Study on the Mechanical Behavior of Al - 7075 after Heat Treatment Process in Biomedical Field

by

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22581

Dessertation submitted in partial fulfilment

of the requirements for the

Bachelor of Engineering with Honours

Mechanical Engineering

Universiti Teknologi PETRONAS,

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CERTIFICATION OF APPROVAL

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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 reference and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(ABU AMIRUL SHAFIQ BIN ABU BAKAR)

ABSTRACT

Aluminium (Al) and Al-based alloys have unique properties such as high strength, low density, and excellent corrosion resistance with as well low cost. These properties are essential for the manufacture of lightweight, high-strength parts for biomedical applications. Al and Al-alloys present a unique combination of strength and biocompatibility. This allows it to be used in medical applications and explains its extensive use as an implant material over the past 50 years. Aluminium alloys 7075 are expected to be used much more widely in the medical field such as apparatus due to their superior biocompatibility, corrosion resistance, low cost and specific strength compared to other metallic materials. These include manufacturing of stethoscope, sterilization tray and crutches. In this study, Aluminium 7075 have undergone heat treatment which was to analyze the mechanical properties of the specimen such as three point bending test and optical microscope test. In the present study, ten selected sample with size of 100mm x 20mm x 6mm were heat treated at various temperature (110°C, 130°C and 150°C) with different aging times (1 hour, 3 hour, and 5 hour) and cooled at room temperature to investigate the effect on the mechanical properties of the specimen. The changes in mechanical behavior have been compared to each other and the best result will be preferred in the medical field. After the experiment, the result was analyze and it shows that HT130-1 has the highest performance compared to others in terms of compression strength, yield strength and energy taken to bend and as well as the optical microstructure shows it is the best outcome compared to others.

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CHAPTER 1

INTRODUCTION

1.0 Background

Among metal materials, aluminium alloys are of great interest especially in the medical field due to their relatively low density, excellent biocompatibility, excellent mechanical performance, low Young's modulus, and excellent electrochemical behavior. For biomedical uses, pure aluminum and aluminum alloys are probably the most desirable metal materials. Stainless steel was the predominant biomedical material for a long time. Nevertheless, new types of alloys such as Al 7075 have been produced recently due to the higher cost to purchase stainless steel. Another factor is that it is difficult to machine the stainless steel into an end product as it consume many factor and another problem Is that stainless steel is not recyclable which leaves the environment impact [1],[2]. A biomedical aluminum alloy has been developed and is currently under development with much greater biocompatibility.

Al and its alloys have a special combination of strength and biocompatibility that allows for medical applications to be used. For example, the development of product surfaces that provide optimal osseo compatibility while enhancing implant longevity is a major challenge for orthopedic biomaterials. Al and Al-alloys have a body fluid effect with over 50 years of experience using biomaterials as implant materials (metal: stainless steel, titanium alloy, cobalt alloy, ceramic, aluminum oxide and zirconium oxide, calcium phosphate, synthetic and natural polymers). Because of its excellent properties such as high tensile strength, durability and high corrosion resistance, it is the most attractive and valuable material [3]. This specific combination of biocompatibility and strength makes it suitable for the use in medical applications.

The alloy composition should be considered when determining the ideal biomedical application to provide the necessary biocompatibility and mechanical strength. Some other materials other than stainless steel such as Ti-6Al-7Nb, Ti6Al-4V, Ti-13Cu-4.5Ni, Ti-25Pd-5Cr and Ti-20Cr-0.2Si are also included in dental titanium alloys. Ti-6Al-4V alloy has been replaced by Ti-6Al-7Nb, Ti-13Nb-13Zr and Ti-12Mo-6Zr for permanent implants due to potential toxic effects or vanadium leaching [1],[2]. Research are carried out to select the best topography of the soil for use in bio-applications. Aluminum is biologically stable and inert with its alloys. This is the fact that there is virtually no shift in transplantation into the human body. Aluminum, however, has low wear resistance and wear resistance due to its low hardness, which can lead to problems with shorter implant life. Through applying effective surface modification techniques, this problem can be greatly overcome. Aluminum was also used in the manufacturing of medical equipment such as surgical trays, stretchers, crutches and stethoscopes. [4].

An important aspect to consider is that both the bulk of the material (important in determining biological performance) and the surface properties (surface chemistry and structure) control the fate of the implant material for the material contact with the surrounding tissue. Bulk materials have to be able to withstand high stress (too high for ceramic and polymer materials, but metal materials are possible. However, micro-tremor is beneficial when the surface properties of the bio material cannot guarantee a stable contact between the surface of the surrounding tissue and the implant, resulting in a fiber coating which weakens the transfer of load at the interface of the bone or implant.

1.2 Problem Statement

Pure aluminium are well known and has many characteristics that impressed the world. However, aluminium alloy especially Al 7075 is a well-established major metal but the performance of the material is a concern in biomedical terms so stainless steel are most likely use in the market currently. But this is a problem as stainless steel are expensive material and the process to machine stainless steel into a product is difficult. Furthermore, another major problem for stainless steel are it is not recyclable which impact the environment. The use of aluminium in this current era is difficult because of the lack of research of this material. It is highly reactive, though the metal is protected by a surface layer of inert transparent oxide (Al^2O^3) that forms rapidly in air, providing excellent corrosion resistance. Next, aluminium is also an abundant waste for the environment from machining, used items and more which will be scrap metal in the near future. The cost of aluminium is also a concern in forming the end product.

1.3 Research Objective

i. To prepare Al-7075 under different temperature and time duration
ii. To study the effect of heat treatment process towards mechanical properties of Al-7075
iii. To compare the performance of Al-7075 in bending test and optical microscope test

1.4 Scope of Study

This project mainly focused on the development and research route of mechanical properties of Al-7075 after undergoing heat treatment process to find out the results such as flexural stress, stress deformation and microstructure etc. All of these properties were examined and follow the appropriate standard and guidelines. We have first undergo heat treatment process by using oven under different temperature and duration of time before going to examination of testing of three point bending test and microstructure testing. We have also study whether Al-7075 is suitable or not in biomedical applications as currently our current era are using stainless steel which are higher in cost, not recyclable and hard to machine to an end product.

In the preparation stage, the specimen of Aluminium 7075 has been acquired from external suppliers and the specimen has been cut into 10 rectangular pieces of same dimension of 100x20x6mm. The specimen were used from bending test and microstructure study. It will first undergo three different heating temperature which were 110°C, 130°C and 150°C. The time use for the heat treatment process for each material was 1 hour, 3 hour, and 5 hour. This process was important in determining the most suitable sample to be used in biomedical field.

CHAPTER 2

LITERATURE REVIEW

2.1 Aluminium as Abundant Waste

The global aluminum demand is forecast at 40 to 50 million kilograms per year. Aluminum (Al) and its alloys are used in a number of fields, including aerospace, marine and automotive. [5]. They are also used for materials from chemical plants, medical equipment, buildings, and some consumer products. Many industries are rising slightly, including architecture, health, and jewelry. Al is primarily used in the dental sector due to its high biocompatibility and low density compared to other dental alloys.

Good strength to weight ratio for aluminium including resistance to oxidation, low cost compared to other materials [3]. On the other hand, it can be very difficult to use dental Al or Al-based alloys, such as the manufacture of partial denture frameworks and ceramic metal prostheses, as this material reacts at high temperatures with investment materials. As before, this titanium is widely used but a special casting machine supplied with helium or argon is required due to the high reactivity of titanium with hydrogen, nitrogen, oxygen and carbon, which greatly increases the cost of the procedure. Because of its lower cost and easier to obtain materials, the market is looking for more aluminum [6]. Many methods has been invented to minimize the cost of the procedure, such as the special fluid dilution needed to combine with the investment, the use of a vacuum environment during casting rather than inert gas, the use of inexpensive alloy elements and the recasting phase.

As the industry meets the public demand for conservation of resources and the environment, recycled metals are becoming increasingly important and cost-effective [5]. Recycling, an important element in the supply of many metals that are used in society, offers environmental benefits in terms of saving energy, reducing waste and reducing energy-saving emissions. While aluminum is one of the most abundant elements in the earth's crust alongside oxygen and silica, global metallic Al production is quite small at 3.0x 10^7 tons, slightly lower than common metals like iron at 1.1x 10^9 tons and titanium at 1.0x 10^5 tons. [5]. The key reason for high metallic Al production is the low cost of manufacturing and also easier to make into material efficiency.

However, the amount of aluminum from metal scrap produced by melting, forging, casting and aluminum parts manufacturing is expected to increase in the future. Because this metal dissolves in a controlled environment and does not require chemical treatment, the scrap produced in the dental sector is very clean. For dentistry, it seemed possible to recycle Ni-Cr and Co-Cr alloys as well as gold-based alloys. In fact, 45% of aluminium is carried into new scrap phase or lost [3].

As shown in Figure 2.1, aluminum has a great characteristic that makes it suitable for the biomedical field. Consequently, the aim of this study was to assess the effect of Al state (as obtained and recast) on mechanical properties such as proportional limit, ultimate tensile strength, elongation, and micro hardness by Vickers, Al microstructure and fracture mode. This is to make it safe for use in the biomedical industry, so there will be no health problems.

Figure 2.1: Characteristic of aluminium

2.2 Aluminium in medical field

Aluminum is a metal component known for several desirable properties such as excellent resistance to oxidation (almost platinum equivalent) and mechanical resistance, low thermal conductivity and high conductivity of electricity. It is a light and strong steel, simple to produce and low density (40% of iron content) as described above [7]. It is ductile and easy to work with when flat. Refractory metals and titanium are as strong as steel because of the relatively high melting point, but 60 percent lighter than platinum, but twice as cost-effectively. Such properties make aluminum highly resistant to ordinary fatigue. When exposed to air, this metal forms a passive oxide layer, but is ductile in an oxygen-free environment. In addition, it burns when heated and like most organic acids, burns when immersed in sulfuric acid and nitrogen chloride.

Aluminum is used in several areas, including engineering, chemical industry (due to resistance to corrosion and chemical attack), naval industry (used in undersea equipment, desalinated seawater), nuclear industry (used in heat production) and Nuclear power plant recuperator, war industry (missile and arms manufacturing) [8]. When used as a metal, approximately 54% of aluminum is used in the aviation and aerospace industries to manufacture engine parts and turbines, fuselage of aircraft and rockets [5].

In several places, aluminum has been used historically, primarily in engineering. As Figure 2.2 shows demineralized histologic section showing the biocompatibility of implant surface of aluminium. However, aluminium is also widely used in the medical field and dentistry, mainly with characteristics such as high corrosion resistance, low toxicity, very low allergen potential, and biocompatibility that allows a good biological response when in contact with living organisms as Figure 2.3 shows mineralized histological section of aluminium alloy implant installed in rabbit tibia 30 days post-operative. The rate of success is high. This preferred biological response is due, according to several writers, to the limited release of ions, the stability of the compounds produced, and the limited biological effects of these ions. Furthermore, a layer of titanium dioxide is formed immediately when aluminum comes into contact with oxygen (air). This is a strong barrier to metal dissolution. Many researchers also conclude that this chemically inert coating of titanium dioxide is a major cause of titanium in vivo and the biological properties and has a negligible corroding propensity. Nevertheless, it has been found that titanium ions are released in the presence of fluoride, so when a piece of titanium is exposed in your mouth, it is advised that you stop using fluoride.

