T5 temper 6063 has an ultimate tensile strength of at least 22,000 psi (152 MPa) in thicknesses up to 0.5-inch (13 mm), and 21,000 psi (145 MPa) from 0.5 to 1.0-inch (25 mm) thick, and yield strength of at least 16,000 psi (110 MPa) up to 0.5-inch (13 mm) and 15,000 psi (103 MPa) (from 0.5 to 1.0-inch (25 mm). It has elongation of 8%.

Component	Wt. %	Component	Wt. %	Component	Wt. %
Al	Max 97.5	Mg	0.45 - 0.9	Si	0.2 - 0.6
Cr	Max 0.1	Mn	Max 0.1	Ti	Max 0.1
Cu	Max 0.1	Other, each	Max 0.05	Zn	Max 0.1
Fe	Max 0.35	Other, total	Max 0.15		

Figure 2.4.2.1 : Components Percentage of Aluminum Alloy 6063(T5)

Physical Properties	Metric	English	Comments
Density	2.7 g/cc	0.0975 lb/in³	AA; Typical
Mechanical Properties			
Hardness, Brinell	60	60	AA; Typical, 500 g load; 10 mm ball
Hardness, Knoop	83	83	Converted from Brinell Hardness Value
Hardness, Vickers	70	70	Converted from Brinell Hardness Value
Ultimate Tensile Strength	186 MPa	27000 psi	AA; Typical
Tensile Yield Strength	145 MPa	21000 psi	AA; Typical
Elongation at Break	12 %	12 %	AA; Typical; 1/16 in. (1.6 mm) Thickness
Modulus of Elasticity	68.9 GPa	10000 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Poisson's Ratio	0.33	0.33	
Fatigue Strength	68.9 MPa	10000 psi	AA; 500,000,000 cycles completely reversed stress; RR Moore machine/specimen
Shear Modulus	25.8 GPa	3740 ksi	
Shear Strength	117 MPa	17000 psi	AA; Typical
Electrical Properties			
Electrical Resistivity	3.16e-006 ohm-cm	3.16e-006 ohm-cm	AA; Typical at 68°F

Figure 2.4.2.2 : Main Properties of Aluminum Alloy 6063(T5)

Thermal Properties			
CTE, linear 68°F	23.4 µm/m-°C	13 µin/in-°F	AA; Typical; Average over 68-212°F range.
CTE, linear 250°C	25.6 µm/m-°C	14.2 µin/in-°F	Average over the range 20-300°C
Specific Heat Capacity	0.9 J/g-°C	0.215 BTU/lb-°F	
Thermal Conductivity	209 W/m-K	1450 BTU-in/hr-ft²-°F	AA; Typical at 77°F
Melting Point	616 - 654 °C	1140 - 1210 °F	AA; Typical range based on typical composition for wrought products 1/4 inch thickness or greater
Solidus	616 °C	1140 °F	AA; Typical
Liquidus	654 °C	1210 °F	AA; Typical
Processing Properties			
Annealing Temperature	413 °C	775 °F	hold at temperature for 2 to 3 hr; cool at 50°F per hour from 775 to 500°F
Solution Temperature	521 °C	970 °F	
Aging Temperature	182 °C	360 °F	hold at temperature for 1 hr
Aging Temperature	204 °C	400 °F	hold at temperature for 1 hr

Figure 2.4.2.3 : Other Properties of Aluminum Alloy 6063(T5)

Chapter 3

METHODOLOGY

3.1 Introduction

To determine whether the joint can be created on the conventional lathes machine, several pre testing was conducted and a few joints had to be created to get a common idea of how the process would work.

There were very limited parameters that needed to be consolidated before the experiment process can begin. Among the parameters are the physical and mechanical properties of the metal and rotating speed (RPM) on lathes machine. These characteristics are important in order to ensure the metals can be welded in the already impossible conditions using lathes machine. Using this characteristics, a pre – welding conditions can be determined what the optimum RPM would be to start with in order to start work on the welding the two metals together. Once the welding process has been carried, the aluminum round bars will be put through rigorous testing such as the micro – hardness testing and microstructure testing to gain knowledge on the description of the joint.

In order to consolidate the parameters, research had to be carried out on previous papers and journals on what would be the optimum parameters that would be required to achieve a complete weld joint. A single type of aluminum alloy would be used in this case as to this would scope down the different possibilities and matters that may arise using different types of material with different hardness. However with certain poor working conditions, a weld of high standards will be hard to produce due to the incapability of machining using the lathes machine.

This project was carried out in the space of two semesters from January till September 2012. For equipment purposes, this project was basically carried out on the conventional lathes machine using aluminum alloy 6063(T5).

3.2 Project Activities

3.2.1 Sample Fabrication

First of all, the material was procured at 1.9cm or 19mm in the diameter limits which was 1.5cm imposed by the tool stock holder. This created a lot of complications as the supplier had no smaller diameter than 1.9cm. After the material was procured, it had to go through a machining process to cut them into small pieces of 7.5cm long.

Next, the materials had to be lathed in order to achieve the 1.5cm diameter limit. This resulted in the diameter limit being scope to 0.8cm, 1.2cm and 1.5cm. Every each diameter had four pieces of material each that was being used to fabricate.

The machine had very limited options of rotational speed which was 500RPM, 855RPM, 1325RPM and 2000RPM. Due to this, the three highest RPM had to be chosen as 500RPM had been tried before in FYP 1. The melt felt no effect and was not heating at 500RPM.

