A Study Of Aluminum Alloy 6063 Mechanical Properties Under Electrical Discharge Machine (Edm) Wire Cut Machining And Quenching Condition

M. Riaz, Muhd Azhar Ridhwan

Abstract:—Electrical Discharge Machine (EDM) wire cut machining is widely used due to its accurate cutting and clean cutting. The machine is used in tool and die and hole making. Common issue with the EDM wire cut machining is the presence of heat affected zone and “white area”, which can influence the surface integrity of the work piece and can propagate cracks, making the work piece more susceptible to failure. By using heat treatment, the work piece can improve its mechanical properties, allowing to last longer without failure. In this experiment, aluminum alloy 6063 will be machined by using EDM wire cut. The finished specimen is then treated with different heat treatment as per suggested by the journals. After heat treatment, the specimen is then will undergo tensile testing and hardness test. Results will be collected and analyzed

Index Terms:— Aluminum alloy, Wire Cut, Electrical Discharge Machine, Mechanical properties, Quenching conditions, Machining conditions.

1 INTRODUCTION

The Electrical Discharge Machining (EDM) is a method where electrical sparks are used to corrode metals. It is usually used for producing complex shapes in metals. The principle of operation is a wire is move slowly along a path to produce any shapes. EDM wire cut has a few advantages; namely able to produce complex shapes, no burr will appear, accurate machining can be achieved, and delicate work can be done. However EDM wire cut can cause problem in the form of heat affected zone (HAZ). HAZ is characterize by hair line cracks and thin, recast layer. Quenching is a method of rapidly cooling metal parts from austenized and solution treatment temperature. The reason of quenching metal is to cool metal quickly to form the desired microstructural phases. Another reason why quenching is needed is to improve the mechanical properties of a material. This is important as material may exhibit decreasing mechanical properties after undergoes any heat producing process, such as welding. As EDM wire cut do produce heat, there will be HAZ area along the outline, and as stated above, the HAZ area has hair line cracks and thin, recast layer. This research will explore if there is any effect on mechanical properties when aluminum alloy 6063 undergoes EDM wire cut and quenching conditions. It also aims to determine if EDM wire cut machining influence the mechanical properties of aluminum alloy 6063. This research will explore the suitable heat temperature, specific liquid quenching condition, and optimum aging time and temperature that can improve the mechanical properties of aluminum alloy 6063.

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2.1 Material Selection

Aluminum alloy 6063 is a 6-series type aluminum. 6-series type aluminum has magnesium and silicon as its principle alloying element (AlcoTec, 2015). Aluminum alloy 6063 is heat treatable, high resistant towards all types of corrosion, excellent weld ability and braze ability and good electrical and thermal conductor. The mechanical properties and machinability of the aluminum alloy 6063 is influenced by its temper, which in total there are 7; O, T1, T4, T5, T6, T83, T831. It’s typical uses are pipe, railing, furniture, architectural extrusions, truck and trailer flooring, doors, windows, and irrigation pipes (ASM International, 1992). The main reference material for aluminum composition will be from the ASM Handbook. There is a number of different chemical composition in aluminum alloy 6063, in which some of the have a maximum weight percentage and some have range value. Each element can either improve or deteriorate the mechanical properties of the aluminum. The major constituent for the aluminum grade is wrought aluminum 6063. The composition limit of the 6063 alloy, based on the ASM Handbook on Nonferrous Alloys and Special-Purpose Materials, is stated in Table 2.1.

Element	*Composition (wt%)*
Silicon, Si	*0.20 – 0.6*
Iron, Fe	*0.35 max*
Copper, Cu	*0.10 max*
Manganese, Mn	*0.10 max*
Magnesium, Mg	*0.45 – 0.9*
Chromium, Cr	*0.10 max*
Zinc, Zn	*0.10 max*
Titanium, Ti	*0.10 max*
Others	• *0.05 max (each)* • *0.15 max (others)*
Aluminum	*balance*

Table 2.1: *Composition limit of 6063 alloy (ASM International, 1992)*

2.2 Crystal Structure

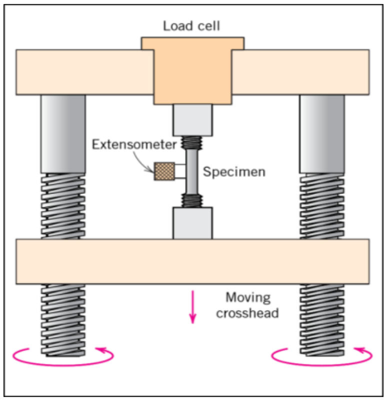
A solid can be classified into crystal structure, as when solidification happens, atoms will arrange themselves into a three-dimensional structure that is keep on repeating. Metals, most ceramics and some polymer will form a crystalline structure under normal solidification conditions. There are many different types of crystal structures in metals, such as face-centered cubic (FCC), body-centered cubic (BCC) and hexagonal close-packed (HCP). In this case, aluminum has an FCC crystal structure with an atomic packing factor of 0.74 (E. T. & MacKenzie, 2010).

