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كلية الدراسات العليا

MECHANICAL DEPARTMENT MSC (PRODUCTION)

A thesis proposes in partial fulfillment requirement of the degree of MSc

EFFECT OF USING WIRE CUTTING PROCESS IN MANUFACTURING OF AIRCRAFT PARTS

أثر إستخدام عملية القطع بالسلك فى عملية تصنيع أجزاء الطائرة

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صدق الله العظیم

Dedications

This work is dedicated to my family and many friends. A special feeling of gratitude to my loving parents, whose words of encouragement and push for tenacity ring in my ears. my mouther, my wife, my brothers.
Also, this work dedicated to many friends, they have supported me throughout the process. I will always appreciate all they have done.
In addition, I dedicate this work to SAFAT Aircraft Manufacturing Center family, where this work is done.
Last, not least dedicate for my homeland Sudan.

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In closing I am deeply grateful my parents for their endless love and patience.

1. Abstract:

The project will present the effect of using wire cutting process in material that is used in aircraft manufacturing as main fitting parts in the aircraft . The project aims to minimize the material waste and time consumed in producing aircraft parts. A specimen was cut using EDM wire cutting and tested for hardness, toughness and tensile strength, these results were then compared to the conceptual design data.

At the end of this research, the wire cutting process is expected to reduce the cost of manufacturing of aircraft parts. It was found that there was a minor difference in the testing results between the wire cut material and CNC machined specimen. It is therefore the designer's responsibility to decide whether it is suitable for use or not.

المستخلص:

هدفت الدراسة الي تشكل المادة الخام عن طريق إستخدام القطع بالسلك وعمل الإختبارات الميكانيكية لتوضيح تأثير العملية على الخصائص الميكانيكية للمادة ومقارنة النتائج مع النتائج المتحصل عليها فى الطريقة الرئيسية المستخدمة فى التصنيع.

وتهدف هذه الدراسة الى تقليل الفاقد فى المادة الخام ومما يودى الى تقليل تكلفتها عن طريق إستهلاكها بالطريقة المثلى والتى تؤدى الى تقليل تكلفة الإنتاج والحفاظ على الموارد كما تساعد في عملية تسهيل وتسريع الانتاج وتقليل الجهد.

وقد أخذت عينة بإستخدام القطع بالسلك و عمل إختبارات الصلابة , الصلادة و إختبار الشد ومقارنة نتائج إختبارات العينة ومقارنتها مع البيانات التصميمية للأجزاء.

وقد وجد من خلال نتائج الإختبارات التى أجريت أن هنالك بعض الإختلافات الطفيفة فى نتائج الإختبارات بين المادة الخام المشغلة بواسطة القطع بالسلك والمشغلة بواسطة ماكينات التحكم الرقمى. عليه يجب الرجوع الى المصمم لتحديد مالإذا كانت الطريقة المقترحة مناسبة للإستخدام أم لا.

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CHAPTER 1
Introduction

1 Introduction

1.1 PREFACE:

Through the centuries, man tried to improve the performance of the manufacturing process to save money, time and reduce the raw material that used in the manufacturing throw reducing the west it may happen during the manufacturing.

The machining of the metallic materials a lot of waste is generated in the raw material.

Aircraft manufacturing is critical area due to safety requirements made to ensure that human lives are preserved. To comply with these requirements aircraft manufacturing has become a costly process, due the special manufacturing processes and material that is used, so the decrease of material scrap rate, and process time decrease the manufacturing cost of the aircraft.

Wire cutting machine is used to remove rough shape of the part instead of using CNC machine for full machining.

The material mechanical properties will be tested to evaluate the serviceability of the material.

The using of wire cutting processes in part manufacturing led to save the money and time in this manufacturing.

1.2 THE PROBLEM STATEMENT:

Air-craft manufacturing center in Sudan using the Aluminum 2024 T3 in air-craft parts, the manufacturing of these part performed by CNC machine, but the raw materials is prepared through using the band saw.

The using of the CNC machining as full machining result in high scrap rate, and increase work done by CNC machine.

The using of wire cutting machine instead of band saw machine lead to less scrap rate and also less work can be carried in CNC machine, but due to small thickness that to be removed in CNC machine may led to change in material properties that not desirable in manufacturing of the air-craft parts.

1.3 SIGNIFICANCE OF THIS RESEARCH:

The project aims to find optimum solution for the loss of the raw material that happen during the machining process. That lead to reduce the waste of the raw material which happened during the machining of the parts.

1.4 THE OBJECTIVES OF THE RESEARCH:

- To test the part material using in air-craft.
- To determine the effect of wire cutting process in material properties.
- To evaluate the material scrap rate the save by the wire cutting process.

1.5 MATERIALS:

- Tensile strength testing device.
- Elongation testing device.
- Yield strength testing device.
- Hardness testing device.
- Wire cutting machine.
- Aluminum 2024 alloy equivalent material Carbone steel Alloy 15CDV6.

1.6 METHOD:

- Test the properties of parts raw material.
- Perform the wire cutting process and testing the following mechanical properties.
- Test the Hardness of the material after using the wire cutting machine.
- Test the Toughness of the material after using the wire cutting machine.
- Strength of the material after using the wire cutting machine.
- Tensile strength after using the wire cutting machine.
- Compare the properties of the material that cut buy wire cutting machine and the properties the required to produce the part.

CHAPTER 2
Theocratical Background

2 THEORETICAL BACKGROUND

2.1 TYPE OF MATERIALS USED IN AIRCRAFT MANUFACTURING:

where we consider structures peculiar to the field of aeronautical engineering. These structures are typified by arrangements of thin, load-bearing skins, frames and stiffeners, fabricated from lightweight, high strength materials of which aluminum alloys are the most widely used examples.

As a preliminary to the analysis of the basic aircraft structural forms presented in subsequent chapters, we shall discuss the materials used in aircraft construction.

Several factors influence the selection of the structural material for an aircraft, but amongst this strength allied to lightness is probably the most important. Other properties having varying, though sometimes critical significance is stiffness, toughness, resistance to corrosion, fatigue and the effects of environmental heating, ease of fabrication, availability and consistency of supply and, not least important, cost.

The main groups of materials used in aircraft construction have been wood, steel, aluminum alloys with, more recently, titanium alloys, and fiber-reinforced composites.

In the field of engine design, titanium alloys are used in the early stages of a compressor while nickel-based alloys or steels are used for the hotter later stages. As we are concerned primarily with the materials involved in the construction of the airframe, discussion of materials used in engine manufacture falls outside the scope of this book.

2.1.1 Aluminum alloys

Pure aluminum is a relatively low strength extremely flexible metal with virtually no structural applications. However, when alloyed with other metals its properties are improved significantly. Three groups of aluminum alloy have been used in the aircraft industry for many years and still play a major role in aircraft construction. In the first of this aluminum is alloyed with copper, magnesium, manganese, silicon and iron, and has a typical composition of 4% copper, 0.5% magnesium, 0.5% manganese, 0.3% silicon and 0.2% iron with the remainder being aluminum. In the wrought, heat treated, naturally aged condition this alloy possesses a 0.1% proof stress not less than 230 N/mm², a tensile strength not less than 390 N/mm² and an elongation at fracture of 15%. Artificial ageing at a raised temperature of, for example, 170◦C increases the proof stress to not less than 370 N/mm² and the tensile strength to not less than 460 N/mm² with an elongation of 8%.

The second group of alloys contain, in addition to the above, 1–2% of nickel, a higher content of magnesium and possible variations in the amounts of copper, silicon and iron. The most important property of these alloys is their retention of strength at high temperatures which makes them particularly suitable for aero engine manufacture. A development of these alloys by Rolls-Royce and High Duty Alloys Ltd replaced some of the nickel by iron and reduced the copper content; these RR alloys, as they were called, were used for forgings and extrusions in aero engines and airframes.

The third group of alloys depends upon the inclusion of zinc and magnesium for their high strength and have a typical composition of 2.5% copper, 5% zinc, 3% magnesium and up to1%nickel with mechanical properties of 0.1% proof stress 510 N/mm², tensile strength 585 N/mm² and an elongation of 8%. In a modern development of this alloy nickel has been eliminated and provision made for the addition of chromium and further amounts of manganese.

Alloys from each of the above groups have been used extensively for airframes, skins and other stressed components, the choice of alloy being influenced by factors such as strength (proof and ultimate stress), ductility, ease of manufacture (e.g. in extrusion and forging), resistance to corrosion and amenability to protective treatment, fatigue strength, freedom from liability to sudden cracking due to internal stresses and resistance to fast crack propagation under load. Clearly, different types of aircraft have differing requirements. A military aircraft, for instance, having a relatively short life measured in hundreds of hours, does not call for the same degree of fatigue and corrosion resistance as a civil aircraft with a required life of 30 000 hours or more.

Unfortunately, as one particular property of aluminum alloys is improved, other desirable properties are sacrificed. For example, the extremely high static strength of the aluminum–zinc–magnesium alloys were accompanied for many years by a sudden liability to crack in an unloaded condition due to the retention of internal stresses in bars, forgings and sheet after heat treatment. Although variations in composition have eliminated this problem to a considerable extent other deficiency showed themselves. Early post-war passenger aircraft experienced large numbers of stress corrosion failures of forgings and extrusions. The problem became so serious that in 1953 it was decided to replace as many aluminum–zinc–manganese components as possible with the aluminum–4 % copper Alloy L65 and to prohibit the use of forgings in zinc-bearing alloy in all future designs. However, improvements in the stress-corrosion resistance of the aluminum–zinc–magnesium alloys have resulted in recent years from British, American and German research. Both British and American opinions agree on the benefits of including about 1 % copper but disagree on the inclusion of chromium and manganese, while in Germany the addition of silver has been found extremely beneficial. Improved control of casting techniques has brought further improvements in resistance to stress corrosion. The development of aluminum–zinc–magnesium–copper alloys has largely met the requirement for aluminum alloys possessing high strength, good fatigue crack growth resistance and adequate toughness.