3.1.2 Sample Testing

To conduct the microstructure and micro hardness test the material were had to be cut using an abrasive cutter. The tiny pieces had to be mounted which would make the grinding and polish job easier. After the piece were cut using the abrasive cutter and mounted, the tiny metal pieces were then sent for grinding and polishing whereby this process took a very long time go get to the shiny surface. By using multiple grinding paper sheets raging from the roughest of 60 till up to 800 the surface of the metal pieces was good before they were sent for polishing. Finally the micro structure and micro hardness processes were carried out. Finally etching was carried out the metal for the microstructure testing.

3.3 Key Milestones (FYP 2 - Gantt Chart)

No	Detail/Week	1	2	3	4	5	6	7	MID SEM BREAK	8	9	10	11	12	13	14	15
1	Project Work Continues																
2	Submission of Progress Report										★						
3	Project Work Continues											★	★	★	★		
4	Submission of Draft Report																
5	Submission of Dissertation (soft bound)															★	
6	Submission of Technical Paper															★	
7	Oral Presentation																★
8	Submission of Project Dissertation (Hard Bound)																★

Table 3.3 : FYP 2 Gantt Chart

Week 9

The 1st milestone was achieved on this week as the progress report was submitted and fabrication process had begun on this week.

Week 10 & 11

On this two week, welding process had properly begun where multiple rod pieces of aluminum alloys were trying to be combined to each other.

Week 12 & 13

Micro – hardness and microstructure testing was carried on both of these two weeks.

Week 14

Dissertation (softbound) and Technical Paper was submitted to Supervisor on this week.

Week 15

Final Dissertation (hardbound) and Oral Presentation will be carried out.

3.4 Tools Used

3.4.1 Equipments

The equipments that were used :

a) Conventional Lathes Machine (Block 21)
b) HV Machine (Block 17)
c) Mounting Machine (Block 17)
d) Optical Microscope (Block 17)
e) Abrasive Cutter (Block 17)

All these equipments above had a helping hand for the author to create the fabrication process and carry out necessary testing for the theoretical and analytical part of results and discussion.

3.4.2 Materials

There material that was selected was the 1.9cm diameter against 100cm length of aluminum alloy 6063(T5) rods. This material was cut into smaller lengths of 7.5cm each.

Chapter 4

RESULT AND DISCUSSION

4.1 Sampling Process

When placed under the microstructure microscope and micro – hardness tester, the material was analyzed and sample data was taken from the metal pieces. The data that was taken will be discussed in the coming subchapters. Two basics test were carried out.

4.2 Data Gathering (Past)

4.2.1 FYP 1(Gathered Data)

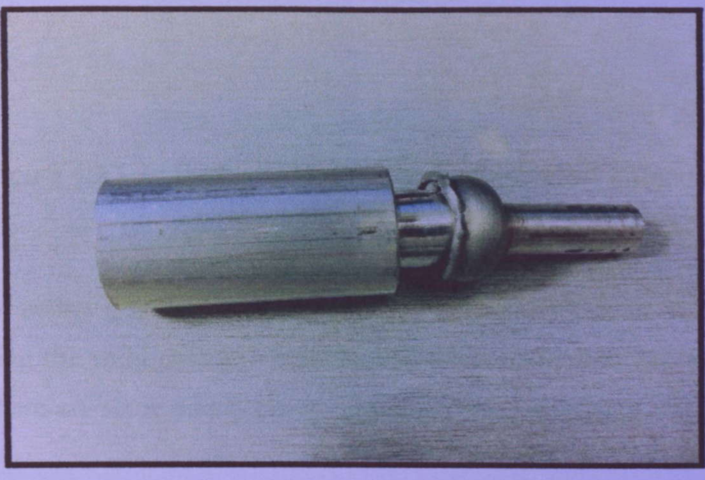

Figure 4.2.1.1 : Rotating and Stagnant Rods after the welding process (broken weld)