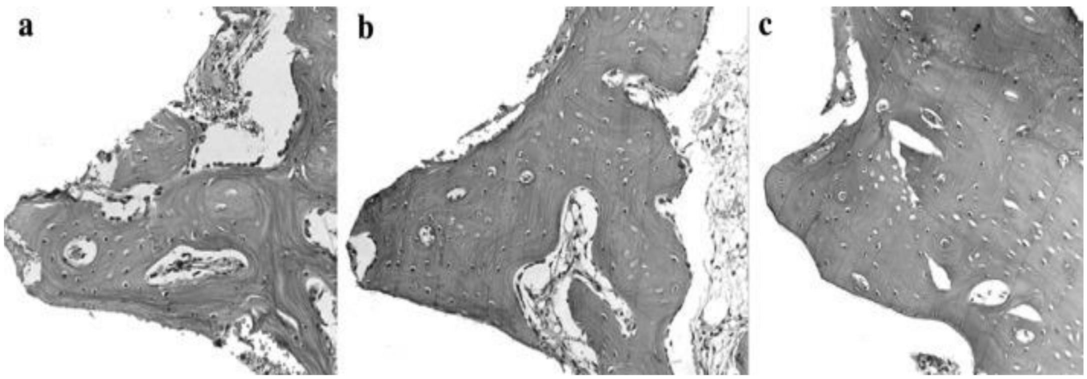

Figure 2.2: Demineralized histologic section showing the biocompatibility of implant surface of aluminium

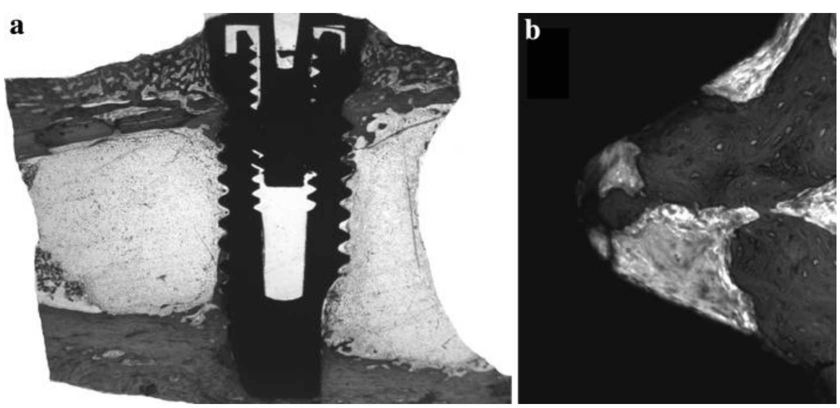

Figure 2.3: Mineralized histological section of aluminium alloy implant installed in rabbit tibia. 30 days post-operative

Aluminum has been used as a manufacturing plant for devices such as stretchers and stethoscope for many years in the medical field. Manufactured from aluminum and aluminum alloys that are commercially safe. A passive coating dependent on aluminum oxide permits adherence to metal surfaces by physiological liquids, protein hard and soft tissues [7]. Aluminum can be used for use in dentistry in various combinations. Pure aluminum consists of 99% aluminum and 1% interstitial elements (carbon, oxygen, nitrogen, hydrogen, iron), and the ratio of these elements has a direct effect on the metal's properties.

In the modern biomedical sector, aluminum tends to be a promising material because there are several possibilities for aluminum use. A blend of strength and lightness due to its physiological stiffness, biocompatibility, corrosion resistance in the oral environment. Aluminium can be thought of as a versatile and practical biomaterial important as show in Figure 2.4, aluminium as strelization tray, Figure 2.5, aluminium as crutches and Figure 2.6, aluminium as stethoscope. Many of its advantages, however, are inexpensive and considered readily available, but the engineering associated with ceramic machining, casting, welding, and application to dental prostheses is still expensive and there is a major limitation. Therefore, the wide use of aluminum in prostheses in the medical field is based on technical progress and more laboratory and clinical research to develop more profitable technologies that demonstrate their efficiency.

Figure 2.4: Aluminium as sterilization tray

Figure 2.5: Aluminium as crutches

Figure 2.6: Stethoscope made out of aluminium

2.3 Heat Treatment Process

Heat treatment is the process of an operation or multiple operations involving heating and cooling of a metal or alloy. For this case, it involves the mild steel in the solid state in such ways as to produce the desired certain microstructure and mechanical properties such as hardness, toughness, yield strength, ultimate tensile strength, young's modulus, percentage of elongation and percentage reduction. The most significant heat treatment process includes annealing, normalizing, hardening and tempering. These methods are commonly modify the mechanical properties of engineering materials especially the steels such Aluminium 7075. Annealing heat treatment method process which consists of heating and holding at an appropriate temperature [9],[10]. It is then followed by cooling process at an appropriate rate. These are usually applied to soften iron or steel materials and improves its grains due to ferrite pearlite microstructure. This is applicable when engineering materials require elongation and appreciable level of tensile strength. Hardening is the heat treatment method that resulted in the increment of hardness o steel piece [11]. This is done by heating it to a certain temperature followed immediately by cooling process at a room temperature.

Tempering is the process of applying toughness testing on hardness to an already hardened piece of steel though the process of reheating at a certain temperature and also followed by immediate cooling process. The level of toughness applied and the hardness to be reduced will determine the temperature needed [12]. To normalize the material, it is heated at an austeritic temperature range and later followed by air cooling [7]. This is essential to obtain a mainly pearlite matrix, which results in higher strength and hardness. Besides, it is used to get rid of undesirable free carbide present in the as-received sample.

Work hardening is a process where the metal is strengthened through certain processes such as rolling or forging. It is the significant technique in the improvement of the properties of alloys which cannot be heat treated. While undergoing these treatments, the number of dislocations in materials and the strength of metal improves [13]. This happens because of the changes of the grain shape and the microstructure becomes more inhomogeneous which does not permit the easy fracture propagation [7]. The change in structure of alloy affects their reaction to annealing and hot working.

2.4 Three-Point Bending Test

Flexural testing measures the force required to bend a beam of plastic material and determines the resistance to flexing or stiffness of a material. Flex modulus is indicative of how much the material can flex before permanent deformation [14]. In case of a plastic lock arm or snap fit assemblies, the arm needs to flex to allow the proper seating of the connection, then flex back into position to lock the connection in place. If the locking mechanism is made of brittle material, then the mechanism would have higher tendency to break when flexed [15]. In an example of support beams the flex testing indicates how much load the beams can bear before flexing and thus a rigid or stiffer material is more adequate for such application. Alternately, a diving board is required to show higher flexing to support the diver's jump.

The three-point bending flexural test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress–strain response of the material. This test is performed on a universal testing machine (tensile testing machine or tensile tester) with a three-point or four-point bend fixture. The main advantage of a three-point flexural test is the ease of the specimen preparation and testing [15]. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate.

The test method for conducting the test usually involves a specified test fixture on a universal testing machine. Details of the test preparation, conditioning, and conduct affect the test results. As shown in figure 2.7, the sample is placed on two supporting pins a set distance apart with force applied in the center.

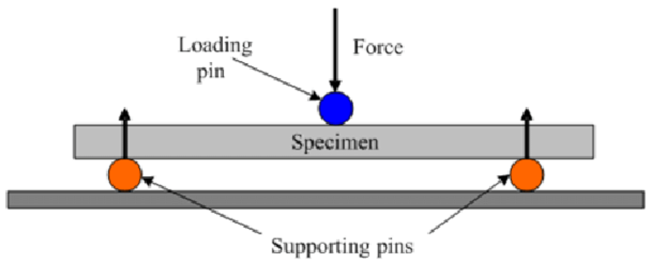

Figure 2.7: Three point bending test operation

Calculation of flexural stress σ_f

$\sigma_f = \frac{3FL}{2bd^2}$ for a rectangular cross section

$\sigma_f = \frac{FL}{\pi R^3}$ for a circular cross section

Calculation of flexural stress ε_f

$\varepsilon_f = \frac{6Dd}{L^2}$

Calculation of flexural modulus E_f

$E_f = \frac{mL^3}{4bd^3}$

in these formulas the following parameters are use:

σ_f = Stress in outer fibers at midpoint, (MPa)

ε_f = Strain in the outer surface, (mm/mm)

E_f = Flexural Modulus of elasticity, (MPa)

F = Load at a given point on the load deflection curve, (N)

L = Support span, (mm)

b = Support span, (mm)

d = Depth or thickness of tested beam, (mm)

D = Maximum deflection of the center of the beam, (mm)

m = The gradient of the initial straight-line portion of the load deflection curve (N/mm)

R = The radius of the beam, (mm)

2.5 Optical Microscope

The optical microscope, also referred to as a light microscope, is a type of microscope that commonly uses visible light and a system of lenses to generate magnified images of small objects. Optical microscopes are the oldest design of microscope and were possibly invented in their present compound form in the 17th century. Basic optical microscopes can be very simple, although many complex designs aim to improve resolution and sample contrast [16]. The object is placed on a stage and may be directly viewed through one or two eyepieces on the microscope. In high-power microscopes, both eyepieces typically show the same image, but with a stereo microscope, slightly different images are used to create a 3-D effect. As shown in figure 2.8, a camera captures the image of the grain size of Aluminium 6061 under optical micrscope (micrograph).

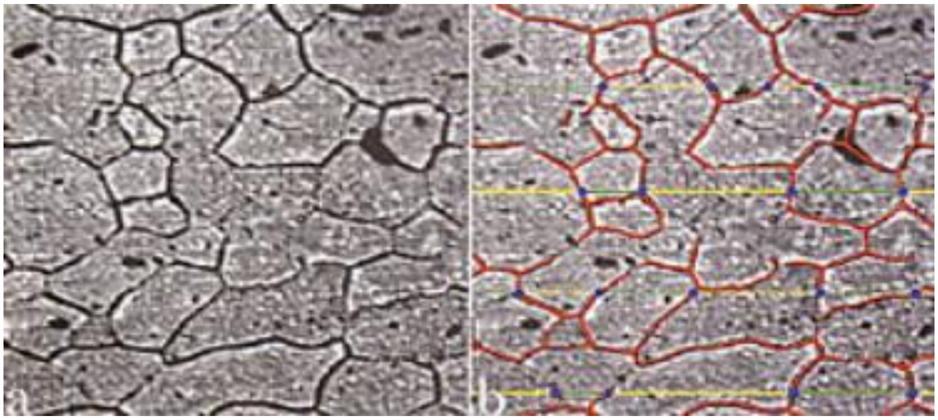

Figure 2.8: Grain size of Aluminium 6061 under optical microscope [7]

The sample can be lit in a variety of ways. Transparent objects can be lit from below and solid objects can be lit with light coming through (bright field) or around the objective lens (dark field). Polarized light may be used to determine crystal orientation of metallic objects [16]. Phase-contrast imaging can be used to increase image contrast by highlighting small details of differing refractive index.

A range of objective lenses with different magnification are usually provided mounted on a turret, allowing them to be rotated into place and providing an ability to zoom-in. The maximum magnification power of optical microscopes is typically limited to around 1000x because of the limited resolving power of visible light [17]. The magnification of a compound optical microscope is the product of the magnification of the eyepiece (say 10x) and the objective lens (say 100x), to give a total magnification of 1,000×. Modified environments such as the use of oil or ultraviolet light can increase the magnification [18],[19]. Alternatives to optical microscopy which do not use visible light include scanning electron microscopy and transmission electron microscopy and scanning probe microscopy and as a result, can achieve much greater magnifications.

When using a camera to capture a micrograph the effective magnification of the image must take into account the size of the image. This is independent of whether it is on a print from a film negative or displayed digitally on a computer screen [20]. In the case of photographic film cameras the calculation is simple; the final magnification is the product of: the objective lens magnification, the camera optics magnification and the enlargement factor of the film print relative to the negative [17]. A typical value of the enlargement factor is around 5x (for the case of 35 mm film and a 15 × 10 cm (6 × 4 inch) print. In the case of digital cameras the size of the pixels in the CMOS or CCD detector and the size of the pixels on the screen have to be known [19]. The enlargement factor from the detector to the pixels on screen can then be calculated. As with a film camera the final magnification is the product of: the objective lens magnification, the camera optics magnification and the enlargement factor.