2.3 Electrical Discharge Machining – Wire Cut

Electrical Discharge Machining – Wire Cut (EDM Wire Cut) or Wire Electrical Discharge Machining (WEDM) is a machining process for cutting conductive material by using controlled electrical sparks. The process is done in presence of a fluid namely dielectric fluid. The electrode is the cutting material, and it is continuously run during machining process. The sparking process happens electrode wire-side surface to the work piece (Jameson, 2001). The development of the EDM Wire Cut took place from the early 1960s to 1970s. A USSR made EDM Wire Cut machine was showed in 1967 at a machine exposition in Canada, using numerical control to control operation movement. Computer numerical control is then replacing the numerical control later on. Ball screws, which enabling anti-backlash, anti-friction table axis became available. Servo motors with encoder and tachometer-feedback made table-axis feed and position control practical. Reduction of stick friction became a reality with anti-friction, preloaded table ways. All the hardware is in place to create a computer-numerical-controlled Electrical Discharge Machining. With ever increasing easy to use software, EDM wire cut is commonly used for through-hole applications, for example stamping and extrusion dies. is obtained from the ASM International Handbook Volume 2 Properties and Selection: Nonferrous Alloys and Special-Purpose Materials. Therefore, the result of this research will be compared with the data below.

2.4 Tension testing

Tension testing a common mechanical stress-strain testing. The test is done by deforming a specimen to fracture, by applying an increase of tensile load that is uniaxially applied along the long axis of a specimen. The specimen is done in a “dog-bone” configuration, allowing confinement of deformation to the narrow center region of the specimen (where uniform cross section is available along its length) and to avoid fracture at the ends of the specimen. A stress-strain test takes a few minutes to be done (Callister, Jr & Rethwisch, 2014) and it is a destructive test; specimen is permanently deformed and usually fractured. The testing will calculate the stress and strain of a material. Stress is defined as applied force in area (Bhaduri, 2018). Stress is the limiting value of force per unit area, as the area approaches zero. Based on the definition, the material is considered to be continuous and cohesive (Hibbeler, 2011). Furthermore, the material should be both homogenous and isotropic. Where σ is average normal stress at any point on the cross-sectional area, P is internal resultant normal force, and A is the cross-sectional area of the bar, which in the case of tension testing, A is the cross-sectional area of the narrow part of the specimen. Strain on the other hand is the ratio of change in length to the original length (Bhaduri, 2018). Normal strain on the other hand is the measure per unit length of the elongation or contraction of a small line segment in the body. Strain is a dimensionless quantity, but it can be expressed in micrometer per meter (µm/m) as in most engineering applications, strain measurement will be small. Tension testing is usually being done in a universal testing machine. The machine is usually connected into a computer to produce the result of the test. The schematic representation of the apparatus will be shown below.



2.5 Hardness Tests

The term ‘hardness’ is a structure-sensitive mechanical property of material, usually associated with the surface. If the material is homogenous in composition and structure, the hardness measured on the surface layer will represent the hardness of the bulk of the material. In general, the hardness is defined as the resistance of a material to permanent or plastic deformation of its surface, usually by indentation, under static or dynamic load (Bhaduri, 2018). A qualitative and arbitrary hardness indexing scheme was developed, which is the Mohs scale. Mohs scale is ranged from 1 on the soft end of talc to 10 for a diamond. Later on, quantitative hardness techniques have been developed in which a small indenter is forced into a surface of a material to be tested, under controlled conditions of load and rate of application. The depth or size of the resulting indentation is measured, which in turn related to a hardness number. In general, softer material will have a larger and deeper indentation, and therefore lower hardness index number (Callister, Jr & Rethwisch, 2014). Hardness test is commonly used over other forms of testing due to several reasons (Callister, Jr & Rethwisch, 2014):

1. Simple and inexpensive testing
2. Test is non-destructive
3. Other mechanical properties can be estimated from hardness data

Figure 2.2 below is the comparison of different hardness scales.

