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BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **EFEECTS OF CARBURIZATION PROSESS ON THE MECHANICAL PROPERTIES OF CARBURIZED MILD STEEL**

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EFFECTS OF CARBURIZATION PROCESS ON THE MECHANICAL PROPERTIES OF CARBURIZED MILD STEEL

NORFARAHANIM BINTI MUHAMAD @ RAMLI

Report submitted fulfillment of the requirements

for the award of the degree of

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EXAMINER APPROVAL DOCUMENT

We certify that the thesis entitled “Effects Of Carburization Process On The Mechanical Properties Of Carburized Mild Steel” is written by Norfarahanim Binti Muhamad @ Ramli. We have examined the final copy of this thesis and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Engineering in Manufacturing. We here with recommend that it be accepted in fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering.

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Special thanks to my parents on their support and cares,

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On her guiding towards my project

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ABSTRACT

Due to the complexity of parameters in carburizing, there has been relatively little work on process variables during the surface hardening process. This work focuses on the effects of carburization process on the mechanical properties of carburized mild steel, at constant temperature, 850°C with different time, 2 hours, 4 hours and 6 hours and quenched in oil. The objectives of this project are to study the influence of carburization process for mild steel and to study the material performance after carburization process. After carburization process, the test samples were subjected to standard test and form the data obtained, ultimate tensile strength and Young's modulus were calculated. The case hardness of the carburized samples were measure. It was observed that the mechanical properties of mild steels were found to be strongly influenced by the process of carburization. It was conclude that the sample carburized at 850°C soaked for four hours followed by oil quenching were better because they showed the higher ultimate tensile strength at 541.41096 MPa.

ABSTRAK

Disebabkan kerumitan parameter dalam pengkarbonan, terdapat sedikit perubahan terhadap pembolehubah proses semasa proses pengerasan permukaan. Kerja ini memberi tumpuan kepada kesan proses pengkarbonan pada sifat-sifat mekanikal keluli lembut, pada suhu malar, 850°C dengan masa yang berbeza, dua jam, empat jam dan enam jam dan direndamkan dalam minyak. Objektif projek ini adalah untuk mengkaji pengaruh proses pengkarbonan terhadap keluli lembut dan mengkaji prestasi bahan selepas proses pengkarbonan. Selepas proses pengkarbonan, sampel ujian telah dikenakan ujian standard dan data diperolehi seperti kekuatan tegangan muktamad dan modulus Young. Kekerasan kes sampel pengkarbonan telah dikira. Ia menunjukkan bahawa sifat-sifat mekanikal keluli lembut telah dipengaruhi oleh proses pengkarbonan. Kesimpulan yang boleh dibuat adalah sampel pengkarbonan pada suhu 850°C dan direndam selama empat jam diikuti oleh pelindapkejutan minyak adalah lebih baik kerana ia menunjukkan kekuatan tegangan muktamad yang lebih tinggi iaitu 541,41096 MPa.

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UTS	Ultimate tensile strength
s	second
˚C	degree Celsius
VH	Vickers Hardness

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

This project is to study the effects of carburization time and temperature on the mechanical properties of carburized mild steel, using activated carbon as carburizer. Carburizing is a process where the steel is heated in a furnace. By means of a carbonaceous medium (gas or salts) the outside layer of a carbon poor component is enriched with carbon by means of carbon diffusion. The increase of carbon content causes the material to harden. The result is a hard and wear resistant surface with a tough core. The carburizing process does not harden the steel it only increases the carbon content to some pre determined depth below the surface to a sufficient level to allow subsequent quench hardening.

As we know there is a little bit of steel in everybody life. Steel has many practical applications in every aspects of life. Steel with favorable properties are the best among the goods. The steel is being divided as low carbon steel, high carbon steel, medium carbon steel, high carbon steel on the basis of carbon content.

Low carbon steel has carbon content of 0.15% to 0.45%. Low carbon steel is the most common form of steel as it’s provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its lower carbon content. It has lower tensile strength and malleable. Steel with low carbon steel has properties similar to iron. As the carbon content increases, the metal becomes harder and stronger but less ductile and more difficult to weld.

Carburizing as a diffusion controlled process, so the longer the steel is held in the carbon-rich environment, the greater the carbon penetration will be and the higher the carbon content. The carburized section will have carbon content high enough so that it can be hardened again through flame or induction hardening. Surface hardening processes are influenced by heat treatment temperature, rate of heating and cooling, heat treatment period, quenching media and temperature as investigated by Schimizu and Tamura [6]. Post heat treatment and pre-heat treatment processes are the major influential parameters, which affect the quality of the part surface hardened. Hardenability is essentially the ease of forming martensite and reflects the ability of a steel to be hardened to a specified depth.

The carburizing furnaces are either gas fired or electrically heated. The carburizing temperature varies from 870 to 940 °C the gas atmosphere for carburizing is produced from liquid or gaseous hydrocarbons such as propane, butane or methane. The study of process parameters in metals during heat treatment has been of considerable interest for some years4,5,6,7 but there has been relatively little work on process variables during the surface hardening process8 since controlling parameters in carburization is a complex problem. The major influencing parameters in carburization are the holding time, carburizing temperature, carbon potential and the quench time in oil. The present work is focused on the effects of carburizing temperature and holding time on the mechanical properties of carburized mild steel.

1.2 PROBLEM STATEMENT

Now days, we can see the demand on making a suitable metal for some condition. For example they will be used in automotive or construction where they required a metal that can stand with certain condition at the low cost of manufacturing process. In order to meet such condition satisfactorily, a material of a soft and tough nature should be employed - something that possesses strength and resistance to wear, and still conforms to standard practice of design regarding the proportions of parts. Such problems have come and have to be met by the manufacturer; they constitute the problem of casehardening. It is not a new subject it is not well understood and not always easy to control.

In this project, we can simulate the suitable casehardening process by control only the time of carbonizing process itself. As we know too much steel absorbs carbon at certain rates depending on the temperature and time will affect the carbon penetration. If an excess of carbon is liberated, the surface of the steel becomes supersaturated with carbon, the result being a brittle structure.

The result that we get from this experiment will be compare to get the optimum time with the greater hardness can achieve without changing the specimen to brittle material. These will help manufacture to estimate the optimum time for carbonizing process can be done in order to get high quality material at the minimum/optimum cost.

1.3 OBJECTIVES

The objectives of the project are:

- To study the influence of carburization process for mild steel.
- To study the material performance after carburization process.

1.4 PROJECT SCOPE

The scopes of this project are:

- Carburization process has been carried out with constant temperature, 850°C with different time, two hours, four hours and six hours.
- Material performance measuring using Optical Microscope, Vickers Hardness Test and Tensile equipment testing.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A review of the literature review was performed to identify studies relevant to the carburizing process, mild steel, and mechanical properties of carburized mild steel. A review of others relevant research also provided in this chapter. The review is detailed so that the information and older research can be used to improve this topic.

2.2 CARBURIZING PROCESS

Carburizing is a case-hardening process in which carbon is dissolved in the surface layers of a low-carbon steel part at a temperature sufficient to render the steel austenitic, followed by quenching and tempering to form a martensitic microstructure. The resulting gradient in carbon content below the surface of the part causes a gradient in hardness, producing a strong, wear-resistant surface layer on a material, usually low-carbon steel, which is readily fabricated into parts. (J.R Davis, 1998)

In gas carburizing, commercially the most important variant of carburizing, the source of carbon is a carbon-rich furnace atmosphere produced either from gaseous hydrocarbons, for example, methane (CH_4), propane (C_3H_3), and butane (C_4H_{10}), or from vaporized hydrocarbon liquids. (J.R Davis, 1998)

Low-carbon steel parts exposed to carbon-rich atmospheres derived from a wide variety of sources will carburize at temperatures of 850°C (1560°F) and above. In the most primitive form of this process, the carbon source is so rich that the solubility limit of carbon in austenite is reached at the surface of the steel and some carbides may form at the surface. Such atmospheres will also deposit soot on surfaces within the furnace, including the parts. While this mode of carburizing is still practiced in parts of the world in which resources are limited, the goal of current practice in modern manufacturing plants is to control the carbon content of furnace atmospheres so that:

- The final carbon concentration at the surface of the parts is below the solubility limit in austenite.
- Sooting of the furnace atmosphere is minimized.