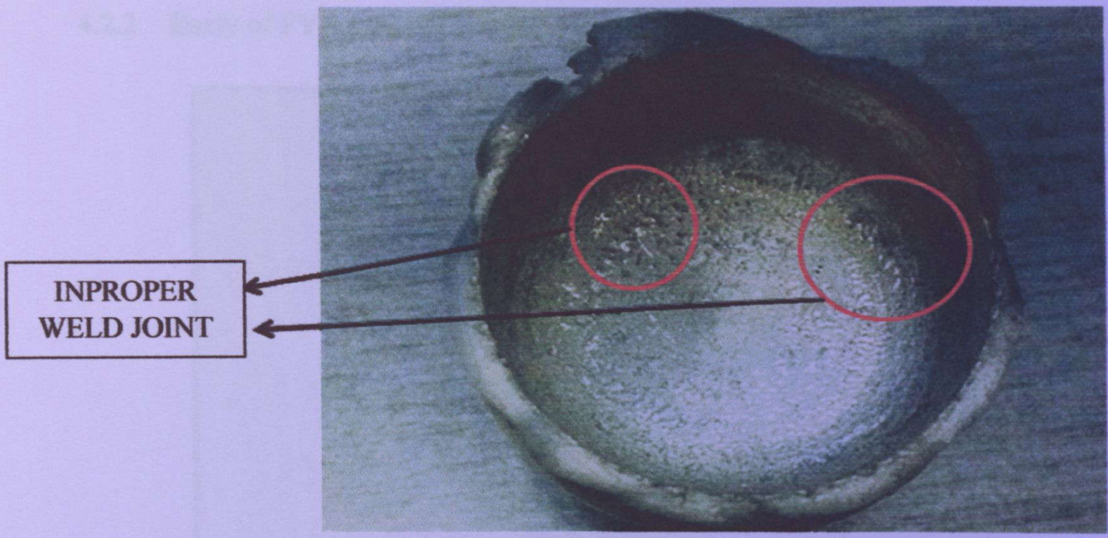

Figure 4.2.1.2 : Stagnant Rod failed joining process – broken formation

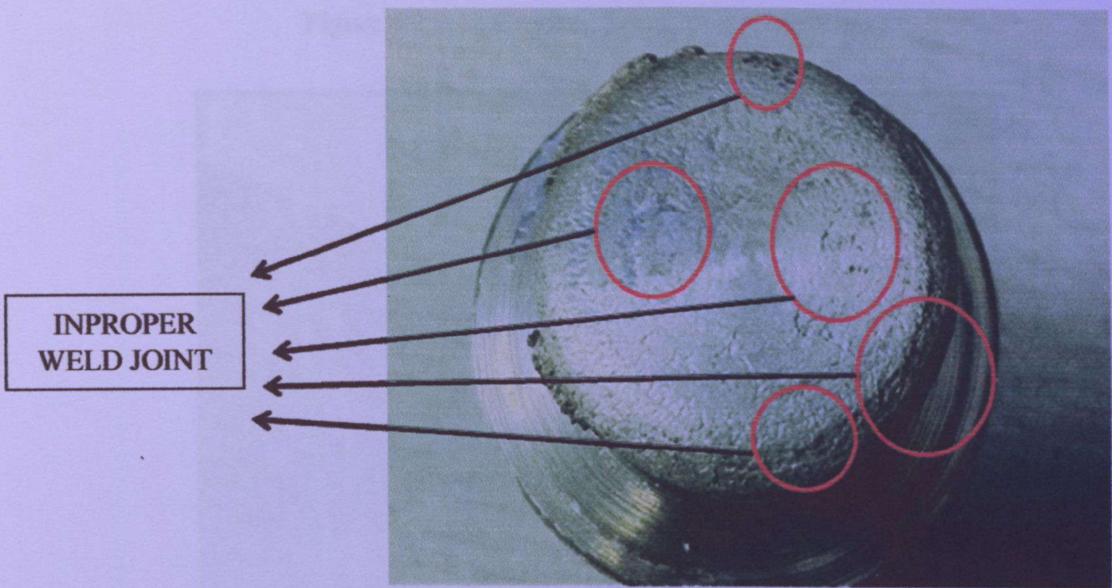

Figure 4.2.1.3 : Rod failed joining process – broken formation

From this, the author got the knowledge that the aluminum had the layering problem whereby during the weld trying to be achieved the formation of the metal is not all around and there are some empty pores. The joint was incomplete resulting in a total failure weld.

4.2.2 Early of FYP 2 (Gathered Data)

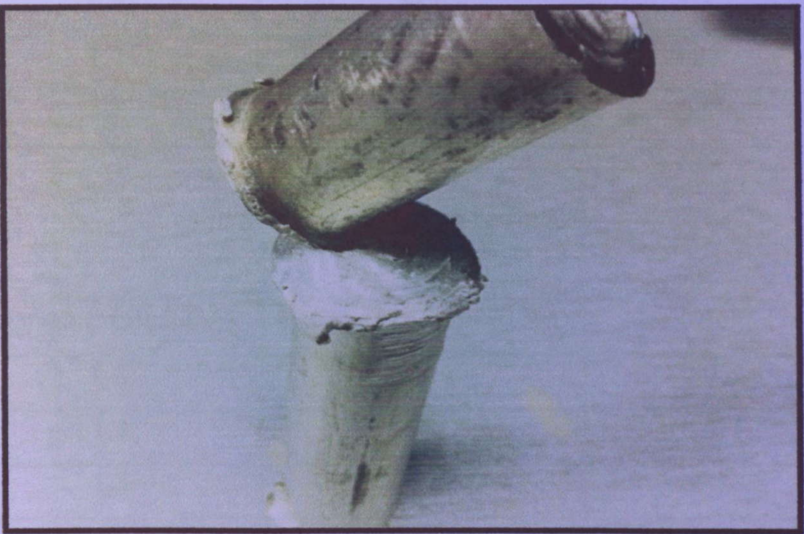

Figure 4.2.2.1 : Crooked Weld Joint (Side View)

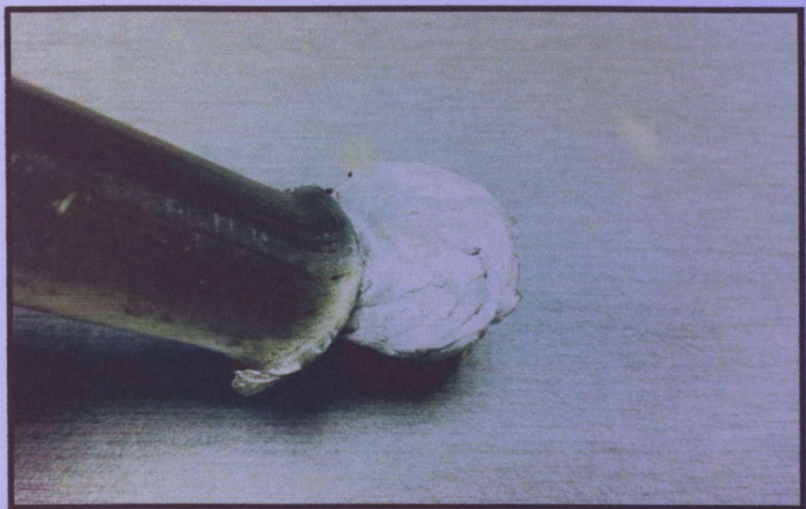

Figure 4.2.2.2 : Crooked Weld Joint

Diameter Used (cm)	Rotational Speed (RPM)	Flash Height
0.8	855	1.3
1.2	855	0.85
1.5	855	0.5