CHAPTER 3

METHODOLOGY

3.1 Process Flowchart

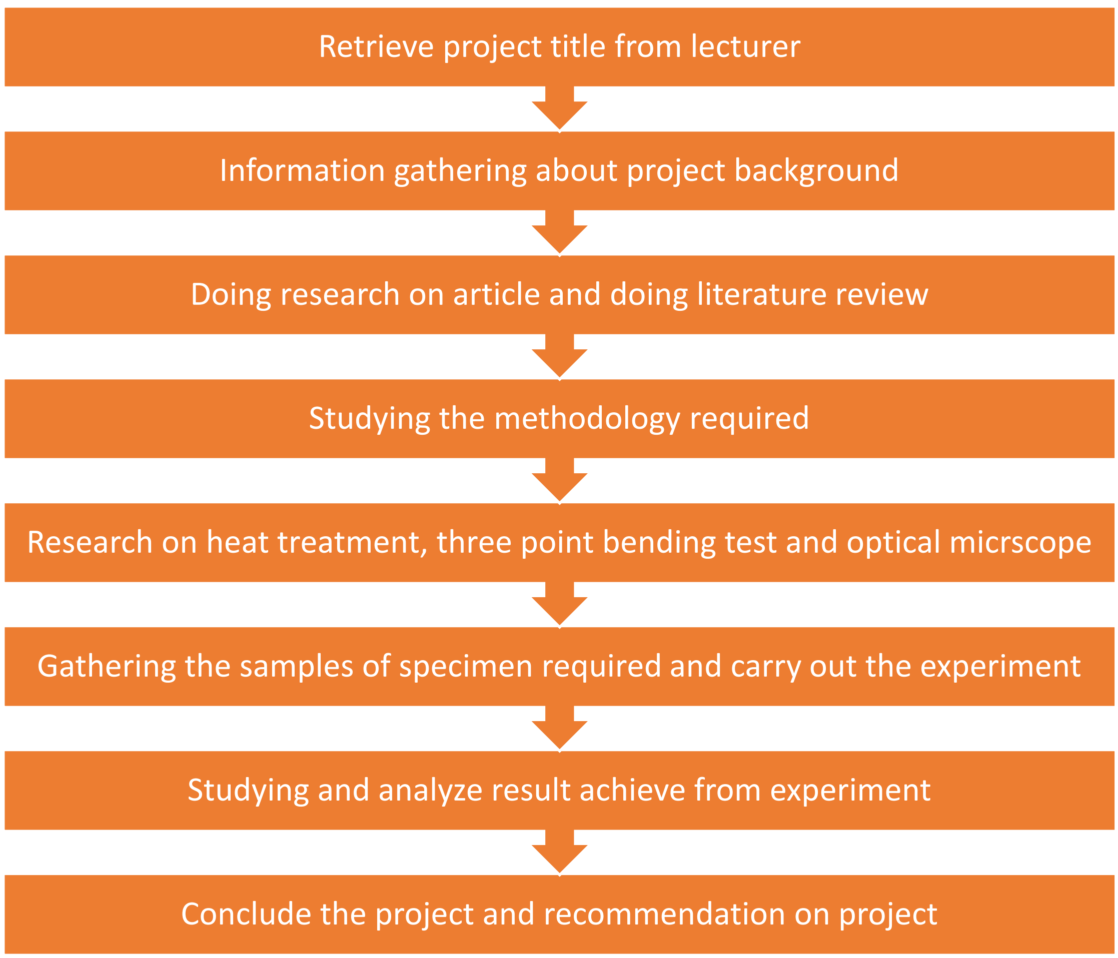

Figure 3.1: Process flowchart of project

Figure 3.1 shows the flow of the project with the experiment process. Firstly, we received the project title from our supervisor and we began to gather the information about the project background. Next, we have done the literature review on the aluminium properties, the usage, heat treatment on aluminium, and aluminum under opticalmicrsocope. We continued with methodology and we did this by first doing more research on each steps required so a perfect result will be achieved such as the temperature and time required under heat treatment and steps in optical microscope. We had then gather the samples of Aluminium 7075 with dimension 100 x 20 x 6mm with having ten samples of same size and continue the experiment. Results had came out and we had analyze and studied the data from the graph to the surface of the aluminium under optical microscope. Finally, we can conclude the data and result and do recommendation onproject on what we can improve even more.

3.2 Research Methodology

As mentioned in this project, we used Al-7075 consisting of several steps, the main focus being heating treatment of the aluminium. Second, to study mechanical behavior, through tensile strength, hardness checking, and microstructure analysis, we need to get the best information of this research. It is necessary to make some calculations, such as the composition ratio and the size needed for the forging process. This measurement was important in determining the final product value and characteristics. We need to make sure that the use in the biomedical field is safe as health problems can be a problem with high temperature reactivity. We will study and examine the aluminium under different temperature and time as well.

3.3 Heat Treatment

The prepared samples of aluminium 7075 were subjected to heat treatment process under different temperature and time. Subsequently, samples will be aged at 3 different temperatures which are 110°C, 130°C and 150°C for three different period times which is at 1 hour, 3 hour and 5 hour using oven, followed by air cooling at room temperature. The heat treatment was conducted according to the ASTM standard B918 – 01 i.e. the standard for the heat treatment of aluminium alloys. Figure 3.2 shows the figure of heat treatment oven used in this project.

Figure 3.2: Oven for heat treatment

All the samples will undergo the experiment under these parameters tabulated in the table 3.1 below.

Table 3.1: Heat treatment of Aluminium 7075 alloys

	Material code	Heating Time (Hours)	Aging Temperature (°C)
Treated Material	HT110-1	1	110
	HT130-3	3	130
	HT150-5	5	150
	HT110-1	1	110
	HT130-3	3	130
	HT150-5	5	150
	HT110-1	1	110
	HT130-3	3	130
	HT150-5	5	150
Non- treated Material	A001	-	-

3.4 Ultimate Tensile Machine

First, the material was heated using oven under different temperature and time. The specimen was then loaded onto the universal tensile machine and hold by two supporters before pressed by crosshead. The test was started by applying force to the specimen at a constant speed. The target time from the start to the end of the test was 30 seconds to 2 minutes. The test ends when the sample breaks or ruptures. This was repeated for the rest of the dog bone shape samples.

In this analysis, we will obtain

1. Tensile strength (our main focus)
2. Elongation at yield and break
3. Nominal strain at break
4. Modulus of elasticity
5. Poisson's ratio

The equipment's required are

1. Universal testing machine (tensile testing machine)

   Figure 3.3 is the figure of universal tensile machine which is used for tensile strength [3]. The material must be professional enough. For most unreinforced plastics, a single column device of 4.5kN is usually sufficient. Also very common are 9kN dual column systems. A large 45kN model may be needed with large materials and strong materials such as reinforced plastics and composites.

Figure 3.3: Universal tensile machine

2. Support

Figure 3.4 displays the supports used to hold the specimen. Necessary to make the specimen hold in place and does not move so an accurate result will be achieved. The distance of the two support specimen is not standardized, therefore a mistake may occurs if the distance is not set accurately corresponding to the length of the specimen.

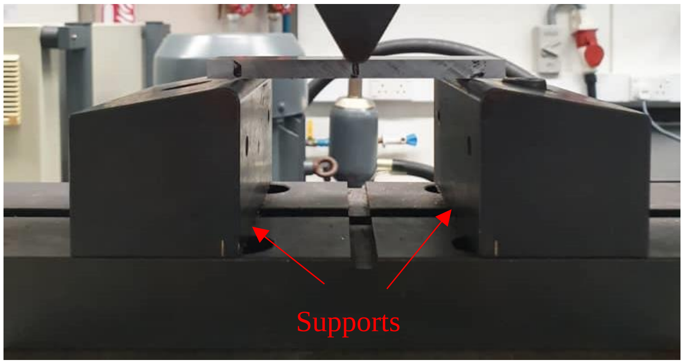

Figure 3.4: Two supports holding the specimen

3. Crosshead

Figure 3.5 shows the crosshead which gives force to the specimen. It will slowly penetrates the specimen until it ruptures at a constant force which we will set it. It is tighten by eight screws to make sure it is tight enough before applying the force to the specimen.

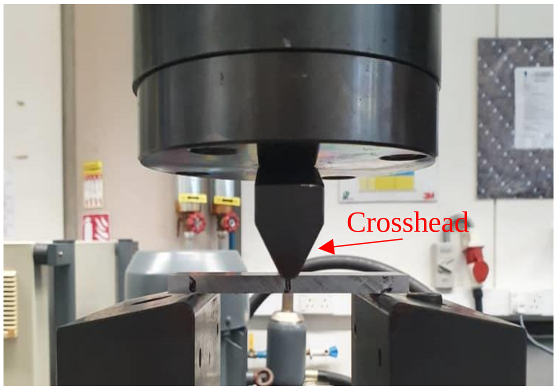

Figure 3.5: Crossheads of the Ultimate Tensile Machine

3.5 Three- Point Bending Test

First, the material has undergone heat treatment under different temperatures and time by oven treatment. After this process, the specimen was then loaded onto the three point bending test. At here, we have got the result of flexural strength, flexural modulus and yield point. As shown in figure 3.6, it shows a specimen undergoing three point bending testing.

Figure 3.6: Three point bending test

To load the material, some procedures is needed to be done in order to get the best and accurate result which are :-

1. Two similar steel bar specimen are prepared for the test and all the specimens should have the same initial dimensions, with the use of vernier calipers to get the accurate size of Length = 150mm, Width = 120mm and Height = 80mm.

2. This bending test was carried out using a universal testing machine (UTM), adjust the supports along the UTM bed so that they are symmetrical with respect to the length of the bed. Place the beam on the two blocks so as to project

equally beyond each block from each end. Check if the load was applied at the center of the beam.

3. The initial reading of the distance between a fixed part on the machine above the specimen were measured and the upper edge of the beam specimen in order to calculate the total final deflection fracture was measured as well. The initial reading was measured using vernier caliper and the load was applied until the specimen fractures. The reading was analyze and the graph was plot which we will be having compression strength, yield strength and energy taken.

The equipment and setup are as follows:-

Cantilever Flexure Frame – A simple apparatus to hold a thin rectangular beam at one end while allowing flexing of the specimen upon the addition of a downward force.

Metal Beam – In this experiment, an aluminium plate was tested. The plate should be fairly rectangular, thin, and long. Specific dimensions should be dependent on the size of the cantilever flexure frame and available weights

Deflection Indicator: A dial gage device that accurately measures (in mm) the deflection of the beam downwards the loads are added.

Range of Weights: Any different small individual weights (in grams) can be used for this test. Very large weights should not be used to not exceed the limit of proportionality.

3.6 Microstructure Testing

Figure 3.7: Optical microscope

Before undergoing microstructure observation by optical microscope as Figure 3.7, preparation was needed for the sample as follows:

1. Sectioning

To build metallographic samples, cutting the specimen into smaller pieces is required for better further process as in figure 3.8. When analyzing parts that failed during use and need to be extracted from a large block of material, section 4 is needed. Metallographic studies of such samples therefore often involve multiple operations of sectioning. Multiple specimens are required for many metallographic studies. A forged metal deformation test, for example, usually requires two parts. One was perpendicular to the central deformation axis and the other was parallel. If the source can be identified on the surface, it is best to study a failed part by selecting a specimen that intersects the source of the failure. Depending on the type of failure, multiple samples from the failure area and adjacent areas may need to be collected.

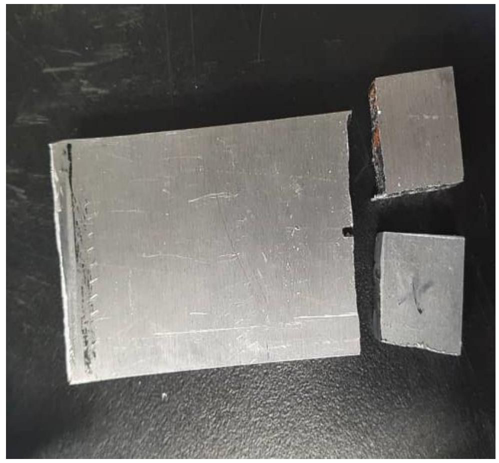

Figure 3.8: Sectioning of Aluminium 7075

2. Mounting of specimens

This move is using a mount for compression. The most popular mounting method is to use molding materials such as bakelite, diallyl phthalate resin and acrylic resin to mold metal samples by heat and pressure. Thermosetting is bakelite and diallyl phthalate, and thermoplastic is acrylic. It was not possible to mount all materials or samples on thermoset or thermoplastic racks. Cycles of heating can cause changes in microstructure and pressure can cause the collapse or deformation of delicate samples. The selected size of the sample may be too large to consider the available size of the mold. These problems are usually overcome by cold mounting. As shown in figure 3.9 shows an auto mounting press machine.

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Figure 3.9: Auto mounting press machine

3. Grinding

Grinding was achieved by polishing the specimen layer using increasingly smaller polishing grits through a sequence of operations. To make the first flat surface and eliminate the sectioning effects, grinding should begin with a coarse grit size. Hack saws, band saws or other rough surfaces in the 80 to 150 mesh range typically require abrasive sizes. From coarse to perfect, grinding must be finished. Grit sizes of 180, 240, 400 and 600 mesh are appropriate grinding sequences. The aim of grinding was to remove oxide layers, damaged layers or uneven surfaces which may have formed during the last operation.

4. Polishing

Polishing was the last step in creating a mirror-like surface that is flat, scratch-free. Figure 3.10 shows a machine that can be used for both grinding and polishing of the specimen. These surfaces were required for both qualitative and quantitative subsequent accurate metallographic interpretation. Mechanical polishing was often used to demonstrate a variety of final polishing techniques, including the use of wrapped cloth wraps and appropriate abrasives for polishing, essentially Nano Silica Graphite. The cover was either spinning or vibrating, and the sample was held by hand, held mechanically, or confined within the polishing area. Polishing should be carried out in a fairly dust-free area for sectioning, mounting and rough grinding.