Endothermic gas (Endogas) is a blend of carbon monoxide, hydrogen, and nitrogen (with smaller amounts of carbon dioxide water vapor, and methane) produced by reacting a hydrocarbon gas such as natural, gas (primarily methane), propane or butane with air. For endogas produced from pure methane, the air-to-methane ratio is about 2.5; for endogas produced from pure propane, the air-to-propane ratio is about 7.5. These ratios will change depending on the composition of the hydrocarbon feed gases and the water vapor content of the ambient air. (J. R Devis, 2002)

A carrier gas similar in composition to endogas produced from methane can be formed from a nitrogen-methanol blend. The proportions of nitrogen and methanol (CH_3OH) are usually chosen to give the same nitrogen-to-oxygen ratio as that of air, that is, about 1.9 volumes of nitrogen for each volume of gaseous methanol.

The successful operation of the gas carburizing process depends on the control of three principal variables:

- Temperature
- Time
- Atmosphere composition.

Other variables that affect the amount of carbon transferred to parts include the degree of atmosphere circulation and the alloy content of the parts.

The maximum rate at which carbon can be added to steel is limited by the rate of diffusion of carbon in austenite. This diffusion rate increases greatly with increasing temperature; the rate of carbon addition at 925°C (1700°F) is about 40% greater than at 870°C (1600°F). (J. R Devis, 2002)

The temperature most commonly used for carburizing is 925°C (1700°F). This temperature permits a reasonably rapid carburizing rate without excessively rapid deterioration of furnace equipment, particularly the alloy trays and fixtures. The carburizing temperature is sometimes raised to 955°C (1750°F) or 980°C (1800°F) to shorten the time of carburizing for parts requiring deep cases. Conversely, shallow case carburizing is frequently done at lower temperatures because case depth can be controlled more accurately with the slower rate of carburizing obtained at lower temperatures. (J. R Devis, 2002)

Therefore, for best results, the workload should be heated to the carburizing temperature in a near-neutral furnace atmosphere. In batch furnaces, parts can be heated in Endogas until they reach the furnace temperature; then carburizing can commence with the addition of the enriching gas. Many new continuous furnaces are being built with separate preheat chambers to ensure that the load is at a uniform temperature before entering the carburizing zone. In continuous furnaces that lack positive separation between heating and carburizing stages, the best that can be done is to:

- Add only Endogas to the front of the furnace.
- Establish a front-to-back internal flow of atmosphere gases by adjusting flow rates and orifice size in the effluent lines at either end of the furnace.

The effect of time and temperature on total case depth shows that the carburizing time decreases with increasing carburizing temperature. In addition to the time at the carburizing temperature, several hours may be required to bring large work pieces or heavy loads of smaller parts to operating temperature. For a work piece quenched directly from the carburizing furnace, the cycle may be lengthened further by allowing time for the work piece to cool from the carburizing temperature to about 843°C prior to quenching. Similarly, additional diffusion and interchange of carbon with the atmosphere will occur during cooling prior to quenching. More complex mathematical models that allow for variations in temperature and atmosphere carbon potential with time can be constructed to allow a better prediction of case depth. (J. R Devis, 2002)

The carbon potential a furnace atmosphere at a specified temperature is defined as the carbon content pure iron that is in thermodynamic equilibrium with the atmosphere. The carbon potential of the furnace atmosphere must greater than the carbon potential of the surface of the work pieces in order for carburizing to occur. It is the difference in carbon potential that provides the driving force for carbon transfer to the parts.

The combined effects of time, temperature, and carbon concentration on the diffusion of carbon in austenite can be expressed by Fick's laws of diffusion.

Fick's first law states that the flux of the diffusing substance perpendicular to plane of unit cross-sectional area is proportional to the local carbon gradient perpendicular to the plane. The constant of proportionality is the diffusion coefficient D, which has the units $(\text{distance})^2/\text{time}$. Fick's second law is a material balance within elemental volume of the system; the flux carbon into an elemental volume of iron minus the flux of carbon out of the elemental volume equals the rate of accumulation of carbon within the volume. Combining the two laws leads to a partial differential equation that describes the diffusion process. (J. R Devis, 2002)

2.3 MILD STEEL

Mild steel is a type of steel that contains only a small amount of carbon and other elements. It is softer and can be shaped more easily than higher carbon steels. It also bends a long way instead of breaking because it is ductile. It is used in nails and some types of wire, it can be used to make bottle openers, chairs, staplers, staples, railings and most common metal products. Its name comes from the fact it only has less carbon than steel.

Mild steel, also called plain-carbon steel, is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications, more so than iron. Low carbon steel contains approximately 0.05–0.3% carbon and mild steel contains 0.3–0.6% carbon; making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. (http://en.wikipedia.org/wiki/Carbon)

It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) and the Young's modulus is 210 GPa (30,000,000 psi).

Low carbon steels suffer from *yield-point runout* where the material has two yield points. The first yield point (or upper yield point) is higher than the second and the yield drops dramatically after the upper yield point. If a low carbon steel is only stressed to some point between the upper and lower yield point then the surface may develop Lüder bands. Low carbon steels contain less carbon than other steels and are easier to cold-form, making them easier to handle. (http://en.wikipedia.org/wiki/Carbon_steel)

2.4 QUENCHING

In materials science, quenching is the rapid cooling of a workpiece to obtain certain material properties. It prevents low-temperature processes, such as phase transformations, from occurring by only providing a narrow window of time in which the reaction is both thermodynamically favorable and kinetically accessible. For instance, it can reduce crystallinity and thereby increase toughness of both alloys and plastics (producedthrough polymerization).
(http://www.astarmathsandphysics.com/a_level_physics_notes/materials/a_level_physics_notes_quenching.html)

In metallurgy, it is most commonly used to harden steel by introducing martensite, in which case the steel must be rapidly cooled through its eutectoid point, the temperature at which austenite becomes unstable. In steel alloyed with metals such as nickel and manganese, the eutectoid temperature becomes much lower, but the kinetic barriers to phase transformation remain the same. This allows quenching to start at a lower temperature, making the process much easier. High speed steel also has added tungsten, which serves to raise kinetic barriers and give the illusion that the material has been cooled more rapidly than it really has. Even cooling such alloys slowly in air has most of the desired effects of quenching.

Extremely rapid cooling can prevent the formation of all crystal structure, resulting in amorphous metal or "metallic glass". (http://en.wikipedia.org/wiki/Quenching)

When quenching, there are numerous types of media. Some of the more common include: air, nitrogen, argon, helium, brine (salt water), oil and water. These media are used to increase the severity of the quench. (Todd, Robert H., Dell K. Allen, and Leo Alting, 2009)

2.5 TENSION

The tension test is the most common test for determining such mechanical properties of materials as strength, ductility, toughness, elastic modulus and strain hardening capability. The test first requires the preparation of a test specimen, typically shown in Figure 2.1. In the United State, the specimen is prepared according to ASTM specifications. Otherwise, it is prepared to the specifications of the appropriate corresponding organization in other countries. Although most tension-test specimens are solid and round, they also can be flat or tubular. (S. Kalpakjian and S. R. Schmid, 2006)