Further development will concentrate on the production of materials possessing higher specific properties, bringing benefits in relation to weight saving rather than increasing strength and stiffness.

The first group of alloys possess a lower static strength than the above zinc-bearing alloys, but are preferred for portions of the structure where fatigue considerations are of primary importance such as the undersurfaces of wings where tensile fatigue loads 355 predominate. Experience has shown that the naturally aged version of these alloys has important advantages over the fully heat-treated forms in fatigue endurance and resistance to crack propagation.

Furthermore, the inclusion of a higher percentage of magnesium was found, in America, to produce, in the naturally aged condition, mechanical properties between those of the normal naturally aged and artificially aged alloy. This alloy, designated 2024 (aluminum–copper alloys form the 2000 series) has the nominal composition: 4.5 % copper, 1.5 % magnesium, 0.6 % manganese, with the remainder aluminum, and appears to be a satisfactory compromise between the various important, but sometimes conflicting, mechanical properties.

Interest in aluminum–magnesium–silicon alloys has recently increased, although they have been in general use in the aerospace industry for decades.

The reasons for this renewed interest are that they are potentially cheaper than aluminum–copper alloys and, being weldable, are capable of reducing manufacturing costs. In addition, variants, such as the ISO 6013 alloy, have improved property levels and, generally, possess a similar high fracture toughness and resistance to crack propagation as the 2000 series alloys.

Frequently, a particular form of an alloy is developed for a particular aircraft.

An outstanding example of such a development is the use of Hiduminium RR58 as the basis for the main structural material, designated CM001, for Concorde. Hiduminium RR58 is a complex aluminum–copper–magnesium–nickel–iron alloy developed during the 1939–1945 war specifically for the manufacture of forged components in gas turbine aero engines. The chemical composition of the version used in Concorde was decided on the basis of elevated temperature, creep, fatigue and tensile testing programs and has the detailed specification of: %Cu %Mg %Si %Fe %Ni %Ti %Al Minimum 2.25 1.35 0.18 0.90 1.0 – Remainder Maximum 2.70 1.65 0.25 1.20 1.30 0.20 Generally, CM001 is found to possess better overall strength/fatigue characteristics over a wide range of temperatures than any of the other possible aluminum alloys.

The latest aluminum alloys to find general use in the aerospace industry are the aluminum–lithium alloys. Of these, the aluminum–lithium–copper–manganese alloy, 8090, developed in the UK, is extensively used in the main fuselage structure of GKN Westland Helicopters’ design EH101; it has also been qualified for Eurofighter 2000 (now named the Typhoon) but has yet to be embodied. In the USA the aluminum– lithium–copper alloy, 2095, has been used in the fuselage frames of the F16 as a replacement for 2124, resulting in a fivefold increase in fatigue life and a reduction in weight. Aluminum–lithium alloys can be successfully welded, possess a high fracture toughness and exhibit a high resistance to crack propagation.

2.1.2 Steel

The use of steel for the manufacture of thin-walled, box-section spars in the 1930s has been superseded by the aluminum alloys described in Section 11.1. Clearly, its high specific gravity prevents its widespread use in aircraft construction, but it has retained some value as a material for castings for small components demanding high tensile strengths, high stiffness and high resistance to wear. Such components include undercarriage pivot brackets, wing-root attachments, fasteners and tracks.

Although the attainment of high and ultra-high tensile strengths presents no difficulty with steel, it is found that other properties are sacrificed and that it is difficult to manufacture into finished components. To overcome some of these difficulties types of steel known as maraging steels were developed in 1961, from which carbon is either eliminated entirely or present only in very small amounts. Carbon, while producing the necessary hardening of conventional high tensile steels, causes brittleness and distortion; the latter is not easily rectifiable as machining is difficult and cold forming impracticable. Welded fabrication is also almost impossible or very expensive. The hardening of maraging steels is achieved by the addition of other elements such as nickel, cobalt and molybdenum. A typical maraging steel would have these elements present in the proportions: nickel 17–19 %, cobalt 8–9 %, molybdenum 3–3.5 %, with titanium 0.15–0.25 %. The carbon content would be a maximum of 0.03 %, with traces of manganese, silicon, Sulphur, phosphorus, aluminum, boron, calcium and zirconium. Its 0.2 % proof stress would be nominally 1400 N/mm^2 and its modulus of elasticity 180 000 N/mm^2.

The main advantages of maraging steels over conventional low alloy steels are: higher fracture toughness and notched strength, simpler heat treatment, much lower volume change and distortion during hardening, very much simpler to weld, easier to machine and better resistance to stress corrosion/hydrogen embrittlement. On the other hand, the material cost of maraging steels is three or more times greater than the cost of conventional steels, although this may be more than offset by the increased cost of fabricating a complex component from the latter steel.

Maraging steels have been used in: aircraft arrester hooks, rocket motor cases, helicopter undercarriages, gears, ejector seats and various structural forgings.

In addition to the above, steel in its stainless form has found applications primarily in the construction of super- and hypersonic experimental and research aircraft, where temperature effects are considerable. Stainless steel formed the primary structural material in the Bristol 188, built to investigate kinetic heating effects, and also in the American rocket aircraft, the X-15, capable of speeds of the order of Mach 5–6.

2.1.3 Titanium

The use of titanium alloys increased significantly in the 1980s, particularly in the construction of combat aircraft as opposed to transport aircraft. This increase continued in the 1990s to the stage where, for combat aircraft, the percentage of titanium alloy as a fraction of structural weight is of the same order as that of aluminum alloy. Titanium alloys possess high specific properties, have a good fatigue strength/tensile strength ratio with a distinct fatigue limit, and some retain considerable strength at temperatures up to 400–500◦C. Generally, there is also a good resistance to corrosion and corrosion fatigue although properties are adversely affected by exposure to temperature and stress in a salt environment. The latter poses particular problems in the engines of carrier operated aircraft. Further disadvantages are a relatively high density so that weight penalties are imposed if the alloy is extensively used, coupled with high primary and high fabrication costs, approximately seven times those of aluminum and steel.

In spite of this, titanium alloys were used in the airframe and engines of Concorde, while the Tornado wing carry-through box is fabricated from a weldable medium strength titanium alloy. Titanium alloys are also used extensively in the F15 and F22 American fighter aircraft and are incorporated in the tail assembly of the Boeing 777 civil airliner. Other uses include forged components such as flap and slat tracks and undercarriage parts.

New fabrication processes (e.g. superplastic forming combined with diffusion bonding) enable large and complex components to be produced, resulting in a reduction in production man-hours and weight. Typical savings are 30 % in man-hours, 30 % in weight and 50 % in cost compared with conventional riveted titanium structures. It is predicted that the number of titanium components fabricated in this way for aircraft will increase significantly and include items such as access doors, sheet for areas of hot gas impingement, etc.

2.1.4 Plastics

Plain plastic materials have specific gravities of approximately unity and are therefore considerably heavier than wood although of comparable strength.

On the other hand, their specific gravities are less than half those of the aluminum alloys so that they find uses as windows or lightly stressed parts whose dimensions are established by handling requirements rather than strength. They are also particularly useful as electrical insulators and as energy absorbing shields for delicate instrumentation and even structures where severe vibration, such as in a rocket or space shuttle launch, occurs.

2.1.5 Glass

The majority of modern aircraft have cabins pressurized for flight at high altitudes.

Windscreens and windows are therefore subjected to loads normal to their midplanes.

Glass is frequently the material employed for this purpose in the form of plain or laminated plate or heat-strengthened plate. The types of plate glass used in aircraft have a modulus of elasticity between 70 000 and 75 000 N/mm^2 with a modulus of rupture in bending of 45 N/mm^2. Heat-strengthened plate has a modulus of rupture of about four and a half times this figure.

2.1.6 Composite materials

Composite materials consist of strong fibers such as glass or carbon set in a matrix of plastic or epoxy resin, which is mechanically and chemically protective. The fibers may be continuous or discontinuous but possess a strength very much greater than that of the same bulk materials. For example, carbon fibers have a tensile strength of the order of 2400 N/mm^2 and a modulus of elasticity of 400 000 N/mm^2.

(Megson, 2010)

2.2 TYPE OF AIRRAFT STRUCTURAL STRESS:

The primary factors to consider in aircraft structures are strength, weight, and reliability. These factors determine the requirements to be met by any material used to construct or repair the aircraft.

Airframes must be strong and light in weight. An aircraft built so heavy that it couldn't support more than a few hundred pounds of additional weight would be useless. All materials used to construct an aircraft must be reliable. Reliability minimizes the possibility of dangerous and unexpected failures.

Many forces and structural stresses act on an aircraft when it is flying and when it is static. When it is static, the force of gravity produces weight, which is supported by the landing gear. The landing gear absorbs the forces imposed on the aircraft by takeoffs and landings.

During flight, any maneuver that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage.