Figure 4.2.2.3 : 855RPM speed

Diameter Used (cm)	Rotational Speed (RPM)	Flash Height
0.8	1325	0.9
1.2	1325	0.5
1.5	1325	0.3

Figure 4.2.2.4 : 1325RPM speed

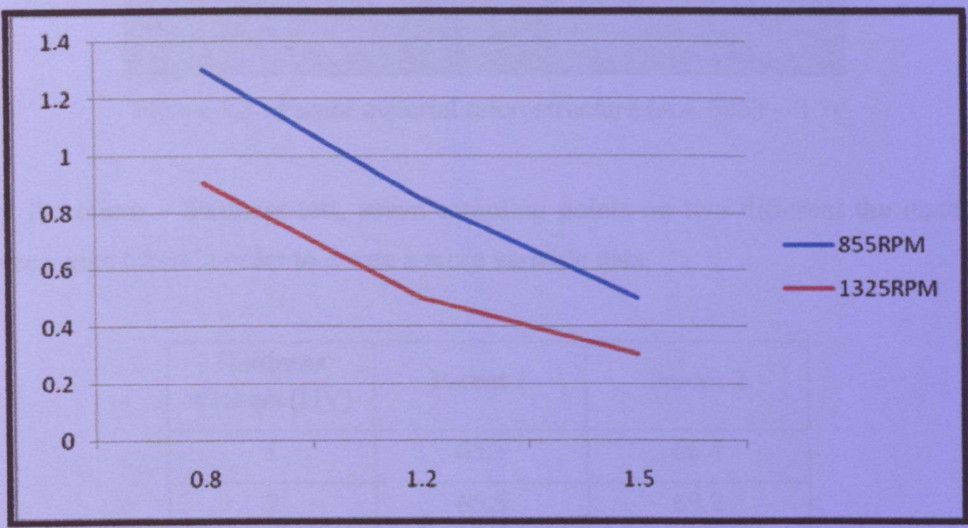

Figure 4.2.2.5 : Comparison Graph

From figures 4.2.2.1 and 4.2.2.2, that was the most solid joint created by the author as to date so far and it is unbreakable as there might be some forging process done.

For the comparison data figure, it shows that thicker the rod and the higher the rotational speed is, the more higher the chance of a welded joint being created.

4.3 Parent Material

As the before the material can be analyzed, the parent material properties had to be analyzed to ensure the results can be consolidated. Below are the details of the parent material properties and microstructure.

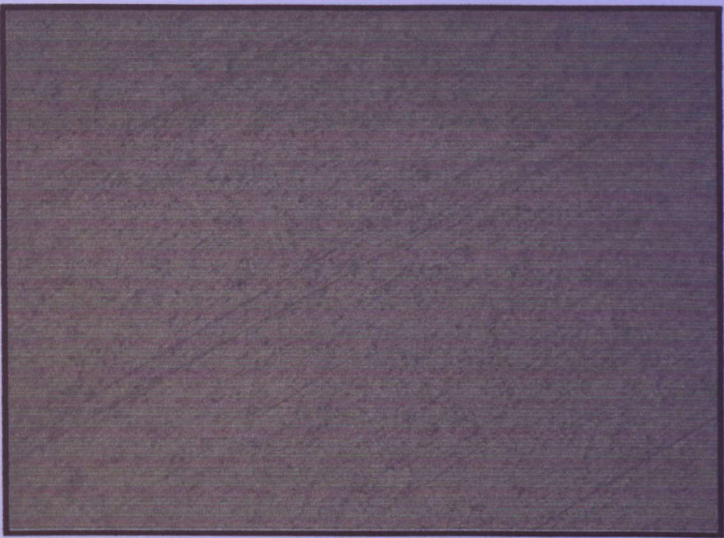

Figure 4.3 : Parent material microstructure (AA 6063 – T5)

For the micro – hardness test, seven sampling points on two different the material pieces were taken in order to create a more variable data.

Hardness Vickers (HV)	Parent 1	Parent 2
1	65.3	66.4
2	65.5	69.2
3	73	71.9
4	74.1	68.6
5	67.2	69.3
6	67.3	66.8
7	68.5	64.5
Average	68.7	68.1

Table 4.3 : Parent material HV (AA 6063 – T5)

In relation to the table above and Fig 2.4.2.2, it proves that the material hardness is indeed 70HV suggested as the AA association. The difference in 2HV might be because the material was lathed before the welding process was carried out. This could be due to the fact that the metal was heating when lathing was being done it to get the 1.5cm diameter.

4.4 Microstructure Test

The microstructure tests were carried out the microscope that was located at block 17 level 1. Below are the samples pictures for the microstructure.