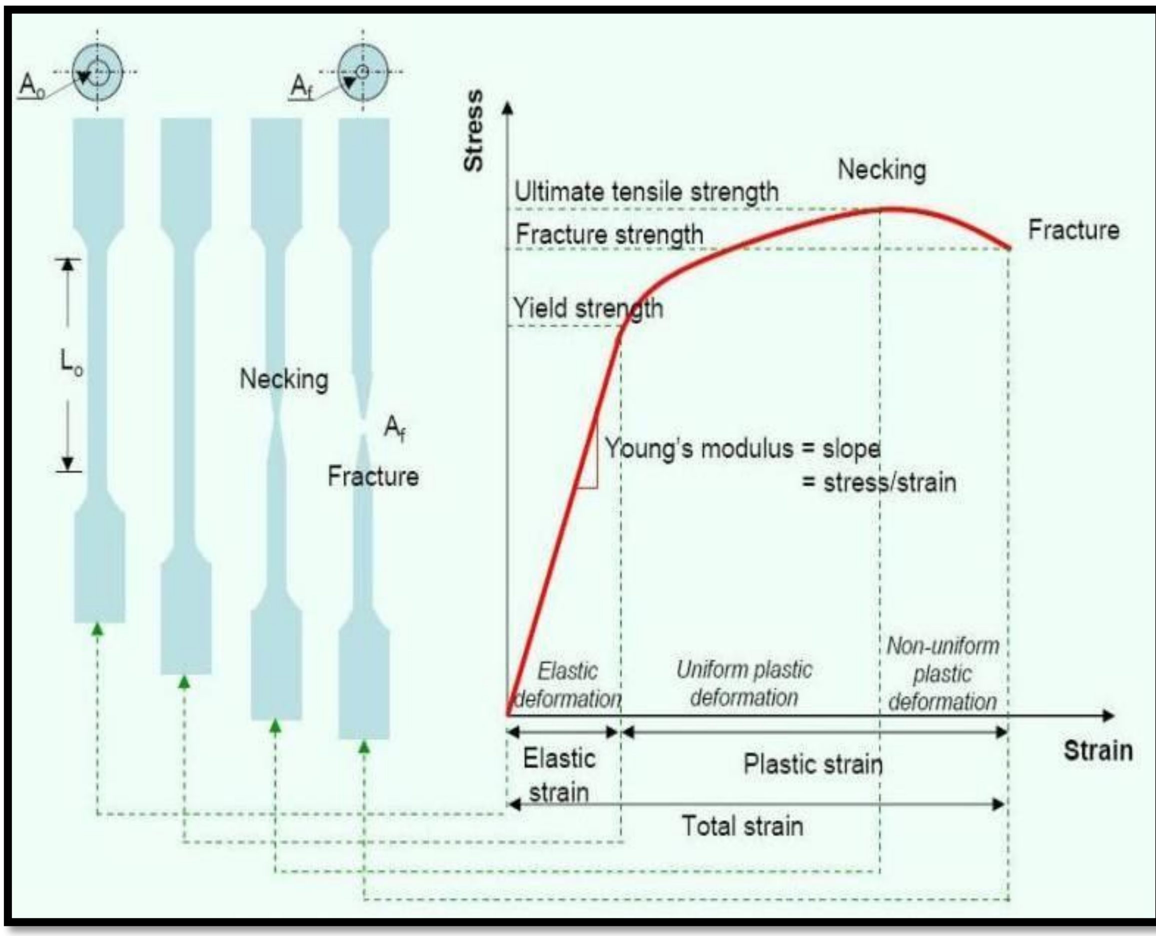

Figure 2.1: Shape of ductile specimen at various stages of testing

2.5.1 Tensile Specimen

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.

The shoulders of the test specimen can be manufactured in various ways to mate to various grips in the testing machine. Each system has advantages and disadvantages; for example, shoulders designed for serrated grips are easy and cheap to manufacture, but the alignment of the specimen is dependent on the skill of the technician. On the other hand, a pinned grip assures good alignment. Threaded shoulders and grips also assure good alignment, but the technician must know to thread each shoulder into the grip at least one diameter's length, otherwise the threads can strip before the specimen fractures. (http://en.wikipedia.org/wiki/Tensile_testing)

In large castings and forgings it is common to add extra material, which is designed to be removed from the casting so that test specimens can be made from it. These specimens may not be exact representation of the whole workpiece because the grain structure may be different throughout. In smaller workpieces or when critical parts of the casting must be tested, a workpiece may be sacrificed to make the test specimens. For workpieces that are machined from bar stock, the test specimen can be made from the same piece as the bar stock. (http://en.wikipedia.org/wiki/Tensile_testing)

2.6 VICKERS HARDNESS TEST

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation. (http://www.indentec.com/downloads/info_vickers_test.pdf)

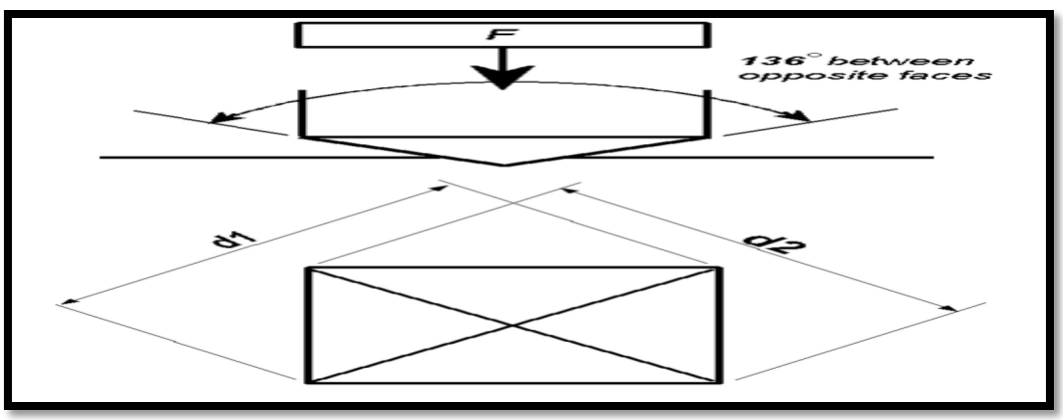

Figure 2.2: Vickers indentation and measurement of impression diagonals

Source: http://www.indentec.com/downloads/info_vickers_test.pdf

F= Load in kgf

d = Arithmetic mean of the two diagonals, d1 and d2 in mm

Table 2.1: Standard Vickers scale

Micro-hardness scales	**Test force F (N)**	**Low-force - hardness scales**	**Test force F (N)**	**Macro-hardness scales**	**Test force F (N)**
HV 0.01	0.09807	HV 0.2	1.961	HV 5	49.03
HV 0.015	0.1471	HV 0.3	2.942	HV 10	98.07
HV 0.02	0.1961	HV 0.5	4.903	HV 20	196.1
HV 0.025	0.2452	HV 1	9.807	HV 30	294.2
HV 0.05	0.4903	HV 2	19.61	HV 50	490.3
HV 0.1	0.9807	HV 3	29.42	HV 100	980.7

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the methodology of this study was carefully discussed in details. The specimen type for this study is Mild Steel. Methodology included in this study is dividing into several steps which are sample preparation, carburizing process, mechanical properties test and analysis on carburized specimens by using Optical Microscope, Vickers Hardness test and tensile testing equipment.

3.2 METHODOLOGY FLOW CHART

Methodology flow chart is use as guidelines and the sequences to make this project go with a smooth. As illustrated in Figure 3.1, firstly literature review was been study with the field that regards to this project. Then, the process begins with preparing the sample of specimens, Mild Steel. In this experiment, the constant temperature, 850°C with different time will be used in carburizing process.