Stresses on the wings, fuselage, and landing gear of aircraft are tension, compression, shear, bending, and torsion. These stresses are absorbed by each component of the wing structure and transmitted to the fuselage structure. The empennage (tail section) absorbs the same stresses and transmits them to the fuselage. These stresses are known as loads, and the study of loads is called a stress analysis. Stresses are analyzed and considered when an aircraft is designed. The stresses acting on an aircraft are shown in figure 1-1.

2.2.1 Tension

Tension (figure 2.1,, view A) is defined as pull. It is the stress of stretching an object or pulling at its ends.

Tension is the resistance to pulling apart or stretching produced by two forces pulling in opposite directions along the same straight line. For example, an elevator control cable is in additional tension when the pilot moves the control column.

2.2.2 Compression

If forces acting on an aircraft move toward each other to squeeze the material, the stress is called compression. Compression (figure 2.1, view B) is the opposite of tension. Tension is pull, and compression is push. Compression is the resistance to crushing produced by two forces pushing toward each other in the same straight line. For example, when an airplane is on the ground, the landing gear struts are under a constant compression stress.

2.2.3 Shear

Cutting a piece of paper with scissors is an example of a shearing action. In an aircraft structure, shear (figure 2.1, view D) is a stress exerted when two pieces of fastened material tend to separate. Shear stress is the outcome of sliding one part over the other in opposite directions. The rivets and bolts of an aircraft experience both shear and tension stresses.

2.2.4 Bending

Bending (figure 2.1, view E) is a combination of tension and compression. For example, when bending a piece of tubing, the upper portion stretches (tension) and the lower portion crushes together (compression). The wing spars of an aircraft in flight are subject to bending stresses.

2.2.5 Torsion

Torsional (figure 2.1, view C) stresses result from a twisting force. When you wring out a chamois skin, you are putting it under torsion. Torsion is produced in an engine crankshaft while the engine is running. Forces that produce torsional stress also produce torque.

2.2.6 Varying stress

All structural members of an aircraft are subject to one or more stresses. Sometimes a structural member has alternate stresses; for example, it is under compression one instant and under tension the next.
The strength of aircraft materials must be great enough to withstand maximum force of varying stresses.

2.2.7 Specific action of stresses

You need to understand the stresses encountered on the main parts of an aircraft. A knowledge of the basic stresses on aircraft structures will help you understand why aircraft are built the way they are. The fuselage of an aircraft is subject the five types of stress—torsion, bending, tension, shear, and compression. Torsional stress in a fuselage is created in several ways. For example, torsional stress is encountered in engine torque on turboprop aircraft. Engine torque tends to rotate the aircraft in the direction opposite to the direction the propeller is turning. This force creates a torsional stress in the fuselage. Figure 2.2 shows the effect of the rotating propellers. Also, torsional stress on the fuselage is created by the action of the ailerons when the aircraft is maneuvered.

When an aircraft is on the ground, there is a bending force on the fuselage. This force occurs because of the weight of the aircraft. Bending increases when the aircraft makes a carrier landing. This bending action creates a tension stress on the lower skin of the fuselage and a compression stress on the top skin.

Bending action is shown in figure 2.3. These stresses are transmitted to the fuselage when the aircraft is in flight. Bending occurs because of the reaction of the airflow against the wings and empennage. When the aircraft is in flight, lift forces act upward against the wings, tending to bend them upward. The wings are prevented from folding over the fuselage by the resisting strength of the wing structure. The bending action creates a tension stress on the bottom of the wings and a compression stress on the top of the wings.

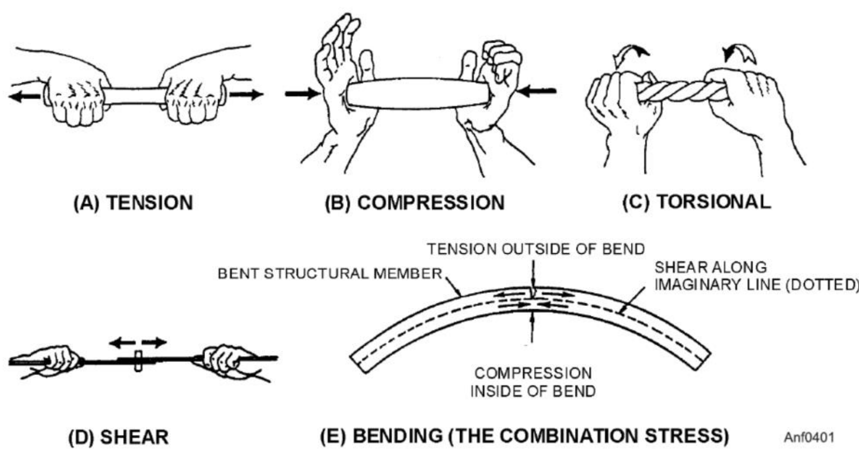

Figure 2.1 Five stresses acting on an aircraft

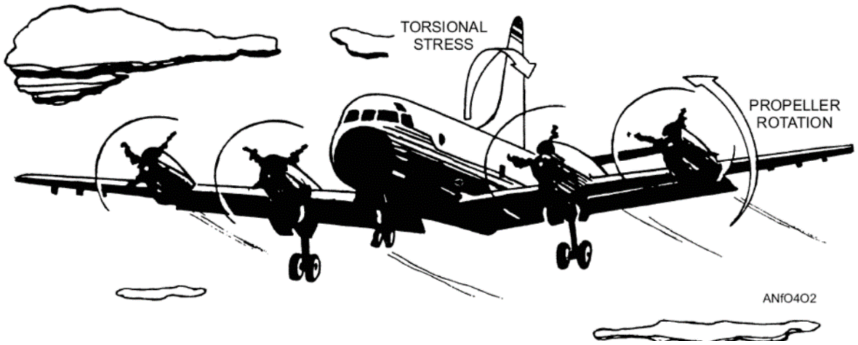

Figure 2.2 Engine torque creates torsion stress in aircraft fuselages.

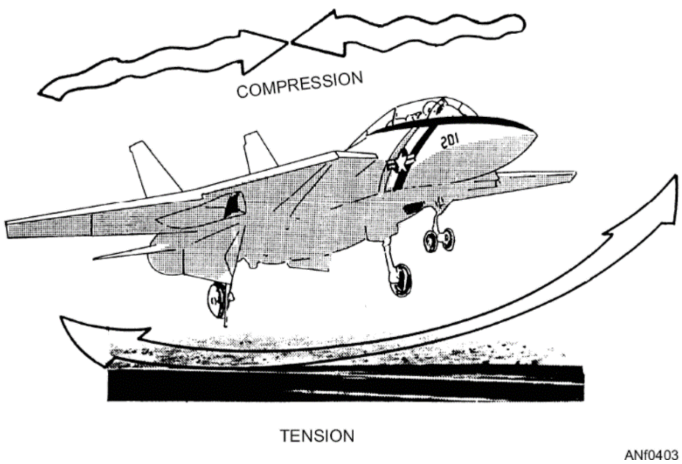

Figure 2.3 Bending action occurring during carrier landing

2.3 CLASSIFICATION AND DESIGNATION OF ALUMINIUM ALLOYS FOR AEROSPACE APPLICATIONS:

Aluminum alloys are classified as heat treatable or non-heat treatable, depending on whether or not they respond to precipitation hardening. The heat treatable alloys contain elements that decrease in solid solubility with decreasing temperature, and in concentrations that exceed their equilibrium solid solubility at room temperature and moderately higher temperatures. The most important alloying elements in this group include copper, lithium, magnesium and zinc.

A large number of other compositions rely instead on work hardening through mechanical reduction, usually in combination with various annealing procedures for property developments. These alloys are referred to as non-heat-treatable or work-hardening alloys.

Some casting alloys are essentially non-heat-treatable and are used as-cast or in thermally modified conditions uninfluenced by solutionizing or precipitation effects. Figure 2.5 gives an overview of the principal types of aluminum alloys.

(f.r, 2006)

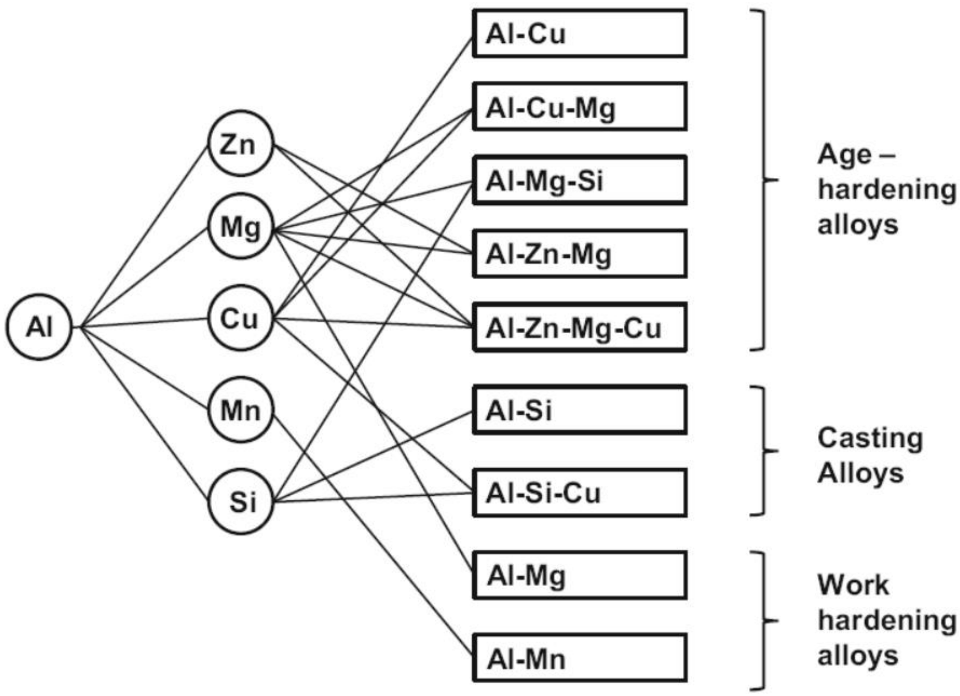

Figure 2.3 The principal types of aluminum alloys

2.3.1 Wrought Alloys

A four-digit numerical designation system is used to identify wrought aluminum and aluminum alloys. As shown below, the first digit of the four-digit designation indicates the group.