Figure 3.10: Grinding and polishing machine

5. Wet Etching

Wet etching has been used where this etching was performed by immersing (or wiping) the specimen in an appropriate etchant (chemical solution) until the required structure is disclosed. Etching is done in a Petri dish or other appropriate container with a loose cover to prevent excessive solvent evaporation, in particular solutions for alcohol and we will be using Hydrochloric acid. In this experiment, we will be using Kellers Etch as it is excellent for aluminium. Most metals lose their bright appearance during etching, indicating that etching occurs. When practiced, the degree of surface dullness will indicate the completion of the etching. The surface was clean of the specimen with cotton soaked in etchant or clean the sample when submerged in the solution if the etching process needs wiping. The sample was washed with running water after completion of etching, then with alcohol, and then dried with warm air (hand dryer). After etching, an optical microscope was used to observe the surface of the sample to study its microstructure. As shown in figure 3.11, it shows a simple mechanism on how wet etching works.

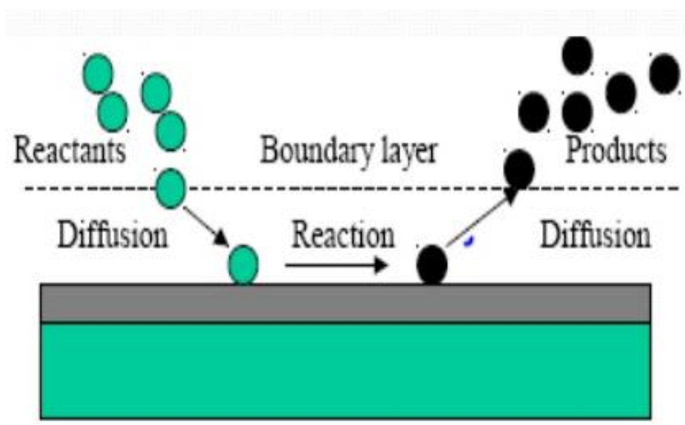

Figure 3.11: Wet etching mechanism [21]

3.7 Gantt Chart

Table 3. 2: Gantt chart of FYP I

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title discussion with supervisor	■	■												
Methodology review and Experimental analysis		■												
Literature review on project title			■	■										
Preparation of extended proposal and proposal defense				■	■									
Presentation for proposal defense									■	■				
Data collection and preparation for Interim report										■	■	■	■	
Interim report submission													■	■

Table 3.3: Gantt chart of FYP II

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Experiment Design														
Gather Aluminium 7075 samples														
Undergo Heat Treatment Process														
Bending Strength Test														
Microscopic Test														
Preparation and submission of Dissertation														
Preparation and presentation of Viva														
Preparation and submission of Hardbound copies														

3.8 Key Milestone FYP

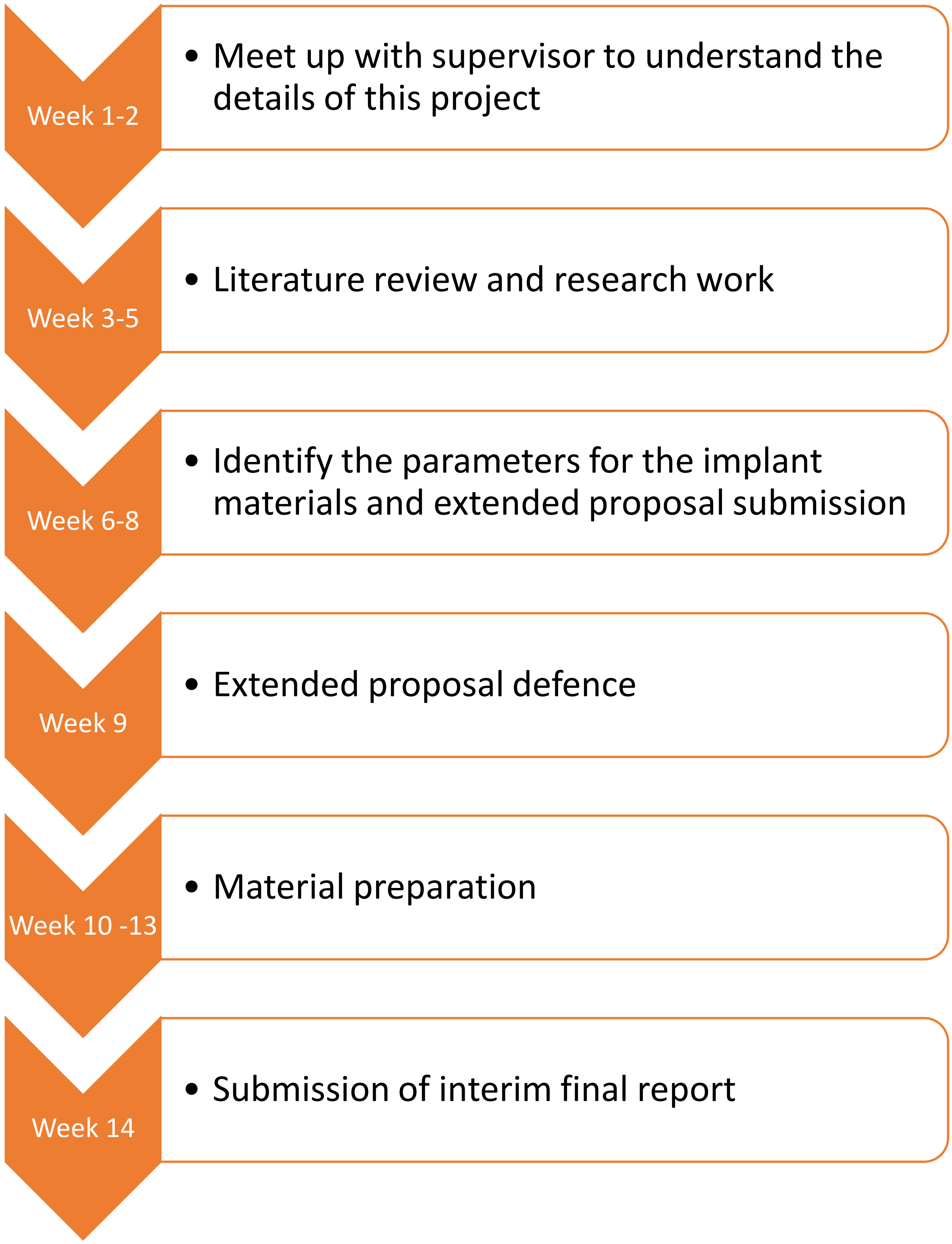

Figure 3.12: Key milestone for FYP 1

Figure 3.13: Key milestone for FYP II

Chapter 4

RESULTS & DISSCUSSION

4.1 Three Point Bending Analysis

Universal Tensile Machine will be used to carry out three point bending test which is located at Block 17, Mechanical Engineering Department, Universiti Teknologi PETRONAS. Perfectly rectangular specimen according to ASTM D790 and ISO 178 requirement of aluminium with a thickness of 6mm, width of 20mm and length of 100mm were used. Testing speed of 5mm/min was used as per suggested in the standard. Based on the experiment, table 4.1 showed the result for all the samples that had been through the three point bending test.

Table 4.1: Three point bending test

	Material code	Load at a given point on the load deflection curve, F (kN)	Support span, L (mm)	Width of test beam, b (mm)	Flexural stress, σ_f (MPa)
Treated Material	HT110-1	6.828	80	10.00	60.978
	HT110-3	7.186	80	10.00	62.848
	HT110-5	7.373	80	10.00	64.185
	HT130-1	7.46	80	10.00	64.217
	HT130-3	7.168	80	10.00	63.129
	HT130-5	7.166	80	10.00	63.578
	HT150-1	6.73	80	10.00	60.584
	HT150-3	6.63	80	10.00	59.742
	HT150-5	6.617	80	10.00	59.342
Untreated	A001	7.046	80	10.00	62.473

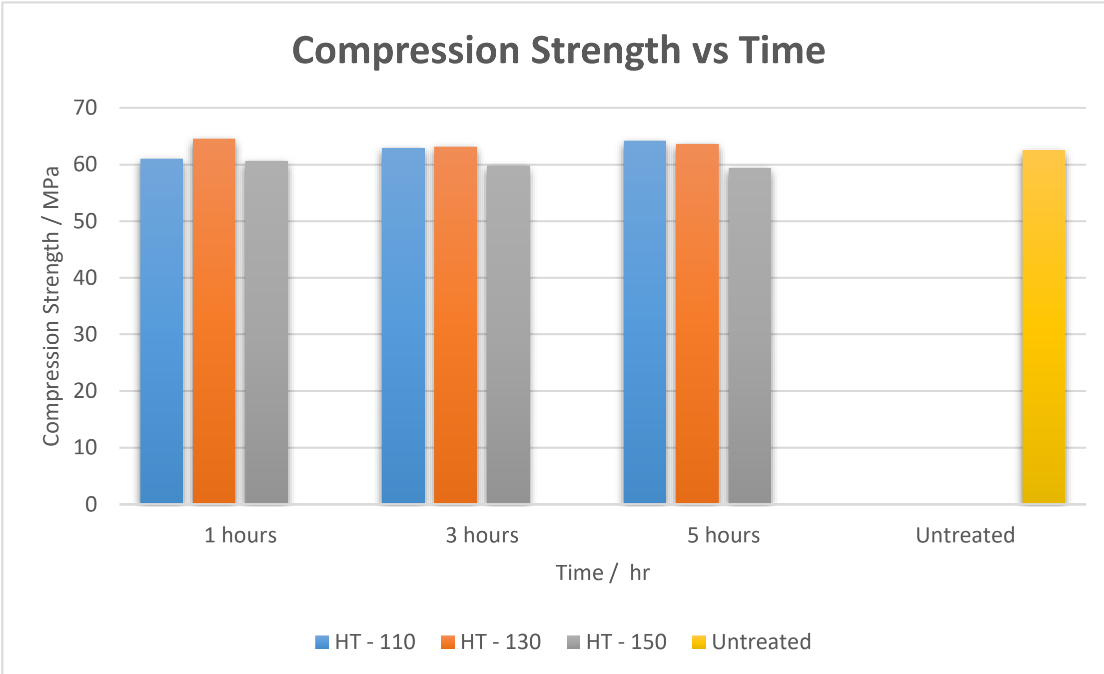

Figure 4. 1: Graph of compression strength vs. time for untreated, 110°C, 130°C and 150°C

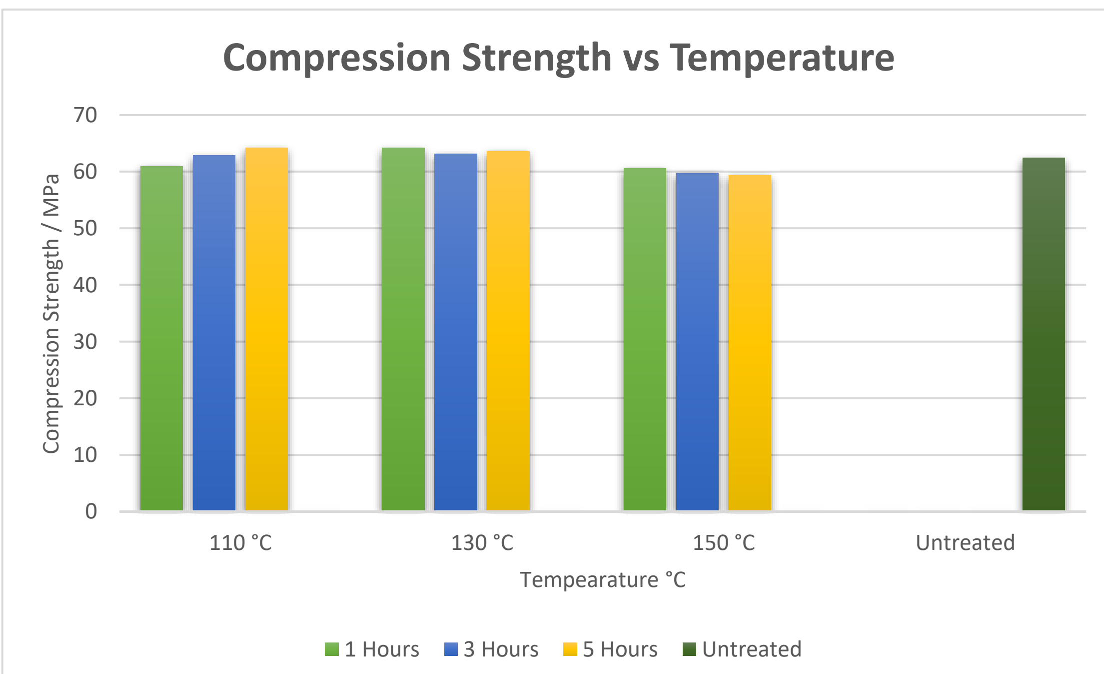

Figure 4. 2: Graph of compression strength vs. temperature for untreated, 110°C, 130°C and 150°C

The graph in Figure 4.1 and 4.2 shows the trend for the compression strength vs. time and temperature at 1 hour, 3 hour and 5 hours and 110°C, 130°C and 150°C. Trends shows that there are constant value in compression strength against different time and temperature and HT130-1 shows the highest compression strength.