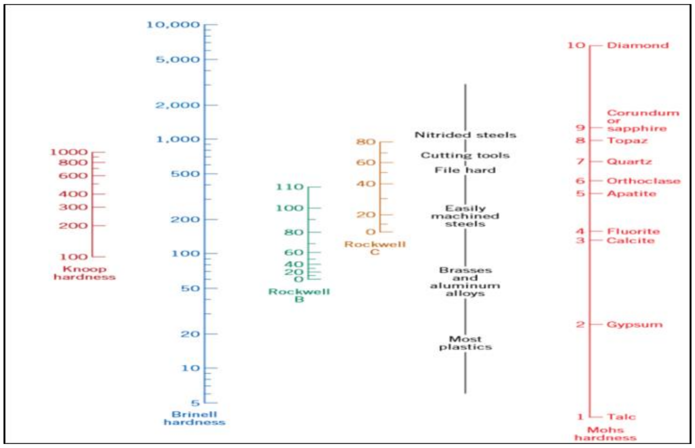


Figure 2.2: *Different hardness scales (Callister, Jr & Rethwisch, 2014)*

3 METHODOLOGY

The step-by-step methodology used for the experiment is outlined below.

1. Determine machining parameters. Machining parameters will be selected, as in this case for EDM machining, selected parameter will be based on stability of the electrical sparks and material removal rate.
2. Machining "dog-bone" specimen. Dog bone will be produced by machining based on ASTM standard
3. Prepare sample for heat treatment. Machined sample will be separated into to-be heat treated samples and as-is samples. The heat-treated sample will be labelled.
4. Prepare sample for mechanical testing (controlled group). The as-is specimen will undergo mechanical testing.
5. Determine solution heat treatment, quenching temperature, and aging method and temperature. Parameters for heat treatment will based on journals.
6. Heat treatment. Starting of heat treatment process.
7. Mechanical testing. Starting of mechanical testing.
8. Collection of mechanical testing data and analysis. Data from mechanical testing will be recorded, collected and analyzed.

The specimen will be cut by using EDM wire cut machine. The machine cut through the work piece by using a wire. The machining will be fed on x and y axis only. The model of the machine used will be the Knuth Smart DEM. The specification of the machine will be shown in Table 3.1.

Specifications SMART DEM	
Working Area	
workpiece length (max.)	450 mm
workpiece thickness (max.)	200 mm
workpiece width (max.)	350 mm
workpiece weight (max.)	300 kg
X axis travel	250 mm
Y axis travel	350 mm
U axis travel	30 mm
V axis travel	30 mm
wire diameter	0.25 mm
cutting capacity (max.)	70 mm²/min
cutting angle (max.)	± 5°/100 mm
wire tensile strength (max.)	1600 N
wire coil, max. weight	6 kg
wire guide	diamond
CNC Control	
software	ELAPT 3.2
controlled axes	X, Y, U, V
input increment (min.)	0.001 mm
Dielectric System	
dielectric fluid	deionized water
filter	paper filter 10µ
dielectric tank capacity	100 l
Drive Capacities	
machine drive power	3 kW
power supply	400 V
Accuracy	
positioning accuracy	0.02 mm
surface roughness (best)	1.2 µm Ra
Dimensions/Weight	
weight	2000 kg
Part No.	180 456

Table 3.1: *Specification of the Smart Knuth DEM EDM wire cut machine (Knuth Smart DEM, n.d.)*

4 EXPECTED OUTCOME

This research aims to find out if EDM wire cut machining influence the mechanical properties of aluminum alloy 6063. In doing so, the research will explore the suitable heat temperature, specific liquid quenching condition, and optimum aging time and temperature that can improve the mechanical properties of aluminum alloy 6063. In essence, it will answer the following research questions:

1. What is the most suitable quenching condition for aluminum alloy 6063 under the EDM process?
2. What is the optimum hardness value of aluminum alloy 6063 after the quenching process under EDM process?
3. How does the tensile behavior of aluminum alloy 6063 change after the quenching process under EDM process?

5 CONCLUSION

The research is based on machining of aluminum alloy 6063 using EDM wire cut machine with quenching condition. The machine parameters are based on the optimal parameters. Those parameters are T_{on}, T_{off}, peak current and voltage. Other parameters such as machine performance, cutting time, cutting cost and others are not covered because this is outside the scope of the study. The microstructure analysis will not be covered as the analysis will take a longer time to complete. Therefore, tests on the mechanical properties will be done on the treated specimens and untreated specimens. The contribution of the research is to supplement knowledge on manufacturing engineering. Any potential research that researches on EDM wire cut machining and also quenching can refer to this research for future works.

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