Aluminum, >99.00 %—1XXX. Aluminum alloys grouped by major alloying element(s); Copper—2XXX; Manganese—3XXX; Silicon—4XXX; Magnesium— 5XXX; Magnesium and Silicon—6XXX; Zinc—7XXX; Other elements—8XXX; Unused series—9XXX.

2.3.2 Cast Alloys

A system of four-digit numerical designations incorporating a decimal point is used to identify aluminum and aluminum alloys in the form of castings and foundry ingots. The first digit indicates the alloy group.

Aluminum, >99.00 %—1XX.X. Aluminum alloys grouped by major alloying element(s); Copper 2XX.X; Silicon with added copper and/or magnesium—3XX. X; Silicon—4XX.X; Magnesium—5XX.X; Zinc—7XX.X; Tin—8XX.X; Other elements—9XX.X; Unused series—6XX.X

2.3.3 Temper Designations

The temper designation system is used for all product forms (both wrought and cast), with the exception of ingots. The system is based on the sequences of mechanical or thermal treatments, or both, used to produce the various tempers. The temper designation follows the alloy designation and is separated from it by a hyphen. Basic temper designations consist of individual capital letters. Major subdivisions of basic tempers, where required, are indicated by one or more digits following the letter. These digits designate sequences of treatments that produce specific combinations of characteristics in the product. Variations in treatment conditions within major subdivisions are identified by additional digits.

T1—Cooled from an elevated-temperature shaping process and naturally aged to a substantially stable condition. This designation applies to products that are not cold-worked after an elevated-temperature shaping process such as casting or extrusion, and for which mechanical properties have been stabilized by room temperature ageing. This designation also applies to products that are flattened or straightened after cooling from the shaping process, whereby the cold-work effects imparted by flattening or straightening are not accounted for in the specified property limits.

T2—Cooled from an elevated-temperature shaping process, cold-worked, and naturally aged to a substantially stable condition. This designation refers to products that are cold-worked specifically to improve strength after cooling from a hot-working process such as rolling or extrusion, and for which the mechanical properties have been stabilized by room temperature ageing. This designation also applies to products in which the effects of cold-work, imparted by flattening or straightening, are accounted for in the specified property limits.

T3—Solution heat treated, cold-worked, and naturally aged to a substantially stable condition. T3 applies to products that are cold-worked specifically to improve strength after solution heat treatment and for which mechanical properties have been stabilized by room temperature ageing. This designation also applies to products in which the effects of cold work, imparted by flattening or straightening, are accounted for in the specified property limits.

T4—Solution heat treated and naturally aged to a substantially stable condition. This designation signifies products that are not cold-worked after solution heat treatment and for which mechanical properties have been stabilized by room temperature ageing. If the products are flattened or straightened, the effects of the cold-work imparted by flattening or straightening are not accounted for in the specified property limits.

T5—Cooled from an elevated-temperature shaping process and artificially aged. T5 includes products that are not cold-worked after an elevated-temperature shaping process such as casting or extrusion and for which the mechanical properties have been substantially improved by precipitation heat treatment. If the products are flattened or straightened after cooling from the shaping process, the effects of the cold-work imparted by flattening or straightening are not accounted for in the specified property limits.

T7—Solution heat treated and overaged or stabilized. T7 applies to wrought products that have been precipitation heat treated beyond the point of maximum strength to provide some special characteristics, such as enhanced resistance to stress corrosion cracking or exfoliation corrosion. This designation also applies to cast products that are artificially aged after solution heat treatment to provide dimensional and strength stability.

T8—Solution heat treated, cold-worked, and artificially aged. This designation applies to products that are cold-worked specifically to improve strength after solution heat treatment and for which mechanical properties or dimensional stability, or both, have been substantially improved by precipitation heat treatment.

The effects of cold work, including any cold work imparted by flattening or straightening, are accounted for in the specified property limits.

T9—Solution heat treated, artificially aged, and cold-worked. This group is comprised of products that are cold-worked specifically to improve strength after they have been precipitation heat treated.

T10—Cooled from an elevated-temperature shaping process, cold-worked, and artificially aged. T10 identifies products that are cold-worked specifically to improve strength after cooling from a hot-working process such as rolling or extrusion and for which the mechanical properties have been substantially improved by precipitation heat treatment. The effects of cold work, including any cold work imparted by flattening or straightening, are accounted for in the specified property limits.

(R.J.H. Wanhill, 2017)

2.4 EFFECTS OF ALLOYING ELEMENTS:

The effect(s) of various alloying elements are given below in alphabetical order.

Some of the effects, particularly with respect to impurities, are not well documented and are specific to particular alloys or conditions.

2.4.1 Chromium:

Is a common addition to many alloys of the aluminum–magnesium, aluminum–magnesium–silicon, and aluminum–magnesium–zinc groups, in which it is added in amounts generally not exceeding 0.35%.

Above this limit chromium tends to form very coarse constituents with other impurities or additions such as manganese and titanium.

Chromium has a low diffusion rate and forms a fine dispersed phase in wrought products. The dispersed phase inhibits nucleation and grain growth. Hence during hot working or heat treatment, chromium prevents grain growth in aluminum– magnesium alloys and recrystallization in aluminum–magnesium–silicon or aluminum– magnesium–zinc alloys.

The main drawback of chromium in heat treatable alloys is the increase in quench sensitivity when the hardening phase tends to precipitate on the preexisting chromium-phase particles.

2.4.2 Copper:

Aluminum–copper alloys containing 2–10% Cu, generally with other additions, form an important family of Al alloys. Both cast and wrought aluminum–copper alloys respond to solution heat treatment and subsequent ageing, with an increase in strength and hardness and a decrease in elongation. The strengthening is maximum between 4 and 6% Cu, depending upon the influence of other constituents. N.B: the ageing characteristics of binary aluminum–copper alloys have been studied in greater detail than for any other system, but all commercial aerospace alloys contain other alloying elements.

2.4.3 Copper–Magnesium:

The main benefit of adding magnesium to aluminum– copper alloys is the increased strength following solution heat treatment and quenching. In certain wrought alloys of this type, ageing at room temperature (natural ageing) causes an increase in strength accompanied by high ductility.

Artificial ageing, at elevated temperatures, results in a further increase in strength, especially the yield strength, but at a substantial sacrifice in tensile elongation.

For both cast and wrought aluminum–copper alloys, as little as about 0.5% Mg is effective in changing the ageing characteristics. In wrought products the effect of magnesium additions on strength can be maximized in artificially aged materials by cold-working prior to ageing. In naturally aged materials, however, the benefit to strength from magnesium additions can decrease with cold-working.

The effect of magnesium on the corrosion resistance of aluminum–copper alloys depends on the type of product and thermal treatment.

Copper–Magnesium plus Other Elements: Al–Cu–Mg alloys containing manganese are the most important and versatile class of commercial high-strength wrought aluminum–copper–magnesium alloys. In general, tensile strength increases with separate or simultaneous increases in magnesium and manganese, and the yield strength also increases, but to a lesser extent. Further increases in tensile strength and particularly yield strength occur on cold-working after heat treatment.

Additions of manganese and magnesium decrease the fabrication characteristics of aluminum–copper alloys, and manganese also causes a loss in ductility. Hence the concentration of manganese does not exceed about 1% in commercial alloys.

Additions of cobalt, chromium, or molybdenum to the wrought Al-4% Cu-0.5% Mg type of alloy increase the tensile properties on heat treatment, but none offers a distinct advantage over manganese.

The cast aluminum–copper–magnesium alloys containing iron are characterized by dimensional stability and improved bearing characteristics, as well as high strength and hardness at elevated temperatures. However, in a wrought Al-4% Cu-0.5% Mg alloy, iron in concentrations as low as 0.5% lowers the tensile properties in the heat-treated condition unless the silicon content is sufficient to sequester the iron as FeSi intermetallic particles. When sufficient silicon is present to combine with the iron, the strength properties are unaffected, although the FeSi particles are detrimental to fracture toughness.

However, if there is excess iron, it unites with copper to form the Cu2FeAl7 constituent, thereby reducing the amount of copper available for heat-treating effects. Silicon also combines with magnesium to form Mg2Si precipitates that contribute to the age-hardening process.

Silver substantially increases the strength of heat treated and aged aluminum– copper–magnesium alloys. Nickel improves the strength and hardness of cast and wrought aluminum–copper magnesium alloys at elevated temperatures. However, addition of about 0.5%Ni lowers the tensile properties of the heat-treated wrought Al-4% Cu-0.5% Mg alloy at room temperature.

2.4.4 Magnesium–Silicon:

Wrought alloys of the 6XXX group contain up to 1.5% each of magnesium and silicon in the approximate ratio to form Mg2Si, i.e. 1.73:1.