4.4.1 Rod 1 – 0.8cm (1325RPM – Almost jointed but with little flash)

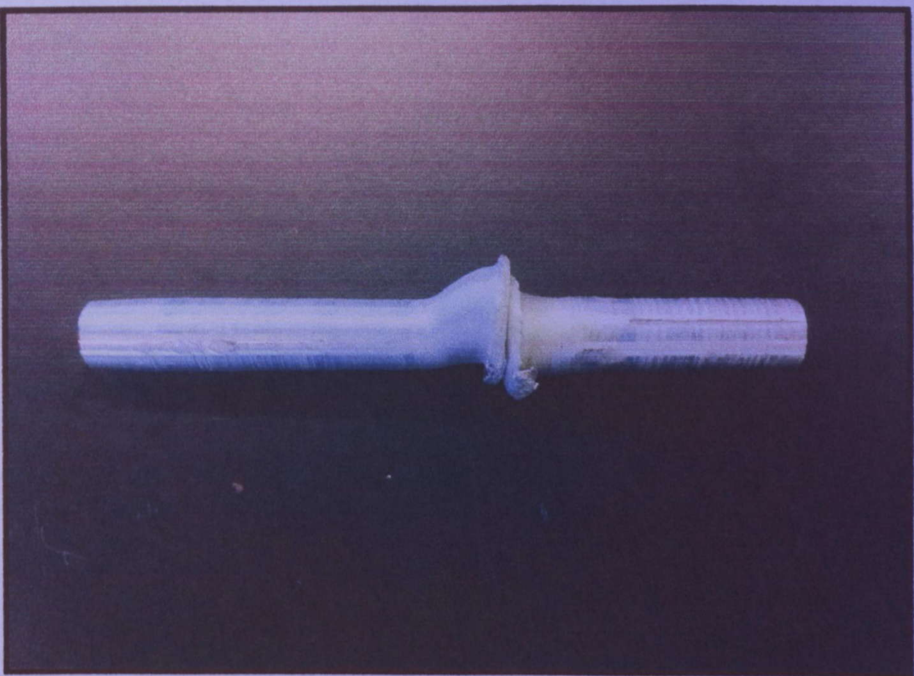

Figure 4.4.1.1 : Original complete joint

Figure 4.4.1.2 : Original joint (opened)