At A001, which is the untreated sample shows the value for the compression strength which is 62.473MPa. For HT110-1, the compression strength slightly increased to 60.978MPa and increased to 62.848MPa at HT 110-3. While at HT110-6, the compression strength rose up to 64.185MPa. Furthermore, HT130-1 showed the compression strength of 64.217MPa and a little bit decreased for HT130-3 which was 63.129MPa but suddenly increased back for HT130-5 to 63.578MPa. After that as for the HT150 series, the compression strength was 60.584MPa for HT150-1, and has decreased to 59.742MPa for HT150-3. Finally for HT150-5, the value was 59.342MPa which has decrease even more from HT150-3. This shows that untreated has the highest compression strength and followed by HT130-1 and HT110-5.

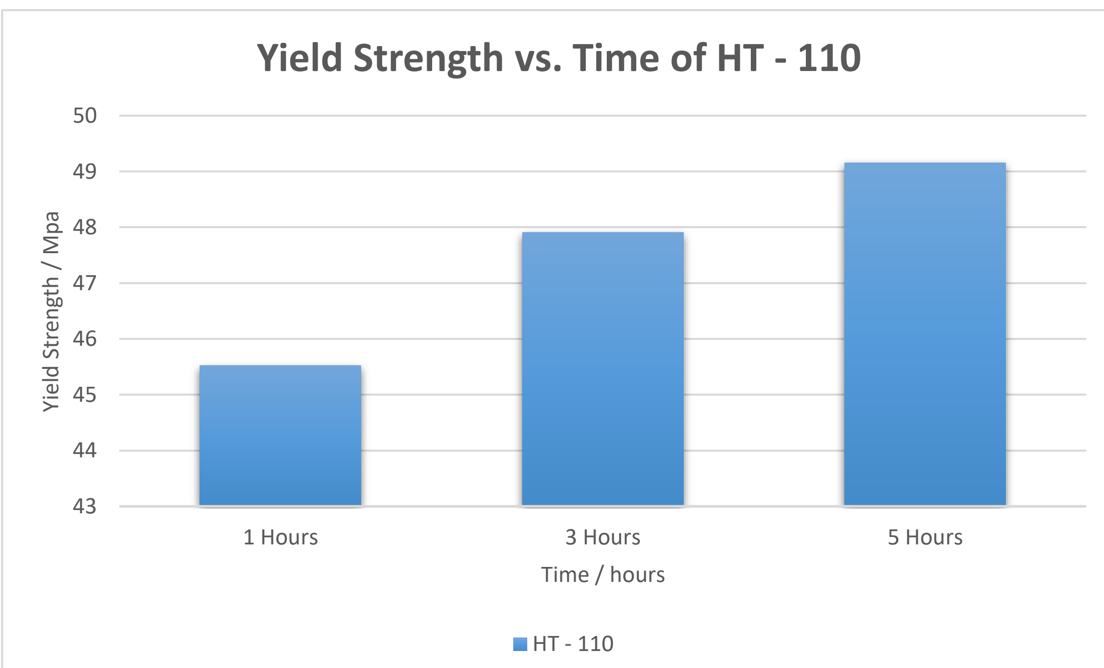

Figure 4. 3: Graph of yield strength vs. time for 110°C for 1 hours, 3 hours, and 5 hours

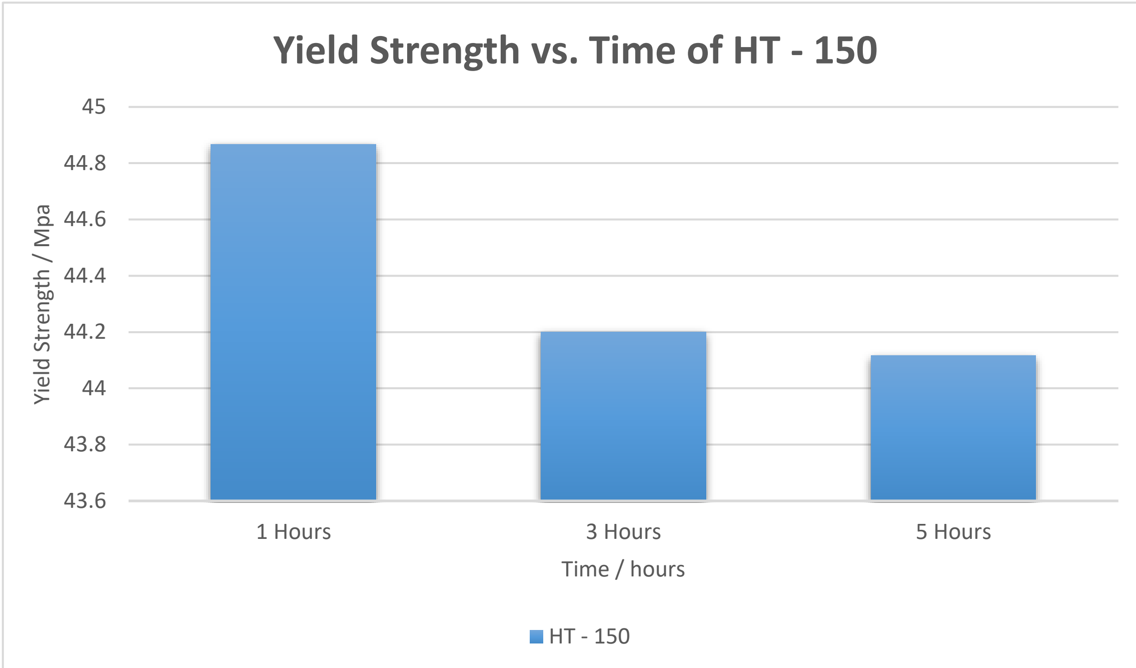

Figure 4. 4: Graph of yield strength vs. time for 130°C for 1 hours, 3 hours, and 5 hours

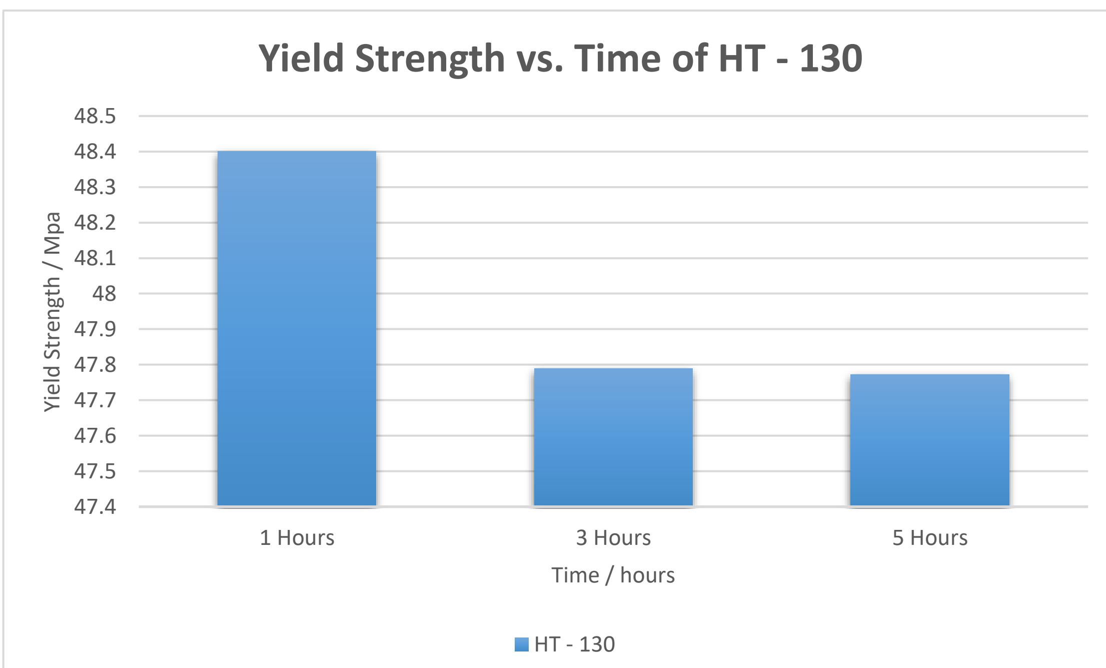

Figure 4. 5: Graph of yield strength vs. time for 150°C for 1 hours, 3 hours, and 5 hours

But by just comparing the compression strength is not enough in designing and proofing a product is perfect. So, the yield strength of all specimen were observed at time 1 hours, 3 hours and 5 hours. The value of yield strength of HT110-1 was 45.52MPa while HT110-3 increased slightly to 47.906MPa and increased even more for HT110-5 at 49.154MPa. Next, as for the HT130 series, for HT130-1, the yield strength was 48.4MPa but decreased for HT130-3 to 47.789MPa and decreased just slightly for HT130-5 which was at 47.772MPa. Furthermore, as for the HT150 series, the yield strength does not change much when compared. For HT150-1, the yield strength was at 44.867, while the HT150-3, the yield strength decreased to 44.201MPa and decreased even more for HT150-5 which was at 44.117MPa. By this, we have known that HT110-5 has the highest yield strength followed by HT110-3 and HT110-1.

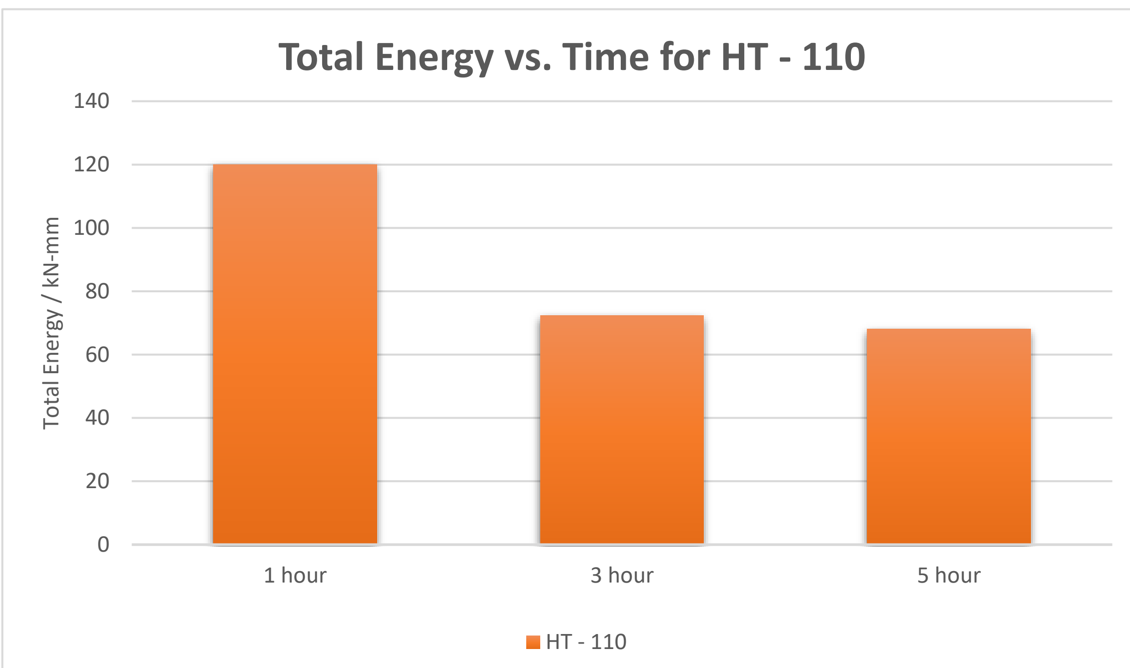

Figure 4. 6: Graph of Total Energy vs. Time for HT-130 at 1 hour, 3 hour and 5 hour