The maximum solubility of Mg2Si in Al is 1.85%, and this decreases with temperature. Precipitation upon age-hardening occurs by formation of Guinier– Preston zones and a very fine precipitate. Both confer an increase in strength to these alloys, though not as great as in the case of the 2XXX or the 7XXX alloys.

Al–Mg2Si alloys can be divided into three groups. In the first group the total amount of magnesium and silicon does not exceed 1.5%. These elements are in a nearly balanced ratio or with a slight excess of silicon. Typical of this group is AA6063, which nominally contains 1.1% Mg_2Si and is widely used for extruded sections. Its solution heat-treating temperature of just over 500 °C and its low quench sensitivity are such that this alloy does not need a separate solution treatment after extrusion, but may be air quenched at the press and artificially aged to achieve moderate strength, good ductility, and excellent corrosion resistance.

The second group nominally contains 1.5% or more of magnesium + silicon and other additions such as 0.3% Cu, which increases strength in the T6 temper.

Elements such as manganese, chromium, and zirconium are used for controlling grain structure. Alloys of this group, such as AA6061, achieve strengths about 70 MPa higher than in the first group in the T6 temper. However, this second group requires a higher solution treating temperature than the first and they are quench sensitive. Therefore, they generally require a separate solution treatment followed by rapid quenching and artificial ageing.

The third group contains an amount of Mg_2Si overlapping the first two but with substantial excess silicon. An excess of 0.2% Si increases the strength of an alloy containing 0.8% Mg_2Si by about 70 MPa. Larger amounts of excess silicon are less beneficial. Excess magnesium, however, is of benefit only at low Mg_2Si contents because magnesium lowers the solubility of Mg_2Si.

In excess silicon alloys, segregation of silicon to the grain boundaries causes grain-boundary fracture in recrystallize ed structures. Additions of manganese, chromium, or zirconium counteract the effect of silicon by preventing recrystallization during heat treatment. Common alloys of this group are \AA6351 and the more recently introduced alloys AA6009 and AA6010. An addition of lead and bismuth to an alloy of this series (AA6262) improves machinability.

2.4.5 Silicon:

In wrought alloys silicon is used with magnesium at levels up to 1.5 % to produce Mg_2Si in the 6XXX series of heat treatable alloys.

High-purity aluminum–silicon casting alloys exhibit hot shortness up to 3 % Si, the most critical range being 0.17–0.8 % Si. However, in aluminum–

copper– magnesium alloys silicon additions (0.5–4.0 %) reduce the cracking tendency.

Small amounts of magnesium added to any silicon-containing alloy will render it heat treatable, but the converse is not true, since excess magnesium over that required to form Mg_2Si sharply reduces the solid solubility of this compound.

Modification of the silicon morphology in casting alloys can be achieved through the addition of sodium in eutectic and hypoeutectic alloys and by phosphorus in hypereutectic alloys.

2.4.6 Titanium:

Is used primarily as a grain refiner of aluminum alloy castings and ingots. When used alone, the effect of titanium decreases with time of holding in the molten state and with repeated re-melting. The grain-refining effect is enhanced if boron is present in the melt or if it is added as a master alloy containing boron largely combined with titanium as TiB_2.

2.4.7 Zinc–Magnesium:

Addition of magnesium to aluminum–zinc alloys develops the strength potential of this alloy system, especially in the range of 3–7.5 % Zn.

Magnesium and zinc form $MgZn_2$, which produces a far greater response to heat treatment than occurs in the binary aluminum–zinc system. On the negative side, increasing additions of both zinc and magnesium decrease the overall corrosion resistance of aluminum, such that close control over the microstructure, heat treatment, and composition are often necessary to maintain adequate resistance to stress corrosion and exfoliation corrosion. (Davis, 1998)

2.5 Ultimate tensile strength definition:

Ultimate tensile strength (UTS) is the maximum stress that a material can withstand while being stretched or pulled. The ultimate tensile strength of a material is calculated by dividing the cross-section area of the material tested by the stress placed on the material, generally expressed in terms of pounds or tons per square inch of material.

The ultimate tensile strength (UTS) is a material's maximum resistance to fracture. It is equivalent to the maximum load that can be carried by one square inch of cross-sectional area when the load is applied as simple tension.

The UTS is the maximum engineering stress in a uniaxial stress-strain test. The UTS can differ, depending on the type of material:

The UTS is not used in the design of ductile static materials because design practices dictate the use of the yield stress. It is, however, used for quality control, because of the ease of testing. It is a common engineering parameter when designing brittle materials, because there is no yield point.

The UTS is usually found by performing a tensile test and recording the engineering stress versus strain curve. The highest point of the stress-strain curve is the UTS. It is an intensive property; therefore, its value does not depend on the size of the test specimen. However, it is dependent on other factors, such as:

- Preparation of the specimen
- Presence of surface defects
- Temperature of the test environment and the material

2.6 Impact test definition:

An impact test is a technique for determining the behavior of material subjected to shock loading in:

- Bending
- Tension
- Torsion

This test is designed to determine how a specimen of a known material will respond to a suddenly applied stress. The test ascertains whether the material is tough or brittle.

The impact test is a method for evaluating the toughness, impact strength and notch sensitivity of engineering materials.

Engineers test the ability of a material to withstand impact to predict its behaviour under actual conditions. Many materials fail suddenly under impact, at flaws/cracks or notches. The most common impact tests use a swinging pendulum to strike a notched bar; heights before and after impact are used to compute the energy required to fracture the bar. In the Charpy test, the test piece is held horizontally between two vertical bars. In the Izod test, the specimen stands erect, like a fence post.

2.7 Hardness definition:

Hardness is defined as the ability of a material to resist plastic deformation, usually by indentation. The term may also refer to resistance to:

- Scratching
- Abrasion
- Cutting
- Penetration

(Parker, 2013)

2.8 SAFAT 03 MACHINING PARTS ALLOY 2024 T3 SPECIFICATIONS:

The aerospace industry has relied on using aluminum in its structures due to its lightness and ease of shaping. The aluminum use has changed with time to incorporate alloys that improve the characteristics of the aluminum used.

The addition of copper and other substances resulted in better products in terms of corrosion resistance, strength and strength-to-weight ratio, one of the most common alloys used is the 2024 aluminum. The addition of copper has enabled the aluminum to become more corrosion resistant but has rendered the aluminum to be un-weldable.

Heat treatments conducted on the alloy has given the manufacturer the ability to work freely at (T0) and then gaining strength throughout T3, T351, T4, and T6. Following the aerospace model has and outer skin made out of aluminum 2024 as well as machined components inside the aircraft.

2.9 WIRE ELECTRICAL DISCHARGE MACHINING (WEDM):

Wire electro discharge machining (WEDM) is the process of material removal of electrically conductive materials using the thermo-electric source of energy.

It is one of the most extended non-conventional machining processes. Wire-cut EDM is typically used to cut plates as thick as 300mm and to make tools, punches, and dies from hard metals that are difficult to machine with other methods. Wire electric discharge machining is based on material removal through a series of repetitive sparks between electrodes i. e, work piece and tool.

In WEDM, material is removed from the workpiece by a series of discrete sparks that occurs between the workpiece and the wire separated by a flow of dielectric fluid, which is continuously supplied to the machining zone. The process uses a thin wire of diameter about 0.1-0.3 mm as tool and the workpiece is mounted on a computer numeric-controlled worktable. Complex two-dimensional shapes that can be cut on the workpiece by controlled movement of the x-y worktable. The wire which is constantly fed from a spool is held between upper and lower diamond guides. The guides are usually CNC controlled and move in the x–y plane. The microprocessor used in CNC controller also enables part of complex shapes to be machined with extraordinary high accuracy. There is no physical contact between tool and workpiece, the microprocessor also constantly maintains the gap between the wire and the workpiece that varies from 0.025 to 0.05 mm.

Aluminum is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their capability to be strengthened by precipitation, their low density, their good corrosion resistance, their high electrical and thermal conductivity and high damping capacity. Aluminum matrix composites (AMCs) have been widely studied since the 1920s and are now used in electronic packaging, sporting goods, amours and automotive industries. Many advantages like improved stiffness, greater strength, reduced density (weight), controlled thermal expansion coefficient, heat management, enhanced and tailored electrical performance etc. can be quantified for better appreciation. For example, elastic modulus of pure aluminum can be enhanced from 70GPa to 240GPa by reinforcing with 60 vol.% continuous aluminum fiber. On the other hand, incorporation of 60 vol. % alumina fiber in pure aluminum leads to decrease in the coefficient of expansion from 24 ppm / 0C to 7 ppm / 0C [3]. AMCs are usually reinforced by AL2O3, Sic and carbon. They are made by dispersing the reinforcements in the metal matrix. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, processing route and reinforcement. ((Harsimran Singh, 2015)

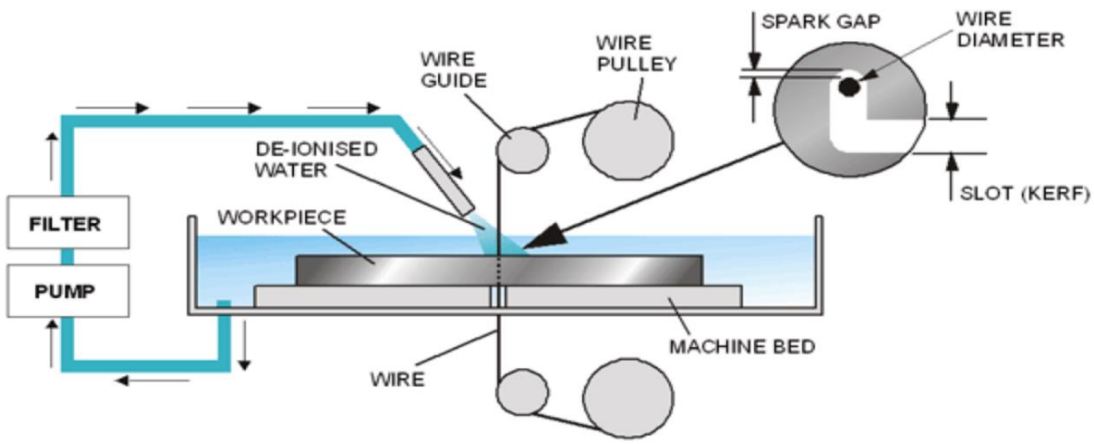

Figure 2.4 Wire electro discharge machining process

CAPTER 3

Methodology

3 METHODOLOGY:

3.1 MATERIALS:

3.1.1 Aluminum Alloy 2024:

Aluminum alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is weldable only through friction welding, and has average machinability. Due to poor corrosion resistance, it is often clad with aluminum or Al-1Zn for protection, although this may reduce the fatigue strength.