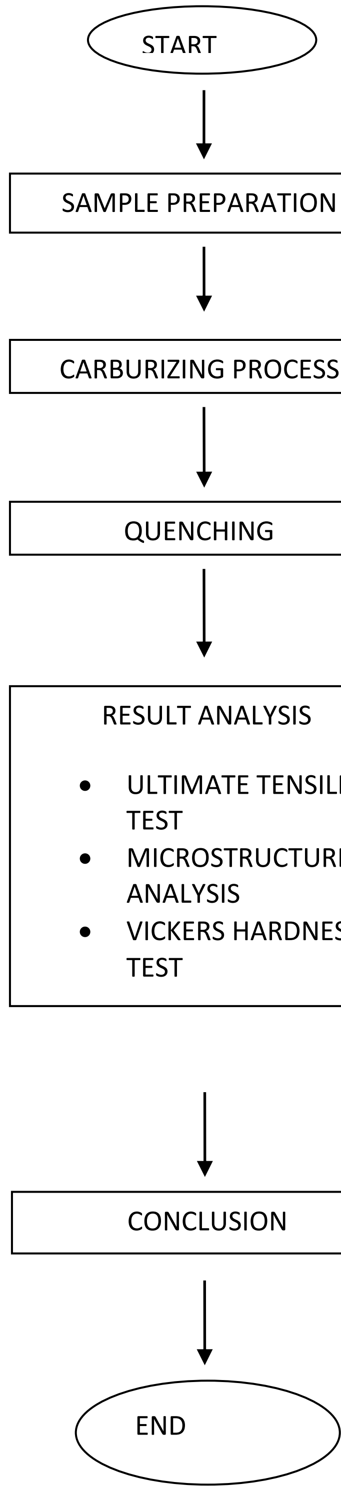

Figure 3.1: Flow chart of project

3.3 SAMPLE PREPARATION

The material used in this project is Mild Steel. The material has been cut into nine specimens with a dimension 20mm width x 2mm height x 100mm length. The material was supplied as an extruded bar. Figure 3.2 shows the band saw machine that is used for cut the raw material of mild steel into small pieces before the specimens had been cut by using sectional cut off machine based on the dimension (Figure 3.3)

Figure 3.2: Band Saw Machine

Figure 3.3: Sectional Cut Off Machine

3.4 CARBURIZING OF MILD STEEL

Carburizing is a heat treatment process in which increasing carbon on the surface of iron or steel followed by heat treatment and hence absorbing carbon liberated when the metal is heated in the presence of a carbon. Depending on the amount of time and temperature, the affected area can vary in carbon content. Longer carburizing times and higher temperatures lead to greater carbon diffusion into the part as well as increased depth of carbon diffusion. When the iron or steel is cooled rapidly by quenching, the higher carbon content on the outer surface becomes hard via the transformation from austenite to martensite.

3.4.1 Carburizing Process

In this process the mild steel samples were placed on the thick bed of carburized kept in stainless steel container and fully covered from all side. The specimens were placed above the compound in the middle and the rest of container was placed with carburizing compound.

The container was closed with the steel cover. The electric furnaces are heated up to 850ºC (1562ºF). The container was then introduced into the muffle furnace and then maintained at constant carburization temperature of 850ºC hours and heated with different time which are two hours, four hours and six hours.

Table 3.1: Carburizing process

EXPERIMENT	**NUMBER OF SPECIMEN**	**CONDITION**
Experiment 1	Specimen 1 Specimen 2 Specimen 3	850ºC, two hours
Experiment 2	Specimen 1 Specimen 2 Specimen 3	850ºC, four hours
Experiment 3	Specimen 1 Specimen 2 Specimen 3	850ºC, six hours

3.5 QUENCHING PROCESS

After carburization process, the specimen had been quenched in industrial engine oil for 10 seconds. Quenching is the rapid cooling of a workpiece to obtain certain material properties.

3.6 TENSILE TEST

The following procedure was adopted in ensuring that the data recorded from tensile test specimens was taken in an organised and consistent manner:

1. Three specimens were chosen. Care is to be taken to ensure that the specimens did not have any notching or cracks from manufacturing or any surface defects that would adversely affect the tensile tests.

2. Before loading the specimens in the Instron machine, the computer system connected to the machine was set up by inputting the necessary information of gauge length and width of the specimen. The computer system was then prepared to record data and output necessary load-deflection graphs.

3. The specimens were loaded into the Instron machine, and a tensile test was performed. The data was recorded electronically in text files and the load-deflection curve was shown on the computer screen as a visual representation.

Figure 3.4: Tensile test machine

3.7 IMAGE ANALYSIS

Surface analysis had been carried out after tensile test. The microstructure of the specimen had been observed by using Optical Microscope. Before the surface analysis process, the specimen underwent cold mounted, grinded with three different grids of sand paper, and polished.

The first step is a holder was clamped to the specimen to make the specimen can stand properly. The ratio composition of acrylic resin powder and acrylic hardener clear liquid is 2:1. The component is mixed and poured into the cup. Then the cup was places in room temperature for a while or until the acrylic been harden.

After finish mounting, the specimens have been grinded using 180, 320 and 600 SiC paper and water as lubrication. This process is to remove the burr at the surface specimen. The next step is specimens had been polished. Finally the specimens had been etched by using 2% of Nital for carbon steel material.

Figure 3.5: Mounting specimen

3.8 VICKERS HARDNESS TEST

Vickers hardness test uses a square-base diamond pyramid as the indenter with the included angle between opposite faces of the pyramid of 136°. The indenter is pressed into the sample by an accurately controlled test force. The force is maintained for a specific dwell time, normally 10 – 15 seconds. After the dwell time is complete, the indenter is removed leaving an indent in the sample that appears square shaped on the surface. The size of the indent is determined optically by measuring the two diagonals of the square indent. The Vickers hardness number is a function of the test force divided by the surface area of the indent. The average of the two diagonals is used in the following formula to calculate the Vickers hardness.

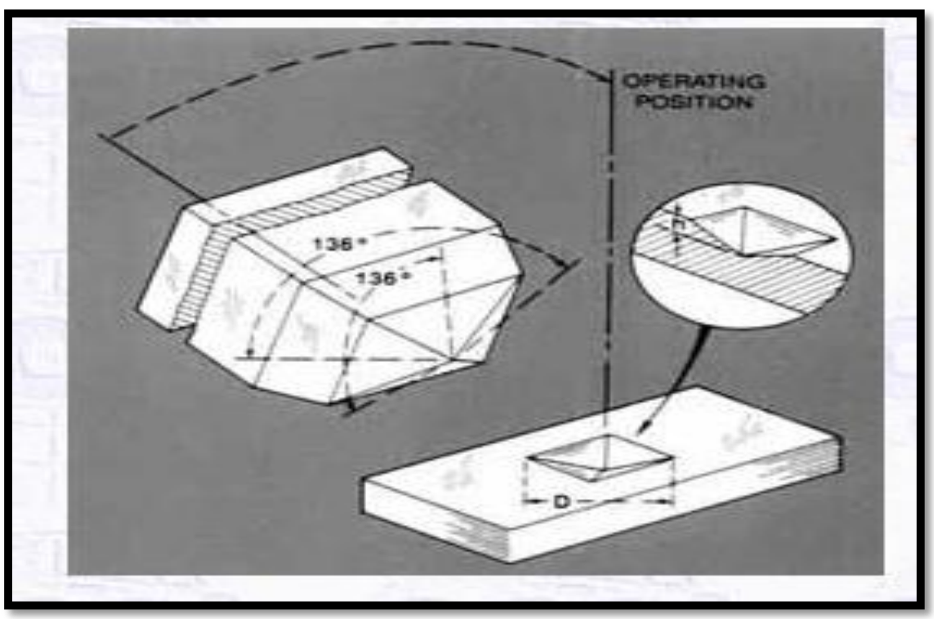

Figure 3.6: Vickers indentation

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this study, the tensile strength, the hardness test and microstructure analysis of the testing part were be analyzed and the result of the testing were reported. The measurement is conducted more than once because to ensure the precision and accuracy. The result from each sample were be averaged to get the actual result.

4.2 TENSILE STRENGTH

Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contact. Tensile strength is the opposite of compressive strength and the values can be quite different.