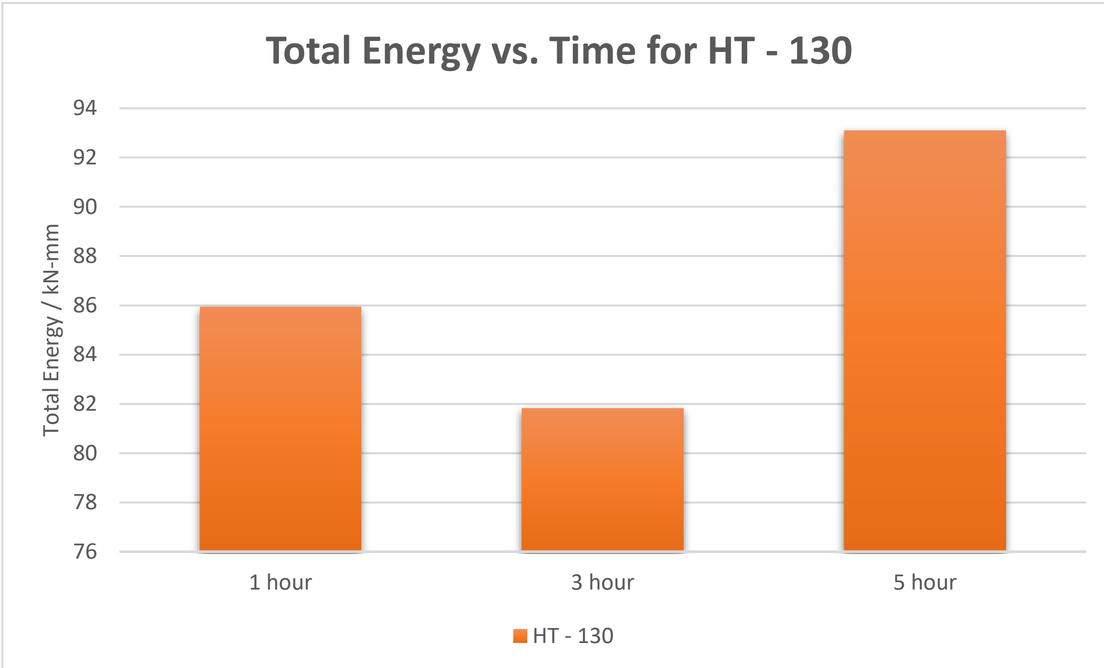

Figure 4.7: Graph of Total Energy vs. Time for HT-150 at 1 hour, 3 hour and 5 hour

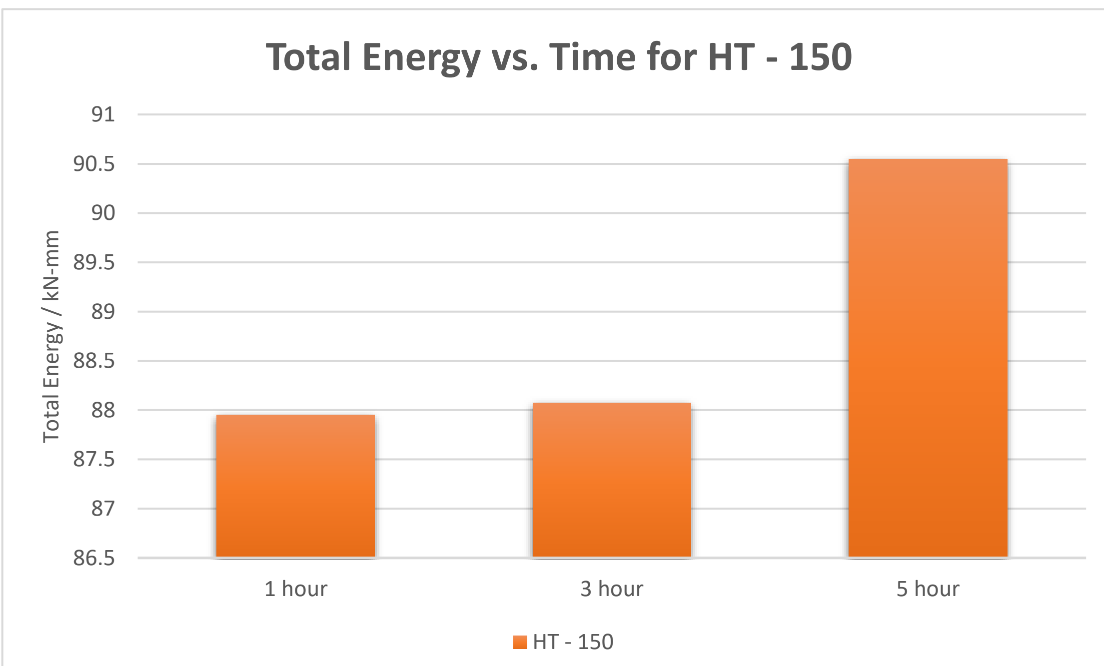

Figure 4. 8: Graph of Total Energy vs. Time for HT-150 at 1 hour, 3 hour and 5 hour

Moreover, we will compare the total energy used as well until breaking of specimen. Firstly, as shown in figure 4.6, HT110-1 has the highest total energy with 119.962kN when compared to HT110-3 and HT110-5 which are 72.29kN and 68.008kN respectively. The total energy decreased for all when compared to HT110 -1 for HT130-1, HT130-3 and HT130-5 with 85.928kN, 81.818kN and 93.102kN respectively by has a decrease and increase rate upon themselves as shown in figure 4.7. Next, as for the HT150 series as shown in figure 4.8, HT150-1 has a total energy of 87.951kN but increased for HT150-3 with 88.074 and increase even more for HT150-5 with 90.547kN. This shows that HT110-1 has the highest energy used when compared to others which shows its toughness in breakage as well compared to others followed by HT110-3 and HT110-5.

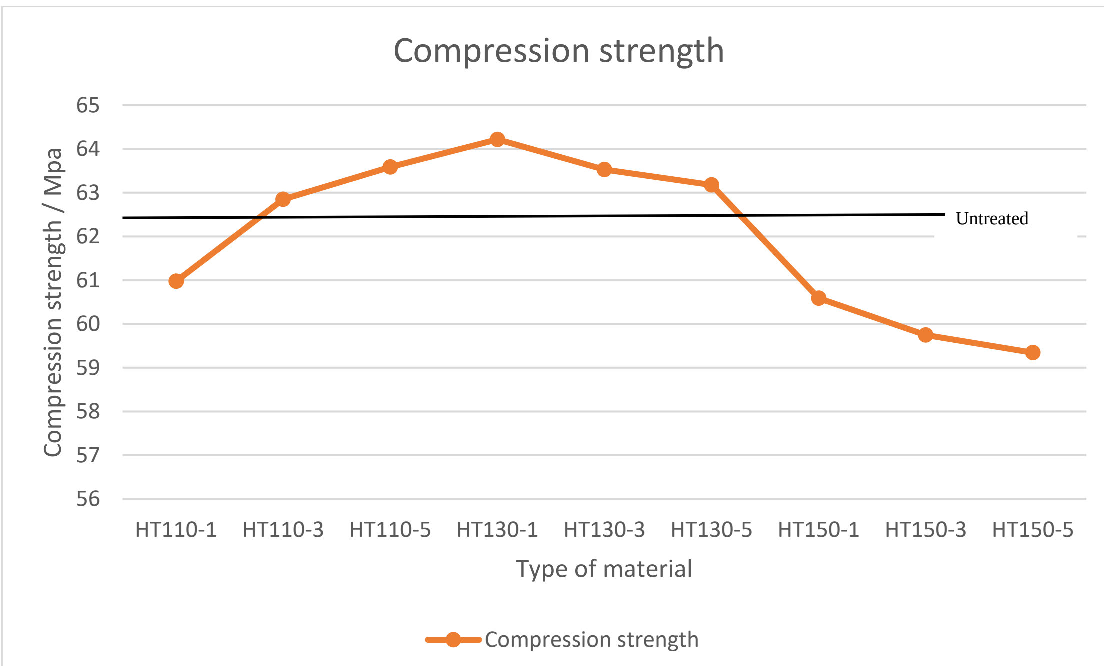

Figure 4. 9: Overall compression strength vs. Type of material

In figure 4.9, it shows the overall compression strength with the type of material respectively and this shows when compared to untreated material, HT130-1 is the best option when compared in terms of compression strength, yield strength and total energy. But we will examine under optical microscope for the first material which is HT110-1 and HT150-5 and as well HT130-1 to show the difference under microscope.

4.2 Optical Microscope

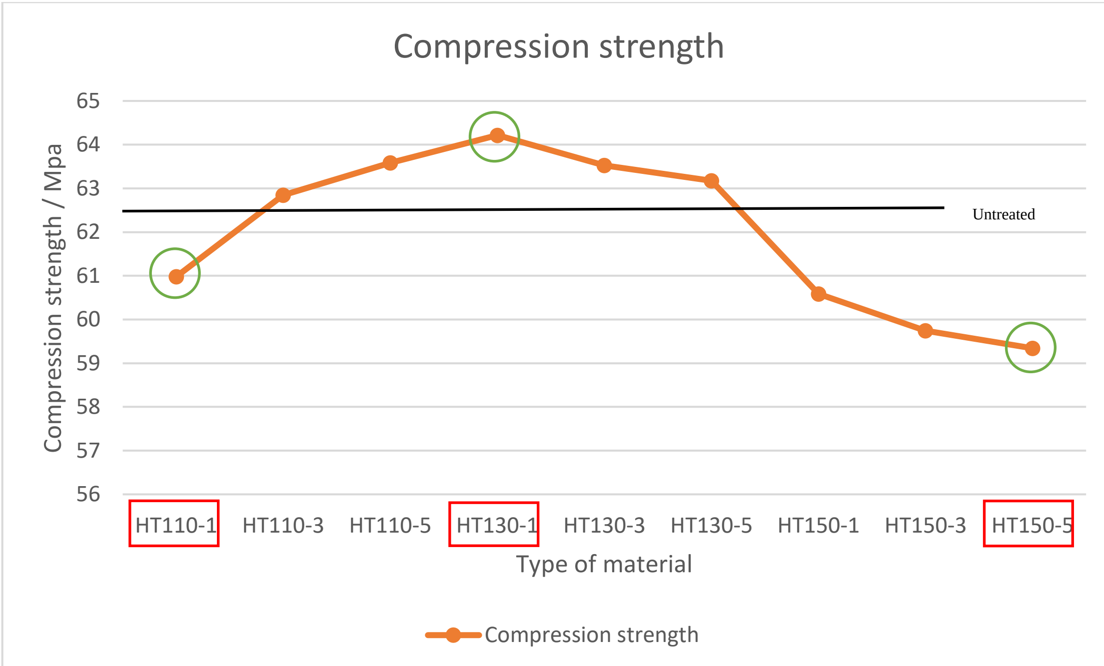

Figure 4. 10: Showing the first, highest and last overall compression strength

From Figure 4.10, it shows that the first HT110-1 has an average compression strength, where HT130-1 has the highest compression strength and HT150-5 which is the last specimen has the lowest compression strength. This specimen has all undergone heat treatment process before proceeding to experiment testing.