Figure 4.4.1.3 : 0.8cm (left side upper) – 1

Figure 4.4.1.4 : 0.8cm (left side lower) – 2

Figure 4.4.1.5 : 0.8cm (right side upper) – 3

Figure 4.4.1.6 : 0.8cm (right side lower) – 4

4.4.2 Rod 2 – 1.2cm (2000RPM – Bad joint but with excessive flash)

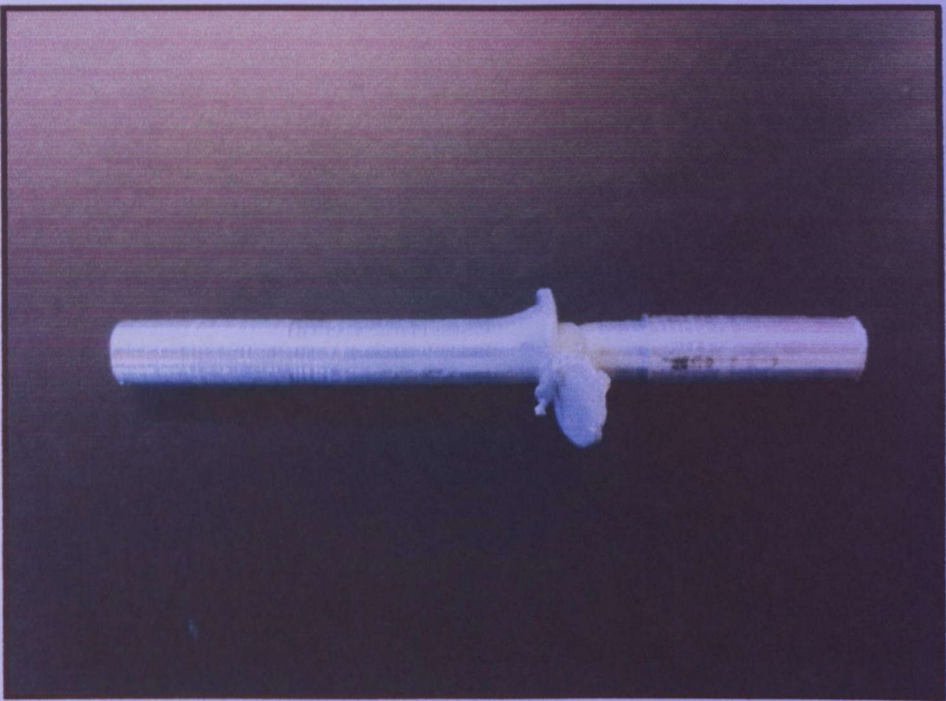

Figure 4.4.2.1 : Original complete joint

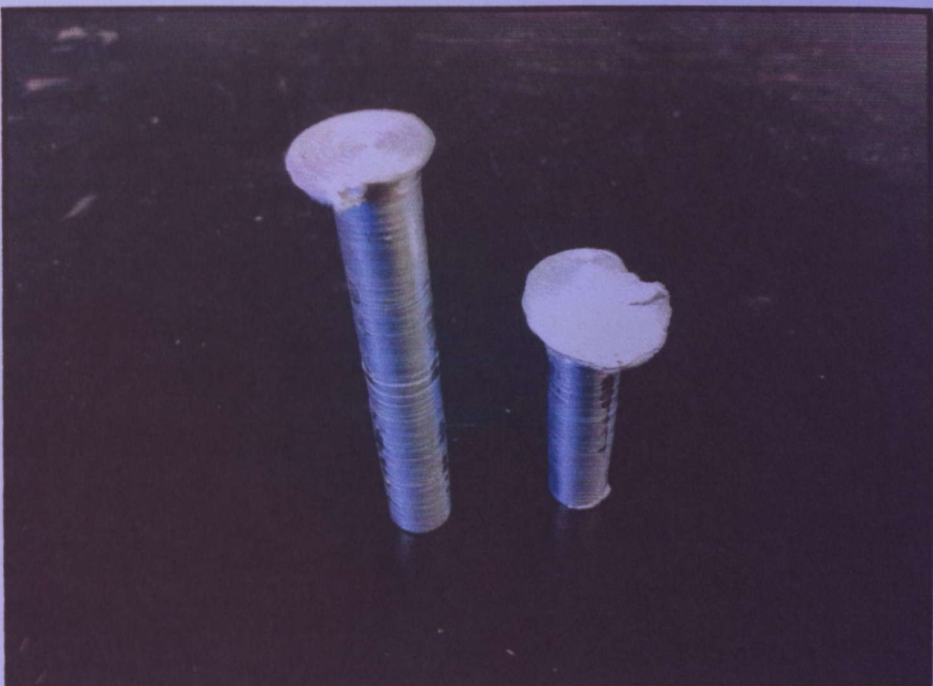

Figure 4.4.2.2 : Original joint (opened)