4.3 TENSILE TEST RESULT

4.3.1 Experiment Without Carburization Process

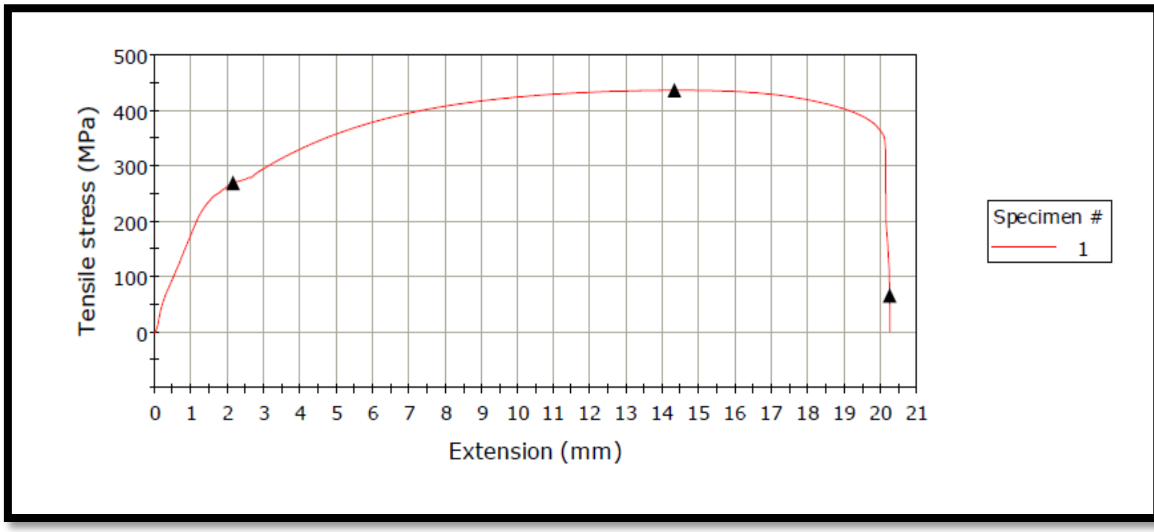

Figure 4.1: Tensile result for mild steel without carburization

4.3.2 Experiment 1 (850°C, Two Hours)

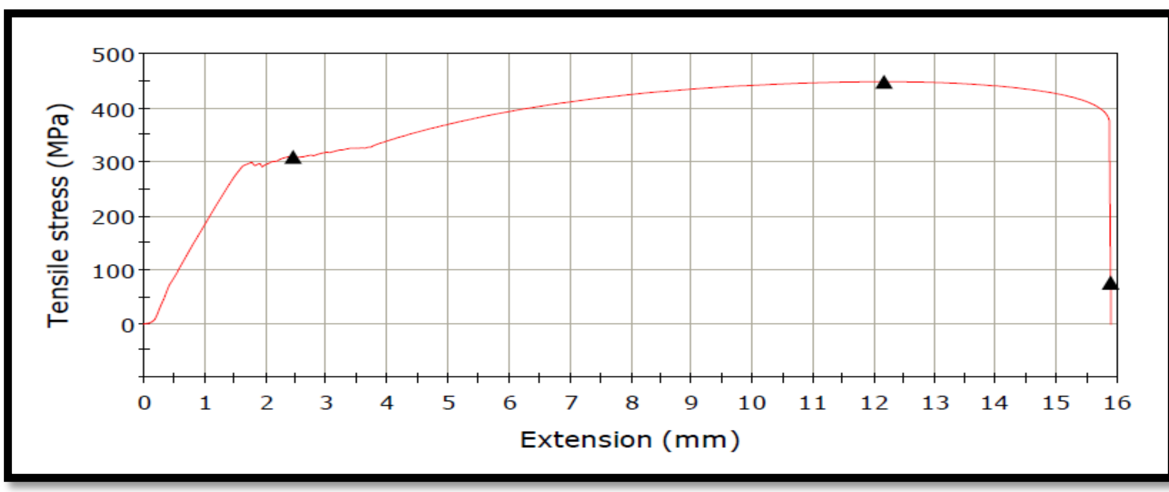

Figure 4.2(a): Specimen 1

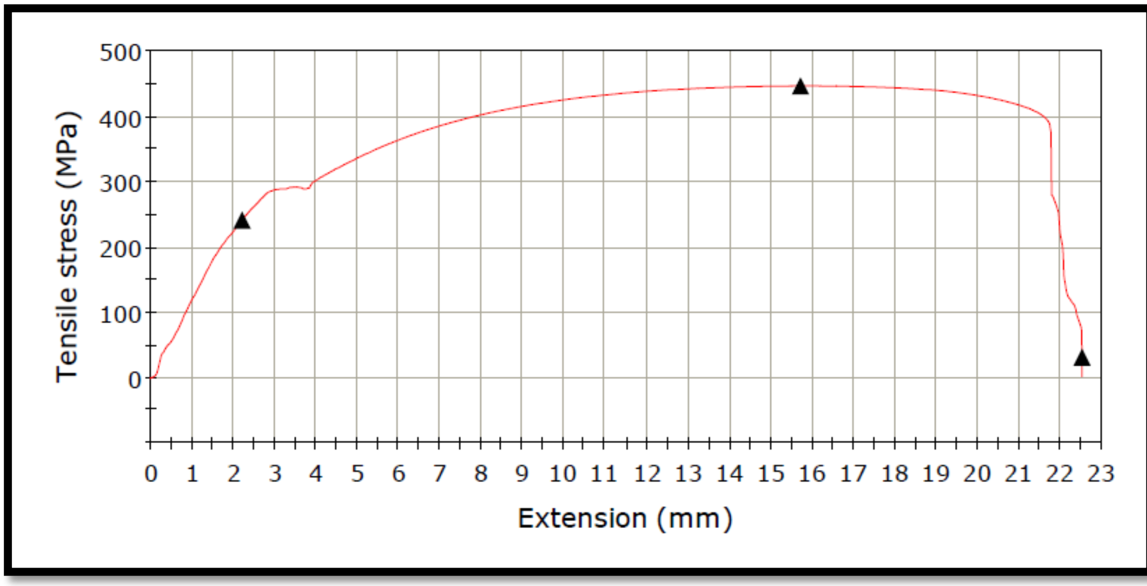

Figure 4.2(b): Specimen 2

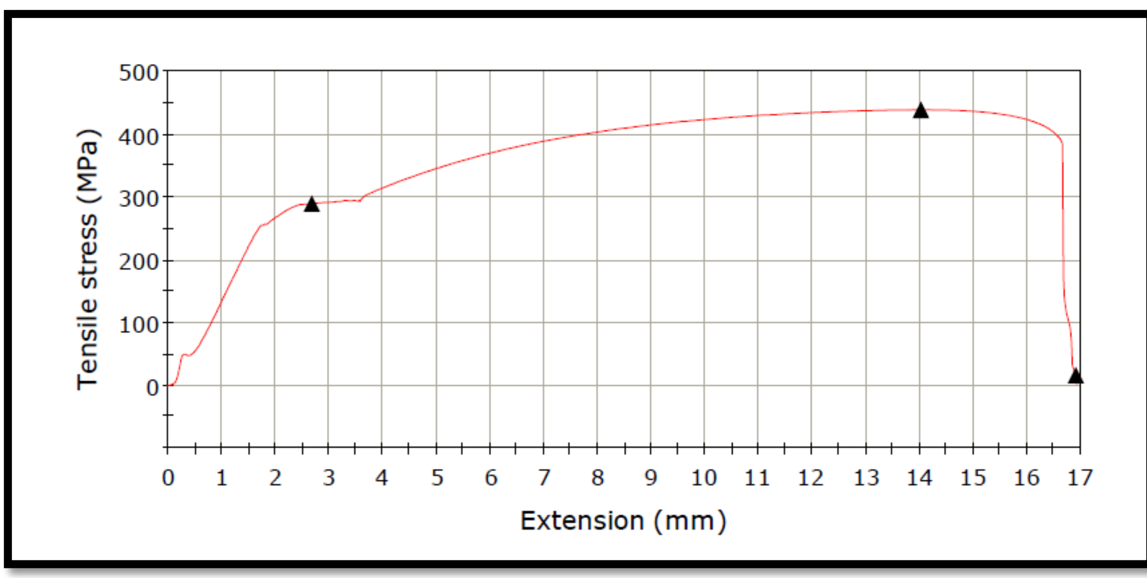

Figure 4.2(c): Specimen 3

Figure 4.2 (a), (b) and (c): Tensile result for 850ºC and two hours carburization