3.1.2 T3 temper 2024:

T3 temper 2024 sheet has an ultimate tensile strength of 58-62 ksi (400-427 MPa) and yield strength of at least 39-40 ksi (269-276 MPa). It has an elongation of 10-15%.

- Firstly, the testing material prepared using wire cut machine as the standard drawing for the different tests.
- Secondly the samples have been taking to the AL Yarmouk industrial complex laboratory to perform the tests.

(Parker, 2013)

3.1.3 Hardness tester:

The hardness is most important material characteristic when the aircraft parts subjected to wear effect. The wear decreases dramatically when the hardness increased and vice versa. The hardness of the sample that has been cut using wire cutting machine and the sample that has been cut using CNC machine is measured using the portable hardness tester type (TH160) made by time group inc, the device has calibration date is 20 Dec 2018.
Impact testing Machine.

- The hardness testing device is calibrated (Brinell Test) previously, and the test done in sample material after cut by using wire cut machine.
- The device used three testing measure to state the hardness of the sample, so that three hardness value registered and the average is considered the hardness of the sample.

- By ends of the harness test, the required test is ended, where those tests are exactly strength required in aircraft parts.

Figure 3.1 hardness testing device (TH160) made by TIME Group Inc,

3.1.4 Tensile testing Machine:

one of the tests done in study is tensile strength, which is done in alyarmouk industrial complex laboratory, and the WAW-600Y (JAINAN Co.) testing machine used to find the measurements for both the sample that has been cut using wire cutting machine and the sample that has been cut using CNC machine.

- The tensile test done by using three samples to find out the required tensile strength measurements.
- The tensile test is done by applying different load up to the sample destructed.
- The elongation continually registered automatically by the computer, and when the three samples test done the average elongation graph is plotted and saved.

Figure 3.2 tensile strength testing machine

3.1.5 Impact testing machine:

One of the tests done in study is impact test, which is done in alyarmouk industrial complex laboratory, and the Charpy impact testing machine used to find the material toughness for both the sample that has been cut using wire cutting machine and the sample that has been cut using CNC machine.

- Secondly, the impact is started when the sample prepared for Charpy test.
- The measurements registered for three sample and the average calculated to state the toughness value for the sample.
- Finally, the hardness test done by using portable hardness testing device.

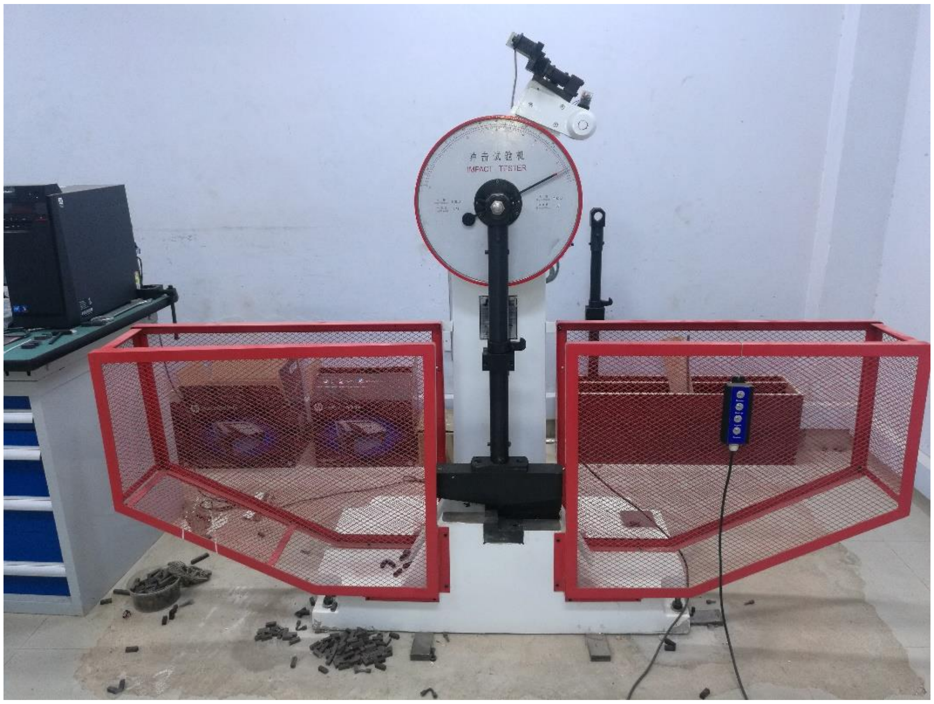

Figure 3.3 Charpy impact testing machine

3.1.6 Material analyzer:

Also, one of the devices used in the study is material analyzer which is call spectrometer, by which the chemical composition for the material specified, where the material is same in both; that has been cut using wire cutting machine and the sample that has been cut using CNC machine.

- The chemical composition test done by using spectrometer to ensure the material of the sample same as the material used in aircraft.
- Before start the testing, the samples prepared as required by testing apparatus, and the machine setup done as well as the testing environment such as room temperature and humidity also has been set as stated by the testing standard.

Figure 3.4 Material Analyzer

3.1.7 The testing material:

The material used in the test is exactly the material used in aircraft parts manufacturing, which aluminum ALLOY 2024 T3.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4 DATA ANALYSIS AND DISCUSSION:

4.1 RESULT:

- The value of the test is compered by the actual result of the design of the aircraft parts to state if the wire cutting can be used for the machining of the parts or not.

4.1.1 Chemical Composition result:

The chemical composition of the sample is determined by using spectrometer an shown in table 4.1.

Element	The percentage of the element composition			
	Sample No1	Sample No2	Sample No3	Average
Si %	0.090	0.083	0.088	0.087
Fe %	0.158	0.150	0.162	0.157
Cu %	7.286	7.541	7.514	7.447
Zn %	0.056	0.037	0.054	0.049
Mn %	1.172	1.162	1.132	1.155
Mg %	2.005	2.025	2.039	2.023
Cr %	0.017	0.014	0.015	0.015
Ni %	0.041	0.031	0.035	0.036
Be %	0.002	0.002	0.001	0.002
Co %	0.033	0.035	0.035	0.034
Pb %	0.068	0.050	0.052	0.057
Sn %	0.052	0.043	0.050	0.048
Ti %	0.041	0.040	0.040	0.040
V %	0.020	0.018	0.020	0.019
Al %	88.959	88.771	88.763	88.831

Table 4.1 Aluminum Alloy 2024 T3 Chemical Composition.

4.1.2 Tensile Testing Result:

According to the standard the material specification required to produce parts, the tensile strength is one of those, so that the standard value can be shown in in figure no, where the result of the sample that has been cut using wire cut machine shown in table 4.2 and figure 4.1.

Specification	ALLOY	Material	ALLUMINUM
SampleNo	2	BatchNo	0032
Shape	planar	TestDate	2019-01-03
Temperature	20.0	Operator	ABU OBIEDA
BreakArea(mm^	44.40	FeH(kN)	13.99
ReH(MPa)	232	FeL(kN)	13.98
Yield.ST(MPa)	232	Fm(kN)	27.47
Rm(MPa)	456	Elong(%)	24.0
R.D(%)	26.0	E(GPa)	7.30
STANDARD	ISO 6892-1 2009,MOD		