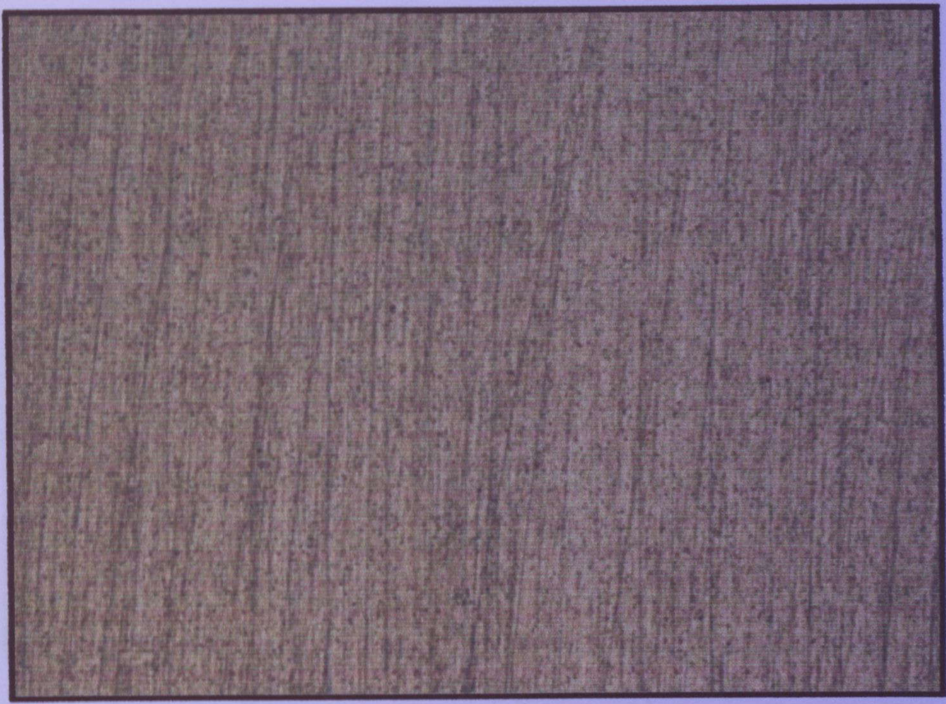

Figure 4.4.2.3 : 1.2cm (left side upper) – 1

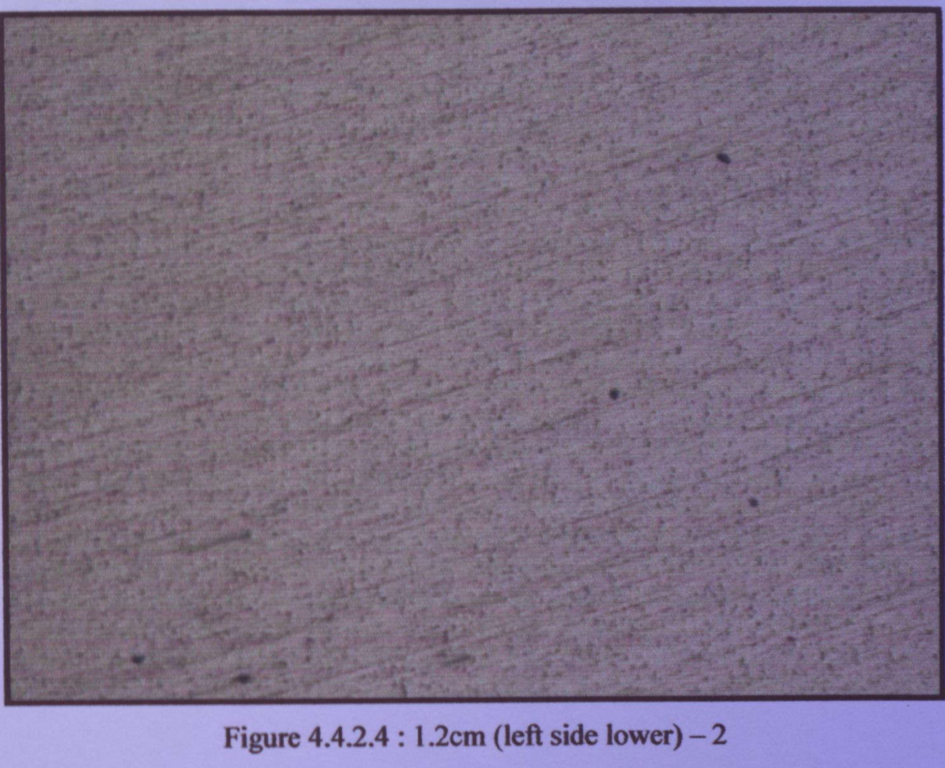

Figure 4.4.2.4 : 1.2cm (left side lower) – 2

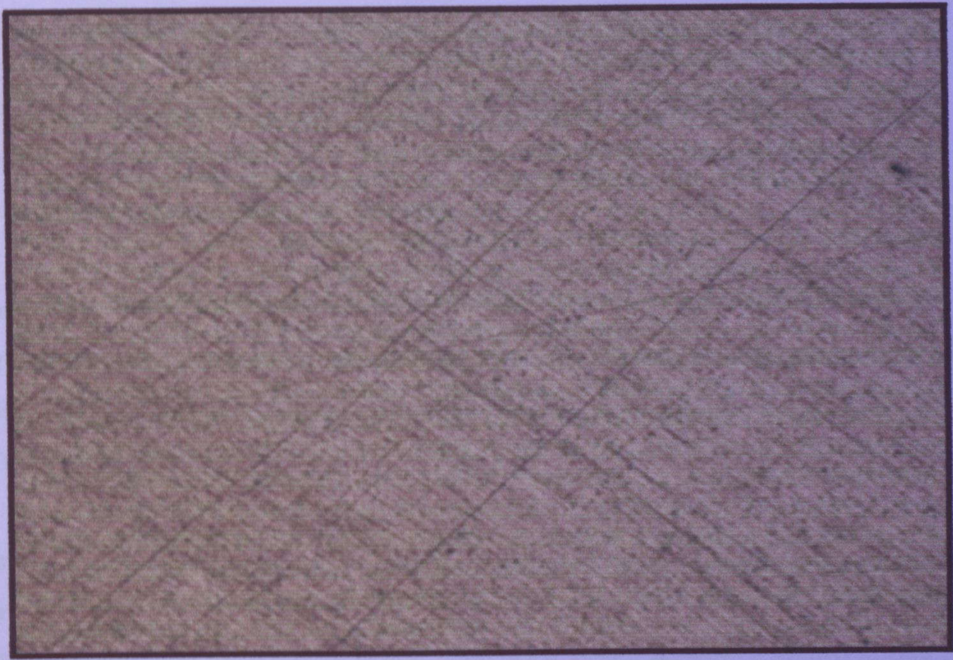

Figure 4.4.2.5 : 1.2cm (right side upper) – 3

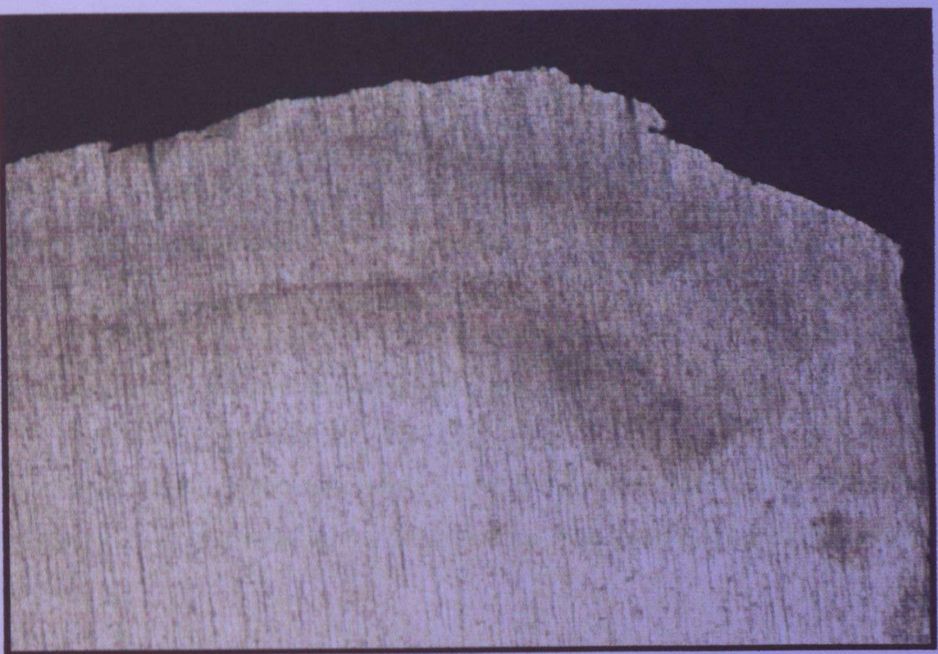

Figure 4.4.2.6 : 1.2cm (right side lower) – 4

4.4.3 Microstructure Test Analysis

From the pictures above, it can be seen that there is not enough heat generation to properly melt the material hence why the material pieces are shaped in such a way that the material is uplifted.

Comparing the microstructure result pictures of the attempt weld material with the parent material, there is not much different that can be seen from the parent material. This mean, the mechanical properties of the attempt weld part should about the same of the parent material.

However looking at figure 4.3.3.6, there are thermal variation marks left. The thermal variation marks in this picture are the colour variation on top left to the right. This actually shows that the dendrite flows when the material is being softened during the weld process.

Despite all of that, the actual material was not welded to proper joints from one end to the other which was hoping to be achieved. This may be one the reason why the welded material looks almost similar to the parent material microstructure.