4.3.3 Experiment 2 (850°C, Four Hours)

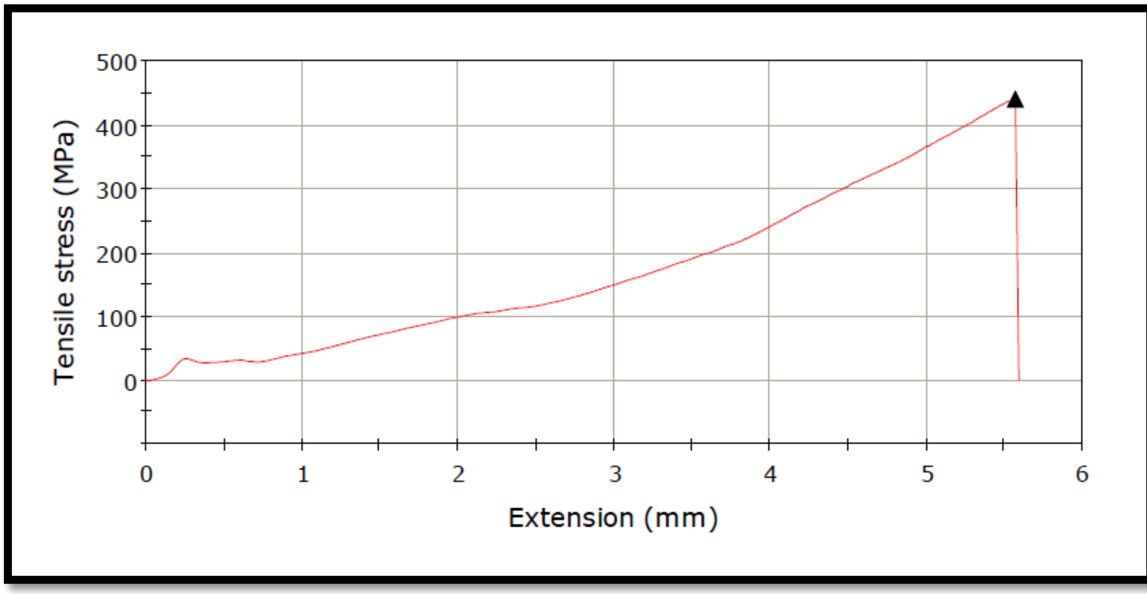

Figure 4.3(a): Specimen 1

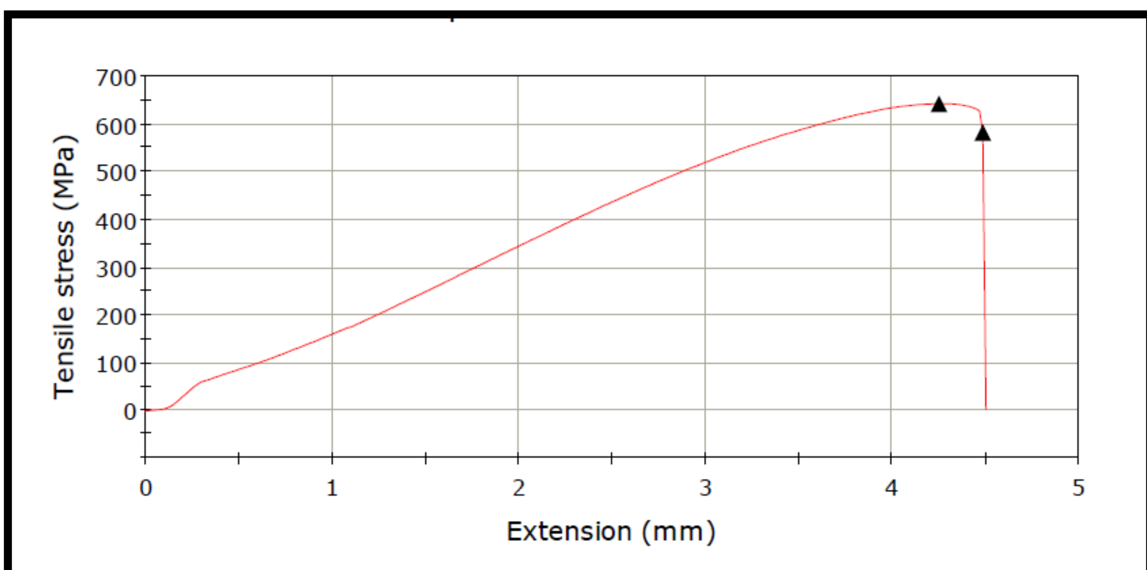

Figure 4.3(b): Specimen 2

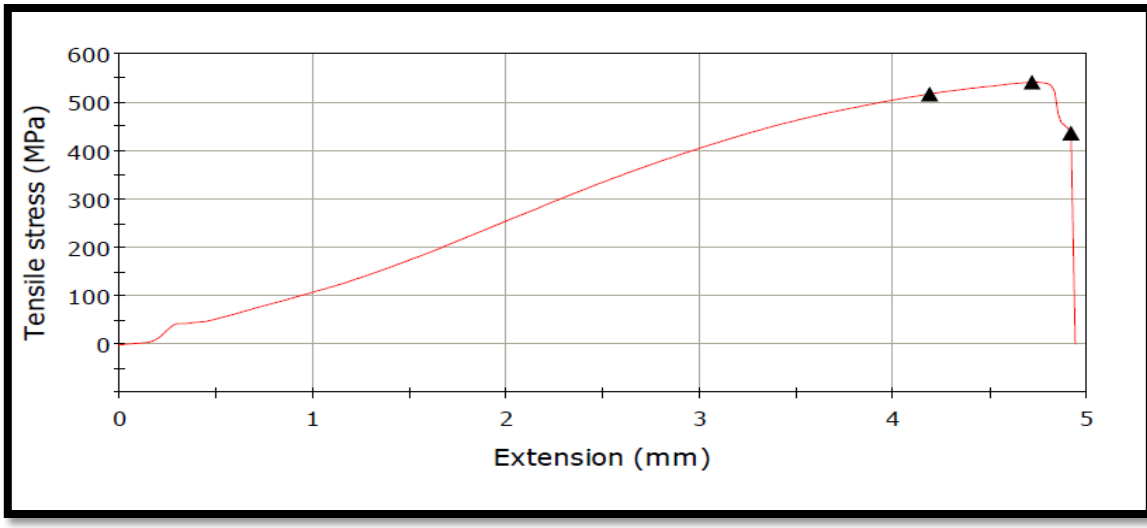

Figure 4.3(c): Specimen 3

Figure 4.3 (a), (b) and (c): Tensile result for 850ºC and four hours carburization