Table 4.2 Aluminum alloy 2024 T3 tensile strength test results

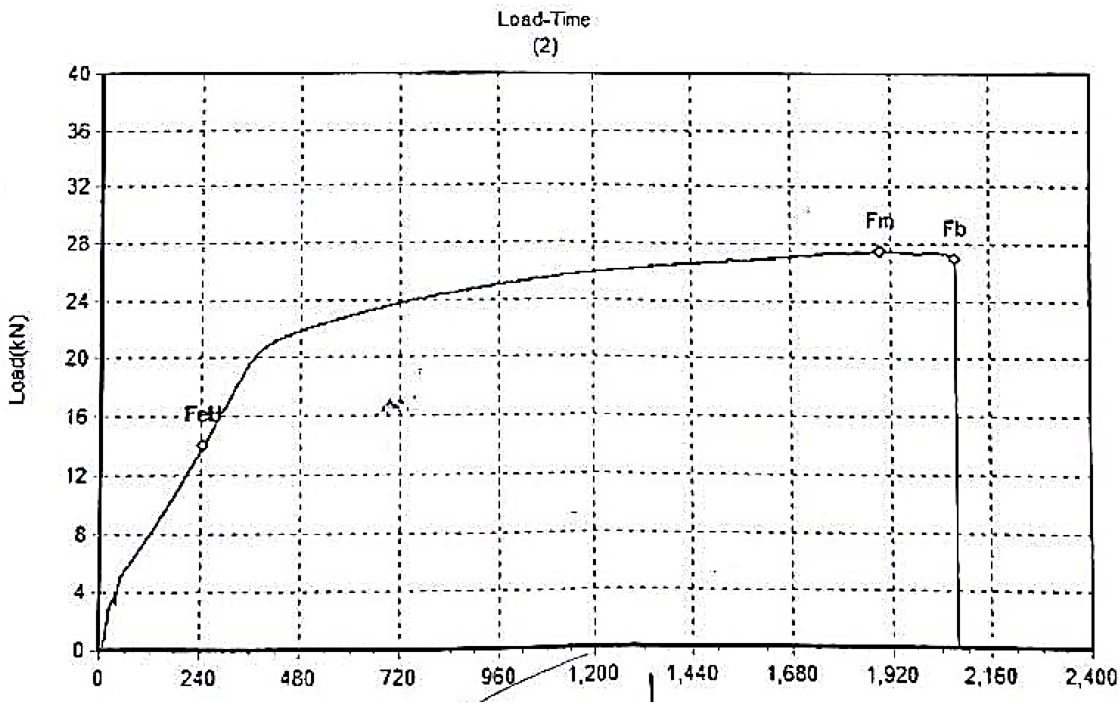

Figure 4.1 Aluminum Alloy 2024 T3 Tensile Strength Test result

The table 4.3 shows the comparison between the tensile Strength when the different loads loaded to on the material machined using CNC/MC and Using Wire Cutting.

NO	Load Time/sec.	Load Standard	Elongation% (Using CNC M/C)	Elongation% (Using Wire Cutting)
1	0	0	0	0
2	24	3.15	3	3
3	48	3.675	3.5	3.5
4	72	4.725	4.5	4.5
5	96	6.3	6	6
6	120	7.875	7.5	7.5
7	144	9.975	9.5	9
8	168	11.025	10.5	10.5
9	192	12.6	12	12
10	216	14.175	13.5	13.5
				Continued…

11	240	15.225	14.5	14.5
12	264	16.8	16	16
13	288	18.375	17.5	17.5
14	312	19.95	19	19
15	336	21.315	20.3	20.2
16	360	21.735	20.7	20.6
17	384	21.84	20.8	20.8
18	408	22.365	21.3	21.1
19	432	22.47	21.4	21.4
20	456	22.785	21.7	21.7
21	480	23.1	22	22
22	504	23.3625	22.25	22.2
23	528	23.625	22.5	22.4
24	552	23.8875	22.75	22.6
25	576	24.15	23	22.8
26	600	24.4125	23.25	23
27	624	24.675	23.5	23.2
28	648	24.9375	23.75	23.4
29	672	25.2	24	23.6
30	696	25.4625	24.25	23.8
31	720	25.725	24.5	24
32	744	25.83	24.6	24.1
33	768	25.935	24.7	24.2
34	792	26.04	24.8	24.3
35	816	26.145	24.9	24.4
36	840	26.25	25	24.5
37	864	26.355	25.1	24.6
38	888	26.46	25.2	24.7
39	912	26.565	25.3	24.8
40	936	26.67	25.4	24.9
41	960	26.775	25.5	25
42	984	26.88	25.6	25.1
43	1008	26.985	25.7	25.2
				Continued…

44	1032	27.09	25.8	25.3
45	1056	27.195	25.9	25.4
46	1080	27.3	26	25.5
47	1104	27.405	26.1	25.6
48	1128	27.51	26.2	25.7
49	1152	27.615	26.3	25.8
50	1176	27.72	26.4	25.9
51	1200	27.825	26.5	26
52	1224	27.8775	26.55	26.05
53	1248	27.93	26.6	26.1
54	1272	27.9825	26.65	26.15
55	1296	28.035	26.7	26.2
56	1320	28.0875	26.75	26.25
57	1344	28.14	26.8	26.3
58	1368	28.1925	26.85	26.35
59	1392	28.245	26.9	26.4
60	1416	28.2975	26.95	26.45
61	1440	28.35	27	26.5
62	1464	28.4025	27.05	26.55
63	1488	28.455	27.1	26.6
64	1512	28.5075	27.15	26.65
65	1536	28.56	27.2	26.7
66	1560	28.6125	27.25	26.75
67	1584	28.665	27.3	26.8
68	1608	28.7175	27.35	26.85
69	1632	28.77	27.4	26.9
70	1656	28.8225	27.45	26.95
71	1680	28.875	27.5	27
72	1704	28.9275	27.55	27.05
73	1728	28.98	27.6	27.1
74	1752	29.0325	27.65	27.15
75	1776	29.085	27.7	27.2
76	1800	29.1375	27.75	27.25

Continued…

77	1824	29.19	27.8	27.3
78	1848	29.2425	27.85	27.35
79	1872	29.295	27.9	27.4
80	1896	29.3475	27.95	27.45
81	1920	29.4	28	27.5
82	1944	29.4525	28.05	27.5
83	1968	29.505	28.1	27.5
84	1992	29.5575	28.15	27.5
85	2016	29.61	28.2	27.5
86	2040	29.61	28.2	27.5
87	2064	29.61	28.2	27.5
88	2088	29.61	28.2	27.5
89	2112	29.61	28.2	0
90	2136	29.61	28.2	
91	2160	29.61	28.2	
92	2184	29.61	28.2	
93	2208	0	0	

Table 4.3 Tensile strength testing result table

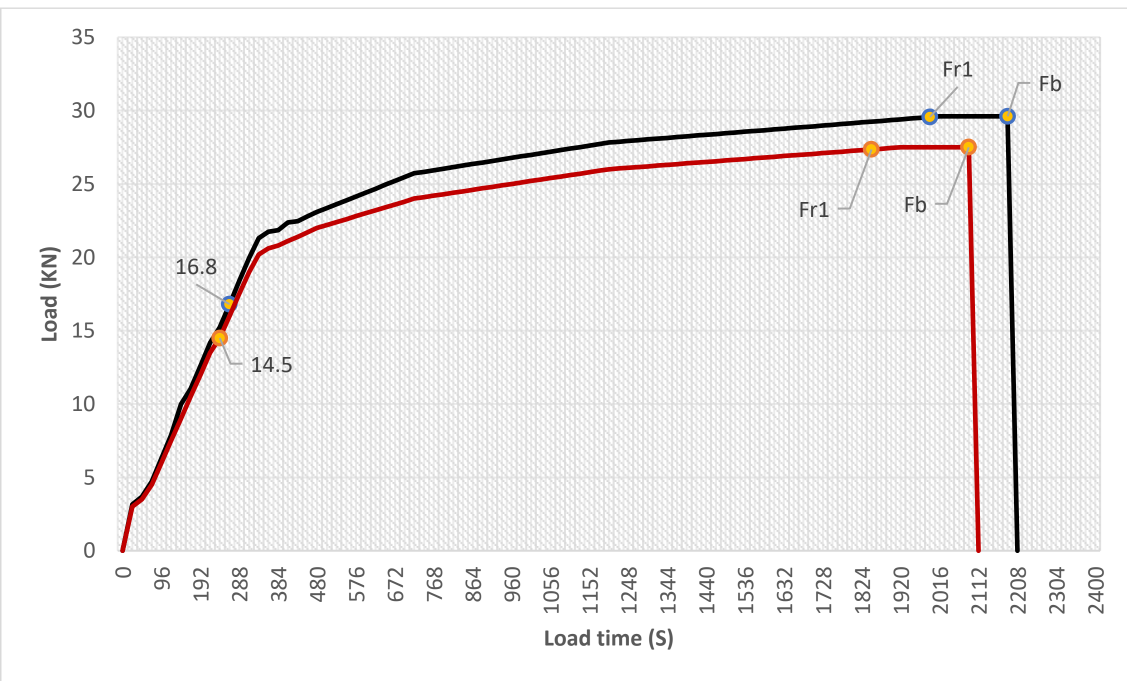

Figure 4.2 comparison between the tensile Strength when using CNC and Wire cutting

4.1.3 Tensile Testing comparison:

The table 4.4 shows the value of the tensile strength compression where the test is done for two samples the first one the material is prepared using wire cutting M/C, and the second sample prepared using CNC M/C.

	Testing Result	Standard value
Ultimate Tensile strength	456 MPa	430 MPa

Table 4.4 Tensile Test Result and standard design Value

4.1.4 Impact testing comparison:

The toughness is important parameter for those aircraft parts subjected to the sudden load, and the standard toughness value, and that determined from impact test can be shown in table 4.5.

	Testing Result	Standard value
Toughness	27.03 J/cm^2	26 J/cm^2

Table 4.5 Toughness Test Result and standard design Value

4.1.5 Hardness testing comparison:

The aircraft parts that subjected to wear effect, the hardness is consider important factor. The hardness standard value, and the hardness of sample that determined by the hardness test shown in table 4.6.