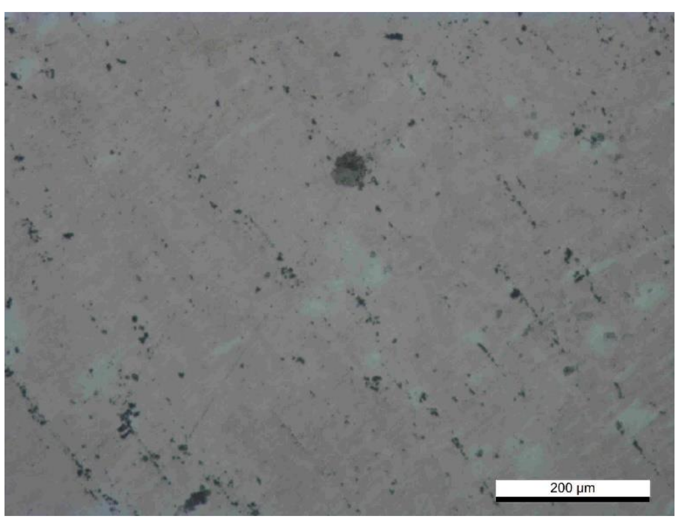

Figure 4. 11: Microstructure of Untreated Specimen

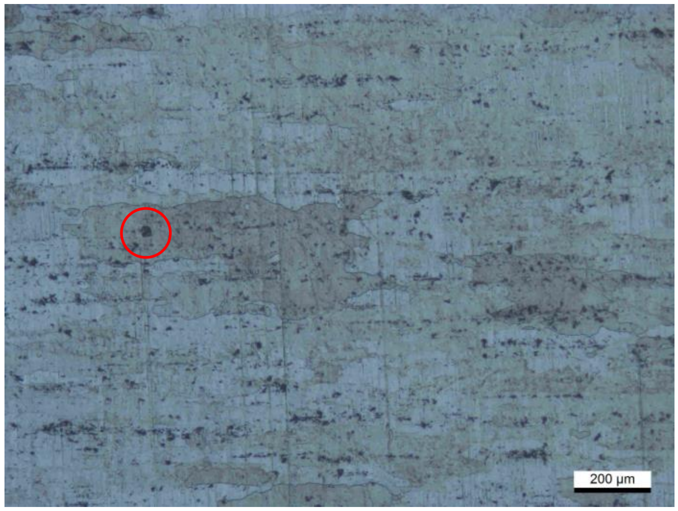

Figure 4. 12: Microstructure of HT110-1 specimen

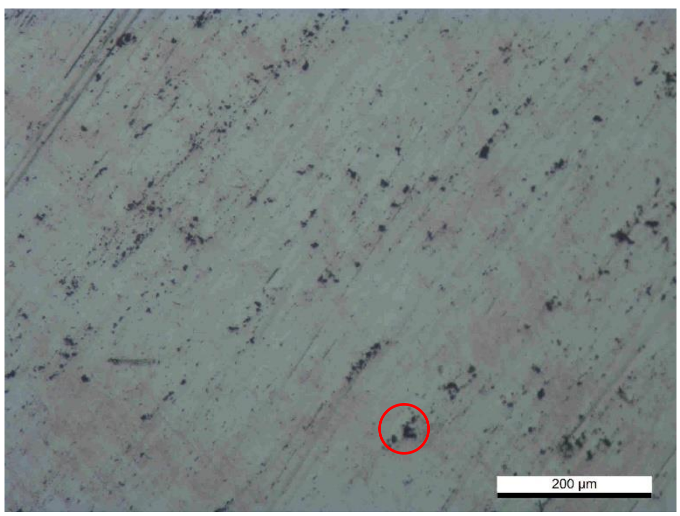

Figure 4. 13: Microstructure of HT130-1 specimen

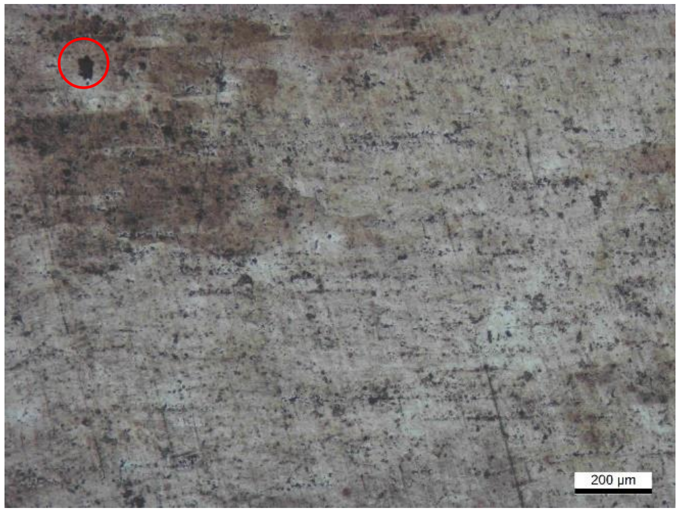

Figure 4. 14: Microstructure of HT150-5

From the microstructure present, the developments of pits and scratches in the specimen is present. This is due to over-etching at the end of the process. In figure 4.11 shows the untreated material, there are no carbon present in the specimen as it has not undergone heat treatment process. When we heat a material, carbon will be present doe to oxidization. Where in figure 4.12, carbon is present but not much in the specimen as it is heated to 110°C at 1 hour as shown in the red circle. In figure 4.13, the carbon increases as the temperature is increased to 130°C at 1 hour. As temperature increase, carbon will increase. This is proven when figure 4.14 shows the carbon presence in the material increases a lot compared to the others.

Thus, this shows that if there is less carbon or more carbon presence in the material, the compression strength will decrease where as if it is at the exact and correct amount, it will boost the compression strength to a better value which can be implemented in the medical field. Although the addition of carbon can provide greater toughness and yield strengths, carbon content of steel itself does not always equate to the alloy's strength. This shows increasing carbon content increases hardness and strength and improves hardenability but also shows that too much carbon also increases brittleness because of its tendency to form Martensite. This is proven in Figure 4.14, where the carbon content is very high which the compression strength is lower than the rest. The role of carbon as an interstitial impeding dislocation movement in the steel matrix factors into strength. Carbon steel undergoes changes in phases and crystal structure (the way the atoms stack up) with temperature

Martensite is incredibly brittle because Body Centred Tetroganol is essentially a sheared state of Body Centred Cubic, and can exhibit a lot of stress within its crystal structure. It is great at impeding slip planes or dislocations within the matrix so much so that it will catastrophically fail rather than deform before ultimate failure, much like ceramics. So, we do now want the material to form Martensite although Martensite is form at 450°C, but we are heating the final specimen (HT150-5) at 150°C at 5 hours which the tendency to form Martensite has a chance. Thus, tis shows that HT130-1 is the best solution for the use in medical field.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion and Recommendation

In conclusion, the objectives of the research have been fulfilled. The first objective was to prepare Al-7075 under different temperature and time duration. From the experiment conducted, we can see clearly the observed that all the samples were perfectly undergone heat treatment with three different temperatures which were 110°C, 130°C and 150°C along with three different time which was 1 hour, 3 hour and 5 hour. Moreover, the next objective which is to study the effect of heat treatment process towards mechanical properties of Al-7075 was also achieve as we have study the microstructure of each material with the presence of carbon when heated. We can clearly see with the right amount of carbon present, it will make the specimen stronger and can be used in the medical field. The last objective that is to compare the performance of Al-7075 in three point bending test and optical microscope test of each specimen was achieve as well based on the collection of data for the compression strength and images of microstructure. This was clearly show that after heat treatment, the compression strength, yield strength and energy taken until rupture increases when heated the specimen at a precise temperature.

Due to excellent bio – compatibility and mechanical strength of Aluminium 7075. Nine samples were heat treated and subsequently tested for three point bending test and optical microscope. Prior to heat treatment process, all the samples were cut into rectangular shape with dimension of 100mm x 6mm x 10mm. Heat treatment process were executed at various time and temperature which includes 1, 3 and 5 hours at 110°C, 130°C and 150°C. The samples were tested for their mechanical properties and then compared to as received untreated sample. Untreated sample of Aluminium

7075 did not undergo heat treatment process.

In three point bending test, the samples showed a constant trend in compression strength against different time and temperature. HT-130 shows the highest compression strength compared to others with a value of 64.217MPa. This is proven with the right amount of heat treatment process, it produces carbon which strengthened the microstructure. But with too much carbon, it will make the material more brittle which will reduce the compression strength. Without any carbon at all, it is still strong but to make it stronger, it is better to undergo 130°C at 1 hour. From the result collected throughout this experiment, it can be concluded that at the right amount of temperature and time to form carbon, the sample should function better in medical field applications compared to none, less or over heated samples as the result obtained from the sample are more comparable to the established standardized value.

Furthermore, it is recommended to undergo the heat treatment process for a less distance apart between temperature such as at 5°C interval to observe if there is a better and stronger aluminium that can be produced. Time is also needed to set at less apart distance such as 10minutes interval to study better the performance as well. With both of these, we can know if at a right better composition of carbon produced in the aluminium will produced the best performance product. Besides, we also need to study the microstructure at for all specimen so we can see clearly the carbon present or perhaps there are any defects in the product which alter the result.

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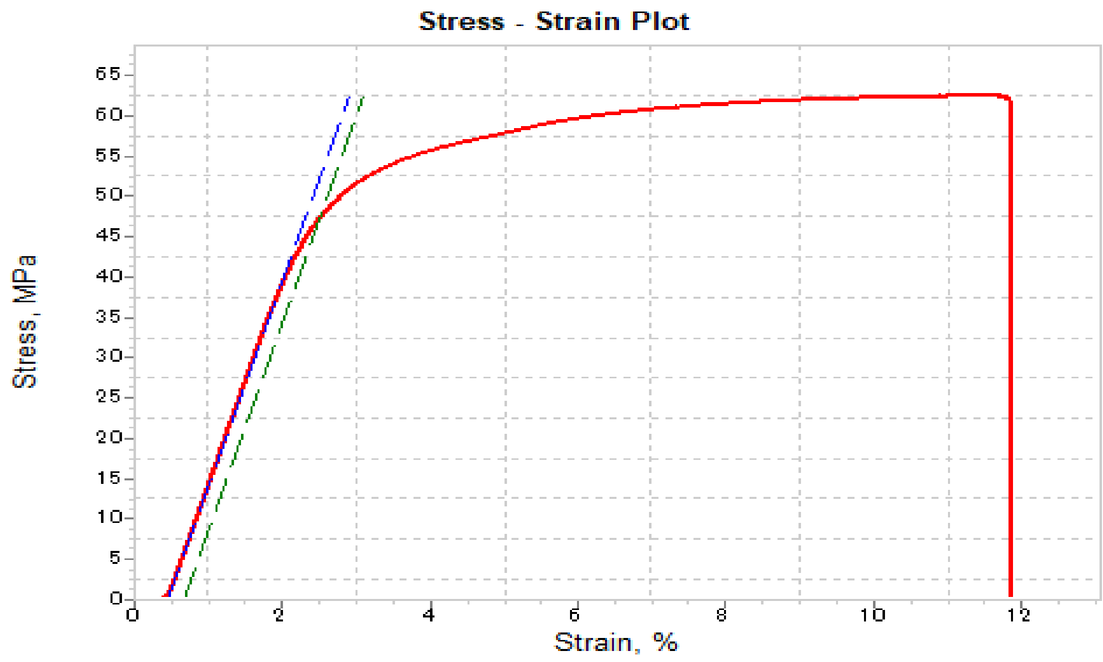
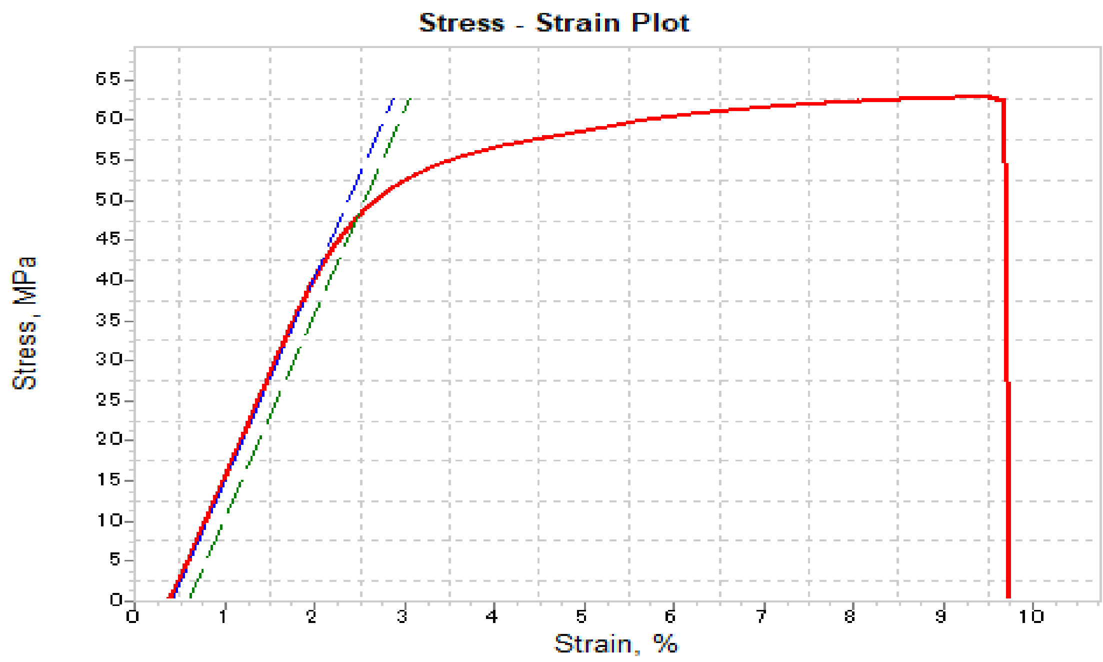
APPENDICES