4.5 Micro – Hardness Test

After the microstructure test had been done, the next micro – hardness of the material was set to be tested. The micro – hardness testing was also carried out at block 17 level, using a micro – hardness tester and the units were in Hardness Vickers or HV. The results will be discussed in the next section. Two sampling points were taken for each piece.

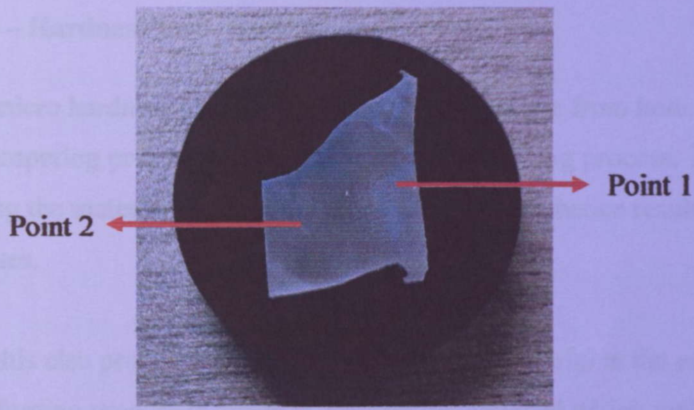

Figure 4.5 : Mounted aluminum piece

4.5.1 Rod 1 – 0.8cm (1325RPM – Almost jointed but with little flash)

Metal Piece (HV)	Point 1	Point 2
1	46.9	50.2
2	50.5	75.2
3	45.2	73
4	47.2	61.8

Table 4.5.1 : HV for aluminum rod 1

4.5.2 Rod 2 – 1.2cm (2000RPM – Bad joint but with excessive flash)

Metal Piece (HV)	Point 1	Point 2
1	43.5	53.6
2	44.8	44.8
3	48.8	60.3
4	47	43.3

Table 4.5.2 : HV for aluminum rod 2

4.5.3 Micro – Hardness Test Analysis

Based on the micro hardness test that was carried, we can see from here aluminum undergoes a tempering process instead of a forging or welding process. This results in the heat making the material softer than it is supposed to be, hence resulting in a lower HV values.

Furthermore, this also proves that the heat affecting the material at the end shows that there is some forging process in terms of melting the material which makes the hardness to drop from by almost 25HV in most of the metal pieces.

4.6 Complete and Final Analysis (Failure of Weld Joint)

Below is the complete results analysis as to why the results were not expected as it was supposed to. The material was not joining due to the below :

a) The metal couldn't be welded because of the extreme vibration from the machine when the stationary piece was pushed against the rotating part. The rotating metal piece was bouncing up and down already even before the welding was done. This could have been possibly due to the ball bearings of the rotating chuck were damaged.

b) When the stationary piece was pushed against the rotating piece, the stationary piece tends to deflect sideway or upwards due the inadequate pressure and force being applied on the tailstock. This could have been from the tailstock gripper had no proper locking mechanism which resulted the pieces to feel the effect of vibrations from the machine and lifting up the metal pieces.

c) The material was heating on the inside end the tailstock gripper rather than the end of the part that was meant to be welded. This creates a wrong metal heat affected zone which results in the metal pieces not being able to be welded properly.

d) Layering problem of aluminum would have been one of the other problems whereby the aluminum creates a protective film on the surface when the weld is trying to be created.

e) Poor machine conditions are also one of the major issues whereby the lathes machines were in bad condition and had not much of capabilities to be tested such as for example the limitations of the rotational speed (RPM) which were 855RPM, 1325RPM and 2000RPM for the highest three rotational speed on the lathes machine.

f) *The other parts of the material rods were analyzed for micro – hardness but* did not show any signs of hardness difference so all of these metal pieces were made obsolete and only the front end pieces were taken. This proves that the metal rods were under stress on the full length except the end parts of it.

Chapter 5

CONCLUSION AND RECOMMENDATION

From this experiment, the experiment was unsuccessful. But it shows there are possibilities that friction welding can be carried out. But due to the deteriorating machine conditions, this experiment was unsuccessful. The microstructure proves that the grains aren't affected by the minor heat affected zones. However, this was contradicted with the micro – hardness results as it proves that somehow the metal changes its properties which results in a lower material properties.

The most effective rotation speed that was noticed from the experiment was 1325RPM. But, the author cannot come to a conclusion with this data. However as read from journal the values of the RPM are around that region so it proves that somehow the value data might be right in terms of consolidating.

The rotational speed (RPM) and force that was being applied need a better understanding as the author just used his regular human body strength to push the tailstock against the rotating chuck. Although the experiment was almost unsuccessful, this is not a proper practice as it maybe concern HSE issues as the lathes machinery parts was not built for these purposes.

The aluminum had melted even when the metal pieces were being lathe which proves that this alloy can metal at low temperature. However due to the complications, the welding process was unsuccessful.

As a recommendation, there are a lot of modifications of the lathes machine that can be done. The most and important part of all would be to install a hydraulic system whereby it can push the stationary metal piece into the rotating piece resulting in the in a proper friction welding process. Furthermore, a bigger tailstock diameter should be fabricated or used whereby a bigger diameter would be able to weld the joint and would cause more heat generation. A jig can also be created in order to hold the stationary metal piece. The rotating chuck should be checked to ensure that there is no vibrating motion which could cause the rotating material to have a downward or upward motion. Finally, if all these modifications are done than just maybe the friction welding process can be achieved on the conventional lathes machine.

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