4.3.4 Experiment 3 (850ºC, Six Hours)

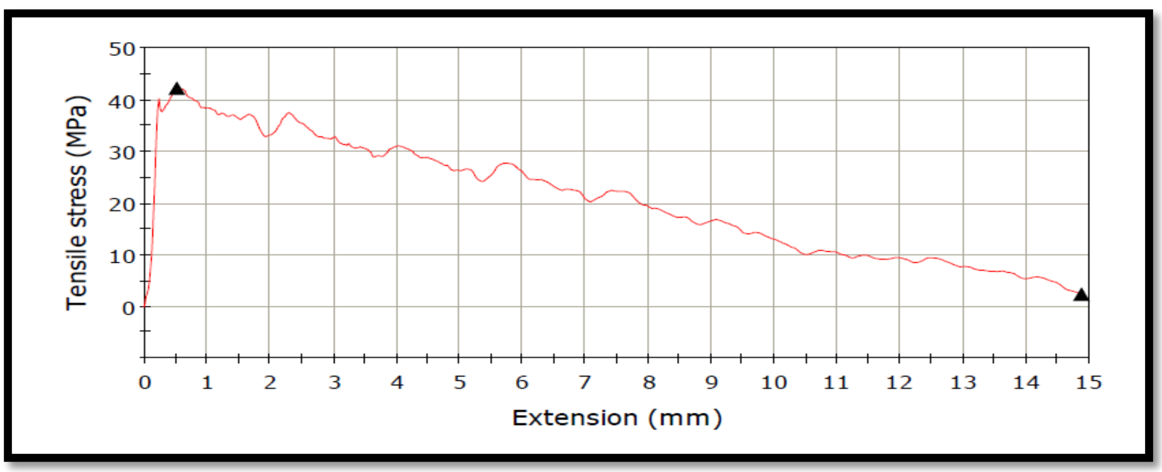

Figure 4.4(a): Specimen 1

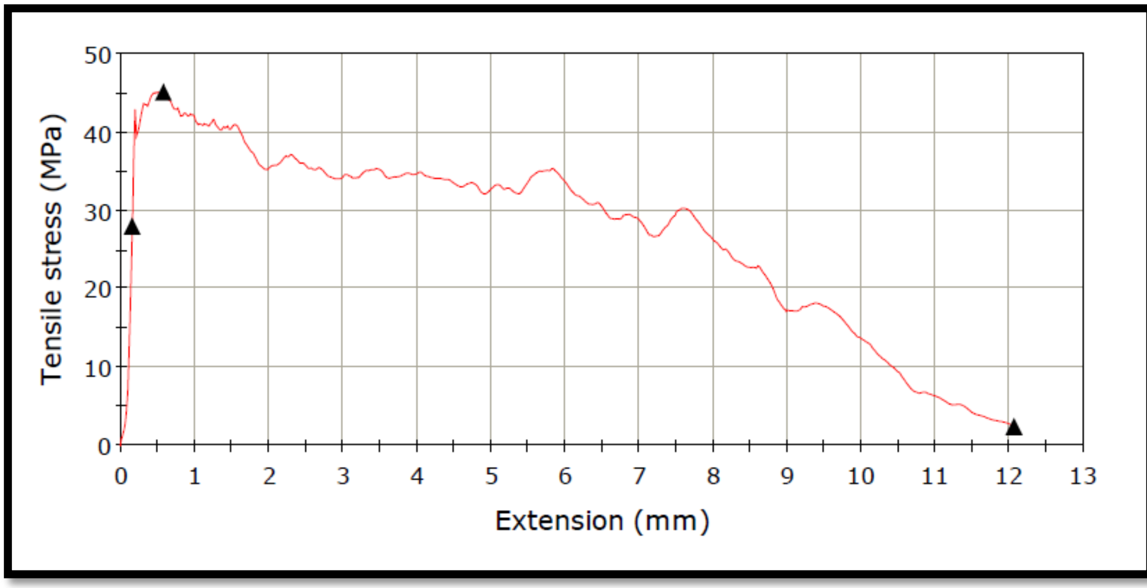

Figure 4.4(b): Specimen 2

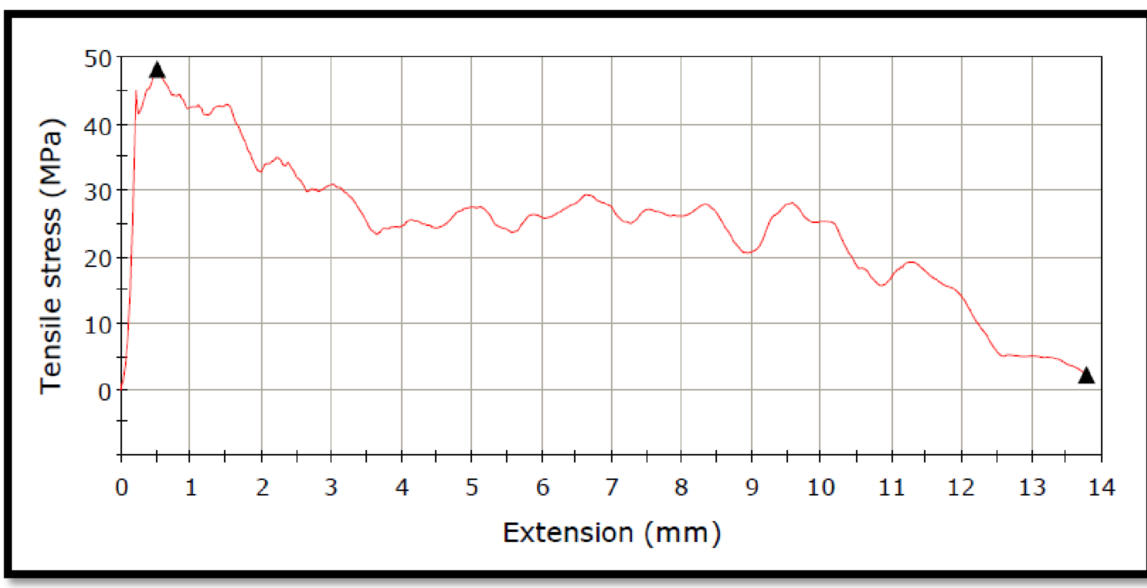

Figure 4.4(c): Specimen 3

Figure 4.4 (a), (b) and (c): Tensile result for 850ºC six hours carburization

Table 4.1: Data for tensile test

Condition	Tensile stress at Maximum Load (MPa)	Tensile stress at Break (Standard) (MPa)	Modulus (Automatic Young's) (MPa)
Without Carburization	**437.23737**	**67.20377**	**158587.8326**
EXPERIMENT 1 (850°C , Two Hours)	1. 447.9477 2. 446.2496 3. 438.1340 **Average: 444.1105**	1. 77.2230 2. 32.6927 3. 17.4902 **Average: 42.4686**	1. 223632.2364 2. 587826.7797 3. 146036.3807 **Average: 319165.1323**
EXPERIMENT 2 (850°C , Four Hours)	1. 440.5477 2. 642.1879 3. 541.4971 **Average: 541.4109**	1. 440.5477 2. 582.1608 3. 436.7198 **Average: 486.4761**	1. 102824.0916 2. 199038.2498 3. 103916.8862 **Average: 135259.7425**
EXPERIMENT 3 (850°C , Six Hours)	1. 42.21105 2. 45.11600 3. 48.19758 **Average: 45.17488**	1. 2.49645 2. 2.54476 3. 2.34655 **Average: 2.46259**	1. 209536.55986 2. -2716.62965 3. 207439.40557 **Average: 138086.4452**

Figure 4.1 show the tensile result for mild steel without carburization while Figure 4.2 (a), (b), and (c) show tensile result for two hours carburization. Then, for Figure 4.3 (a), (b), and (c) are tensile result for four hours carburization and Figure 4.4 (a), (b), and (c) are six hours carburization process. Table 2.1 show the data for tensile test include tensile stress at maximum load (MPa), tensile stress at break (standard) (MPa) and modulus (automatic Young's) (MPa).

In Table 4.1, it were observed that the sample of mild steel without carburizing process, ultimate tensile strength (UTS) is 437.23737 MPa. For the samples for two hours carburizing at the carburizing temperature of 850°C, the average UTS is 444.1105 MPa. This UTS were increased when the carburizing time increased to four hours with constant temperature, 850°C. The average UTS for four hours carburizing time is 541.41096 MPa. This shows that the UTS of samples soaked for four hours improved as the carburizing time increased. The results for six hours carburizing time with carburizing temperature of 850°C , shows that the UTS is sharply drop to 45.17488 MPa.

From Table 4.1 it is clearly seen that for the samples soaked for two hours, the Young's modulus at carburizing temperature of 850°C increased from samples without carburization process of 158587.8326 MPa to 319165.1323 MPa. Then it reduced to

135259.7425 MPa as the carburizing time increased to four hours. The Young's modulus at carburizing temperature of 850°C increased to 138086.4452 MPa at the carburizing time increased to six hours.

Tensile stress at break for the sample without carburization process has the value of 67.20377 MPa. The tensile stress at break at carburizing temperature of 850°C reduced to 42.4686 MPa at the carburizing time increased to two hours. Then it increased to 486.4761 MPa as the carburizing time increased to four hours. The results for six hours carburizing time with carburizing temperature of 850°C , shows that the tensile stress at break is reduced to 2.46259 MPa.

According to tension test specimen without carburization has extension about 20mm. However for the Experiment 1 and 2 it is prove that the carbon content will affect the ductility of the material, where the result shown it decreased the ductility and become brittle. In Experiment 3 the result show that ductility increasing but not goes to the original state. This is due to the arrangement of the grain in the material.

4.4 HARDNESS TEST RESULT

In present experimental work Vickers hardness was measured on carburized, quenched mild steel samples which are carburized under different time range of two hours, four hours and six hours. For each of the samples, test was conducted for three times and the average of all the samples was taken as the observed values in each case.