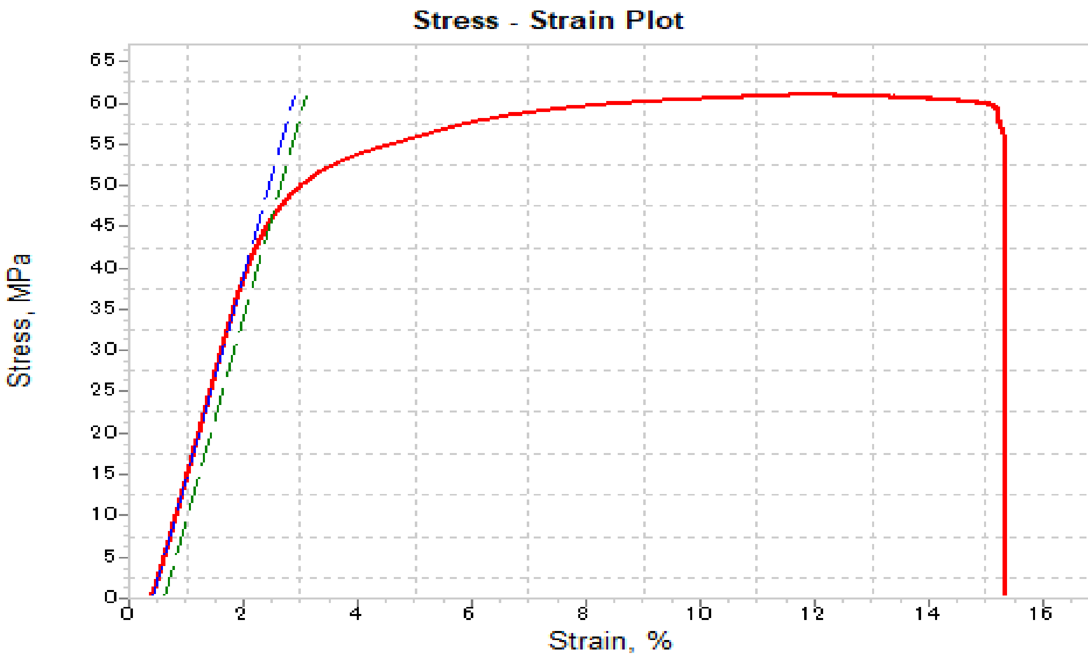
1. Stress deformation graph for untreated specimen



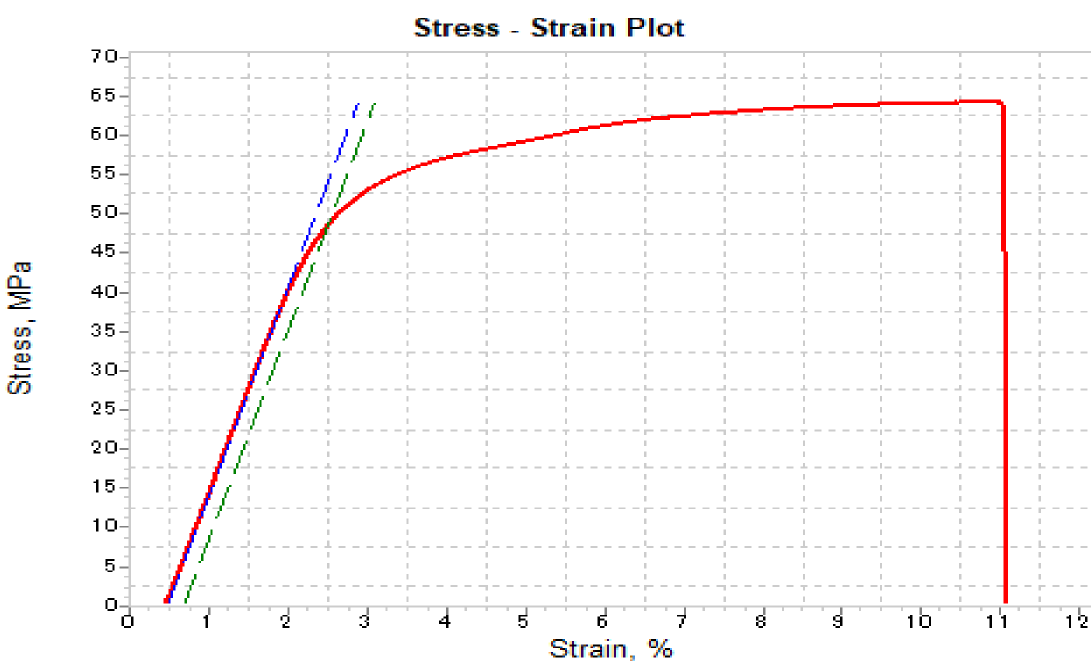
2. Stress deformation graph for specimen treated at T = 110°C for 1 hours



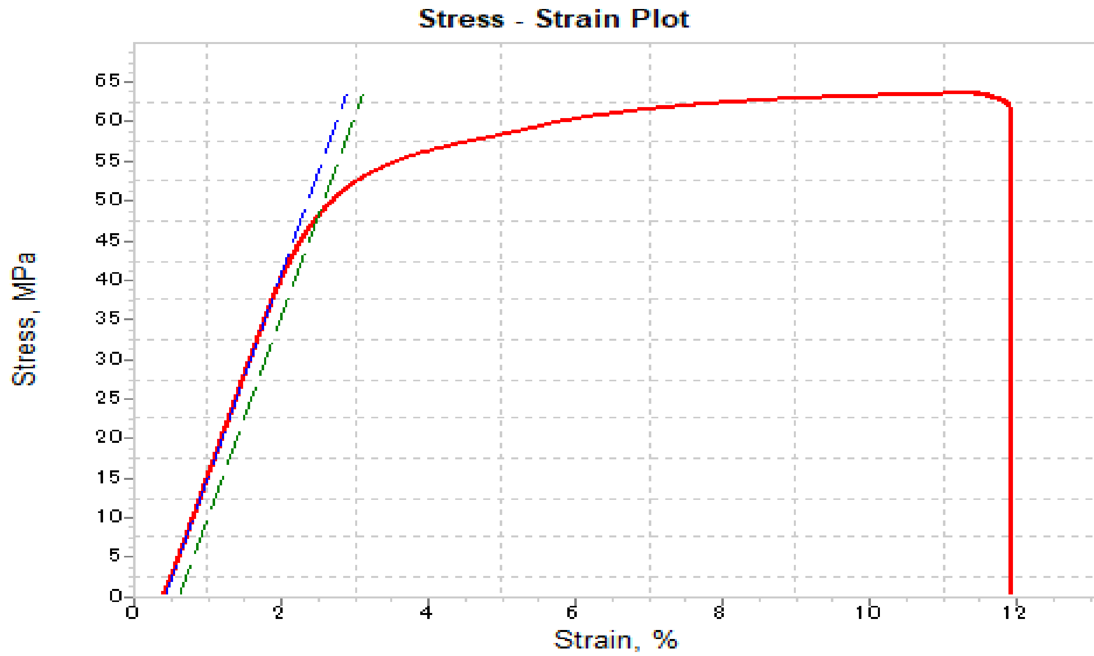
3. Stress deformation graph for specimen treated at T = 110°C for 3 hours



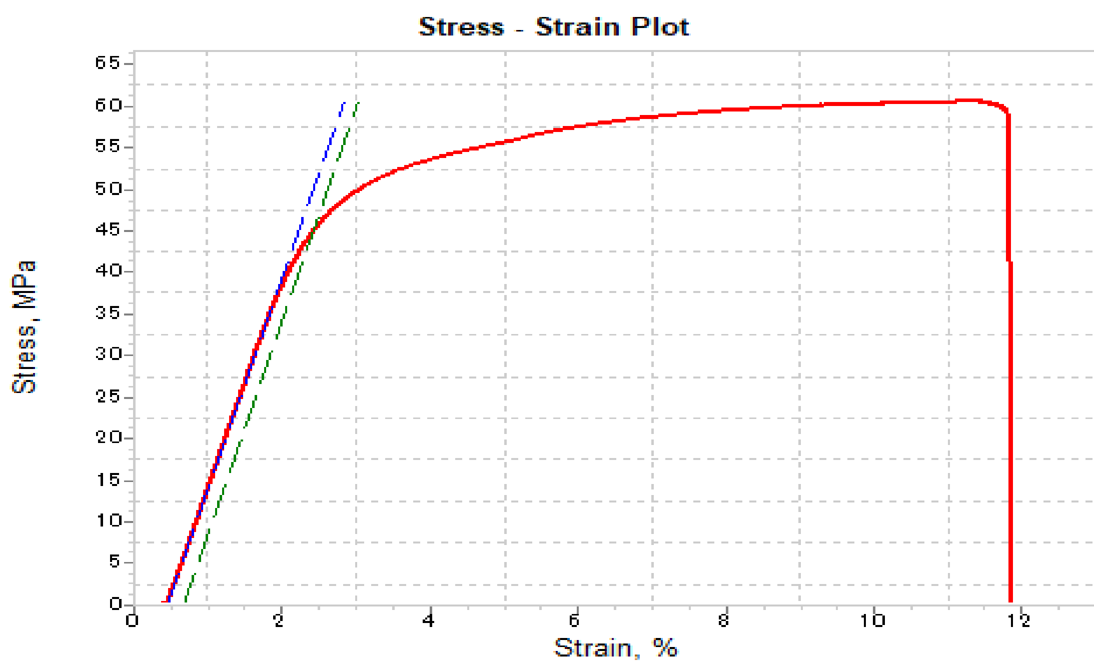
4. Stress deformation graph for specimen treated at T = 110°C for 5 hours



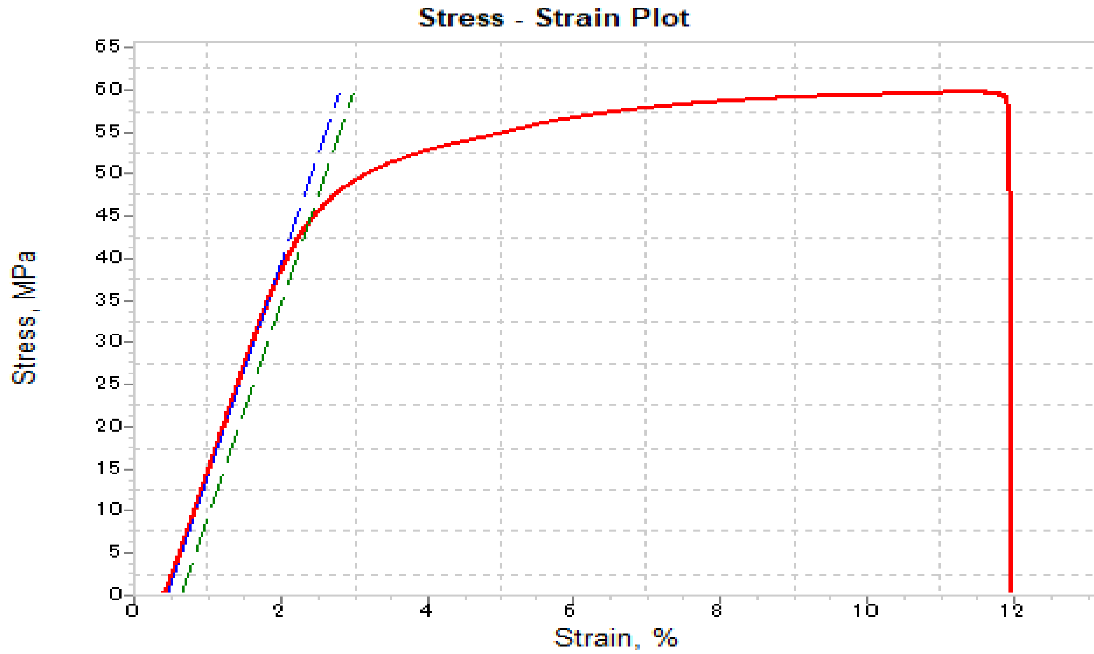
5. Stress deformation graph for specimen treated at T = 130°C for 3 hours



6. Stress deformation graph for specimen treated at T = 150°C for 1 hours



7. Stress deformation graph for specimen treated at T = 150°C for 3 hours



8. Stress deformation graph for specimen treated at T = 150°C for 5 hours