	Testing Result	Standard value
Hardness	115 HB	120HB

Table 4.6 Hardness Test result and standard design Value

4.1.6 Scrap rate of parts using both cnc, and wire cut M/C:

The scrap rate is calculated through measuring the part mass, and the rough stock mass, where the scrap rate when using CNC machine is resultant of subtraction of rough stock from part masses, and the scrap rate when using wire cut machine for preliminary cutting is resultant of subtraction of part mass plus remains of rough stock due to wire cut from the total rough stock. And this can be shown in table no 4.7.

Part no	Block mass	Part mass	Scrap rate using CNC M/C	Scrap rate using Wire cut M/C
30-330-002	0.357 kg	0.096 kg	73%	23%
30-145-025	1.867 kg	0.165 kg	91%	37%
30-155-010	0.838 kg	0.108 kg	87%	29%
30-165-011	0.358 kg	0.055 kg	85%	48%
30-232-062-1	3.469 kg	0.237 kg	93%	54%
Average of Scrap Rate			**86%**	**38%**

Table 4..7Scrap Rate of Parts Using both CNC, and Wire cut M/C

4.2 DATA ANALYSIS DISCUSSION:

As stated by the research objective, to determine the effect of wire cutting process in material properties. hence the previous testing done. the material used for all tests, is the same material used for aircraft parts manufacturing, and the chemical composition shown in table no 1 ensure that.

The sample taken after cut using wire cutting machine is possess 456 MPa ultimate tensile strength, where the material cut using CNC machine only is possess, 430 MPa, and this can be shown in figure no 4.2 and table 4.4.

The toughness of the material also changed from 26 J/cm^2 to 27.03 J/cm^2 when using wire cutting machine as shown in table 4.5.

As well as the material hardness also shift from 120HB to 115HB when using wire cutting machine in preliminary cutting process as shown in table 4.6.

Due to the sensitivity of the aircraft manufacturing field, and according to the safety policies, the above results should be approved by the aircraft designer. When the results approved the wire cutting machining process can be used in preliminary process to produce parts.

The using wire cutting machine in preliminary process to produce parts can reduce about 48% of scrap rate that loss due to using CNC machine only as shown in table 4.7.

So, this saving in the scrap when use the wire cutting machine in preparation of the parts in state of the CNC machine will give a chance to use the cutting part to be used in manufacturing of other parts (smaller parts) so that will help in the use of raw material and reducing the west of it.

Chapter Five

Conclusion & Recommendations

5 CONCLUSION & RECOMMENDATIONS:

5.1 Conclusion:

As discussed in details under Chapter 1, the main aim of the project is to determine the effect of wire cutting process in material properties. The experimental method used to evaluate the mechanical properties of material cut using wire cutting machine, with refer to the ASTM slandered to find the AL2024 T3 that used in parts data sheet.

The wire cutting process has its influence in all mechanical properties of the material sample when it has been tested.

So that if the result gained is approved by aircraft designer, and ensure that the wire cutting process can utilized in the manufacturing process, this can reduce the scrape rate from 86% to 38% when using wire cut process in preliminary part manufacturing process.

5.2 Recommendations:

For the further research and due to the sensitivity of the aircraft manufacturing field, and according to the safety policies, the approve from the aircraft designer should be done by Safat company to state whether to use wire cutting process or not.

Further studies should also be conducted to the heat affected zone of the cutting to determine the offset needed so to leave the end product piece out of the heat affected zone.

6 References

Christensen, R. M. (n.d.) 2013. *The Theory of Materials Failure.*: Oxford.

Davis, J. (1998). *Aluminum and Aluminum Alloys.* ASM International.

f.r, S. (2006). *Weight strength analysis aircraft structures.*

Harsimran Singh, H. K. (2015). Review on wire electrical discharge machining (wedm) of aluminum matrix composites. *International Journal of Mechanical and Production Engineering*.

Megson, T. (2010). *An Introduction to Aircraft Structural Analysis (4th Edition).*

Parker, D. T. (2013). *Aircraft Manufacturing in the Los Angeles Area in World War II.* Building Victory.

R.J.H. Wanhill. (2017). *Aerospace Materials and Material Technologies.* Indian Institute of Metals Series.

Appendix:

Metal tensile test certificate:

YARMOUK INDUSTRIAL COMPLEX Technical Support Department Management of Research and Development Central Laboratory	Revision No:	النسخة مضبوطة
Author:	Approved by:	

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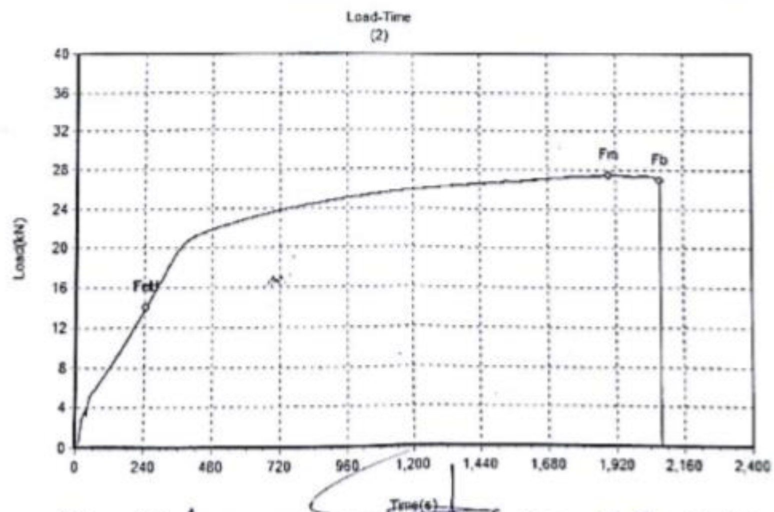
Metal tensile report test

Specification	ALLOY	Material	ALLUMINUM
SampleNo	2	BatchNo	0032
Shape	planar	TestDate	2019-01-03
Temperature	20.0	Operator	ABU OBIEDA
BreakArea(mm^	44.40	FeH(kN)	13.99
ReH(MPa)	232	FeL(kN)	13.98
Yield.ST(MPa)	232	Fm(kN)	27.47
Rm(MPa)	456	Elong(%)	24.0
R.D(%)	26.0	E(GPa)	7.30
STANDARD	ISO 6892-1 2009,MOD		

ultimate tensile strength



Tech. Name: Abuobieda Gasim Signe: .... Date: 3-1-2019........

Superviser Name: Ahmed Gaber Signe: .... Date: 3-1-2019........

Lab.Manag. Name Bashir Saddig Signe: .... Date: 3-1-2019........

Model No.: F.P.9.006	**Issue No.: 03/1**	**Issue Date: April 2014**

Ultimate tensile strength certificate 1

Hardness test result certificate:

Approved by:

شهادة التحليل الميكانيكي

التاريخ	3.1.2018
رقم شهادة التحليل	1
رقم العينة	2
نوع العينة	Allumínum
رقم أمر العمل	بدون
المواصفة المرجعية	حسب الطلب
الجهة الطالبة	الورشة

الخواص الميكانيكية:

الخاصية	الشد	الاستطالة	مساحة المقطع	الصدم	الصلادة		
	(kgf/mm^2)	(%)	(%)	(J)	HRC	HV	HB
المطلوب							
المتحصل عليه							115

فني المعمل	الاسم: محمد بشير	التوقيع:	التاريخ: 3.1.2019
الملاحظ	الاسم: المهندس [illegible]	التوقيع:	التاريخ: 3.1.2019
اعتماد مدير العمل	الاسم: [illegible]	التوقيع:	التاريخ: 3.1.2019

رقم النموذج: F.P.9.006	رقم الإصدار: 03/1	تاريخ الإصدار: ابريل 2014م

Toughness test certificate 1

Chemical composition analyses result certificate:

Date: 01/03/19 09:51:58
Sample: 2
Ref. Alloy:

Program: Al_Orientation
Operator: Mr.Sami
Analysis Mode: Standardized concentration

	Si %	Fe %	Cu %	Zn %	Mn %	Mg %	Cr %	Ni %	Be %	Co %
1	0.090	0.158	7.286	0.056	1.172	2.005	0.017	0.041	0.002	0.033
2	0.083	0.150	7.541	0.037	1.162	2.025	0.014	0.031	0.002	0.035
3	0.088	0.162	7.514	0.054	1.132	2.039	0.015	0.035	0.001	0.035
Avg.	0.087	0.157	7.447	0.049	1.155	2.023	0.015	0.036	0.002	0.034

	Pb %	Sn %	Ti %	V %	Al %
1	0.068	0.052	0.041	0.020	88.959
2	0.050	0.043	0.040	0.018	88.771
3	0.052	0.050	0.040	0.020	88.763
Avg.	0.057	0.048	0.040	0.019	88.831

VD = Gost 1131-76

Chemical composition analyses certificate 1

Impact testing report:

YARMOUK INDUSTRIAL COMPLEX Technical Support Department Management of Research and Development Central Laboratory	Revision No: نسخة مضبوطة
Author:	Approved by:

Impact Testing Report

SampleNo	1	Area	80.0
Material	Iron	Operator	mohammed
Temperature	25		
Result			
No.	Energy(J)	Toughness(J/cm²)	
1	21.6	27.03	

Tech.Name: ELKHZIN Signe: .... Date: 7.1.2019

Superviser Name: Ahmed Omar Signe: .... Date: 7.1.2019

Lab.Manag.Name: .... Signe: .... Date: 7.1.2019

Model No.: F.P.9.006	Issue No.: 03/1	Issue Date: April 2014

Impact testing certificate 1