Table 4.2: Data for hardness test

Condition (Carburization)	**Hardness (HV)**	**Average (HV)**
Without Carburization	1) 211.6	211.6
Experiment 1 (850°C, two hours)	1) 290.6 2) 251.3 3) 218.9	253.6
Experiment 2 (850°C, four hours)	1) 416.5 2) 478.9 3) 473.9	444.4
Experiment 3 (850°C, six hours)	1) 572.2 2) 551.9 3) 611.0	578.4

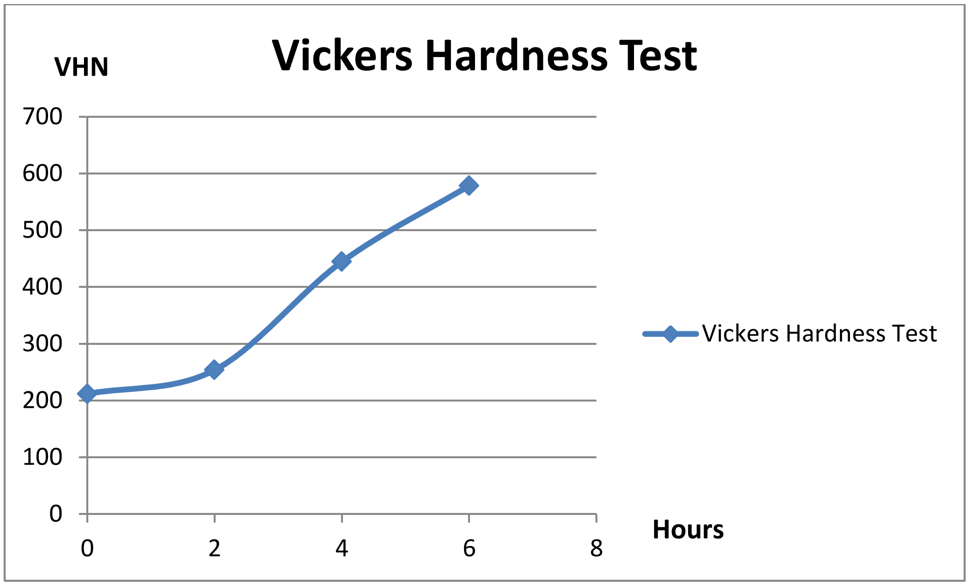

Figure 4.5: Vickers hardness result for all samples

Table 4.2 shows that the data for Vickers hardness for mild steel. From figure 4.5, it were observed that the Vickers hardness number (VHN) for specimen of mild steel without carburization process is 211.6 VHN. For the specimen of Experiment 1, the Vickers hardness test is 253.6 VHN. While, for Experiment 2, the Vickers hardness increased to 444.4 VHN. It then increased to its maximum value of 578.4 VHN as the carburizing time increased to six hours in Experiment 3. Because of the case hardening process, it will increased the surface carbon content on the outer surface becomes hard via the transformation from austenite to martensite, while the core remains soft and tough as a ferritic and/or pearlite microstructure. Hence it will increase the surface's hardness as per shown in the Figure 4.5.

4.5 MICROSTRUCTURE ANALYSIS

The microstructure analysis test was performed to determine the thickness of carbon coated layer using the Optical Microscope. For each of the samples, test was conducted for three times and the average of all the samples was taken as the observed values in each case.

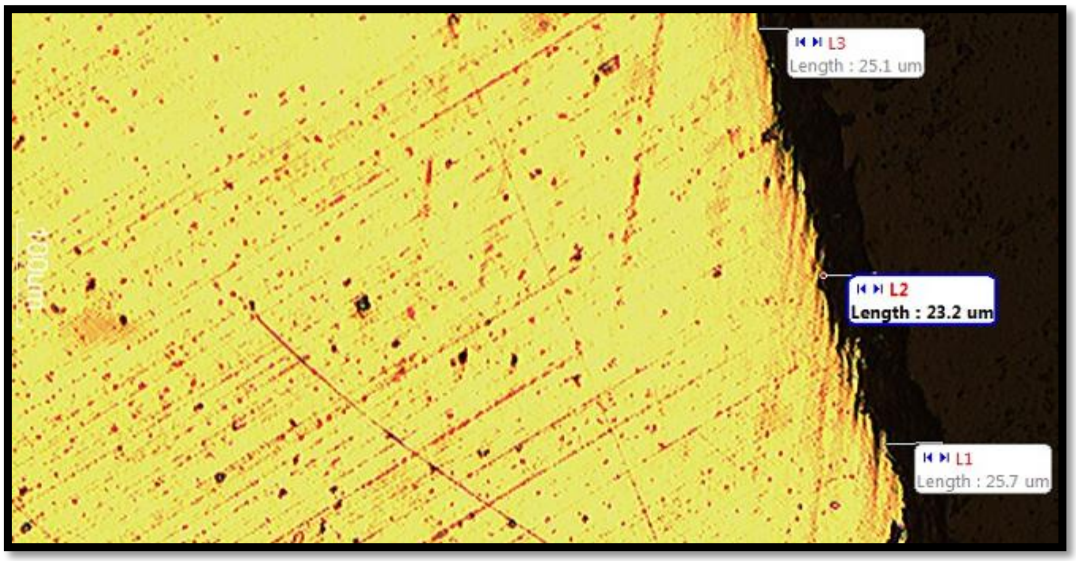

Figure 4.6: Microstructure analysis result for Experiment 1 (850°C, two hours)

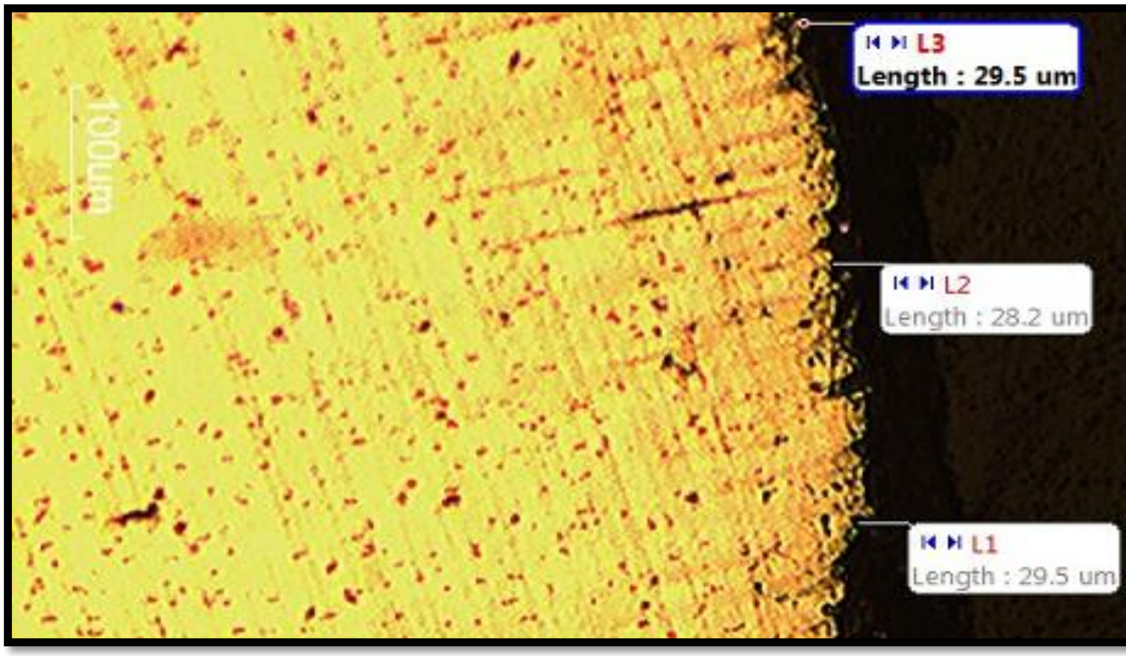

Figure 4.7: Microstructure analysis result for Experiment 2 (850°C, four hours)

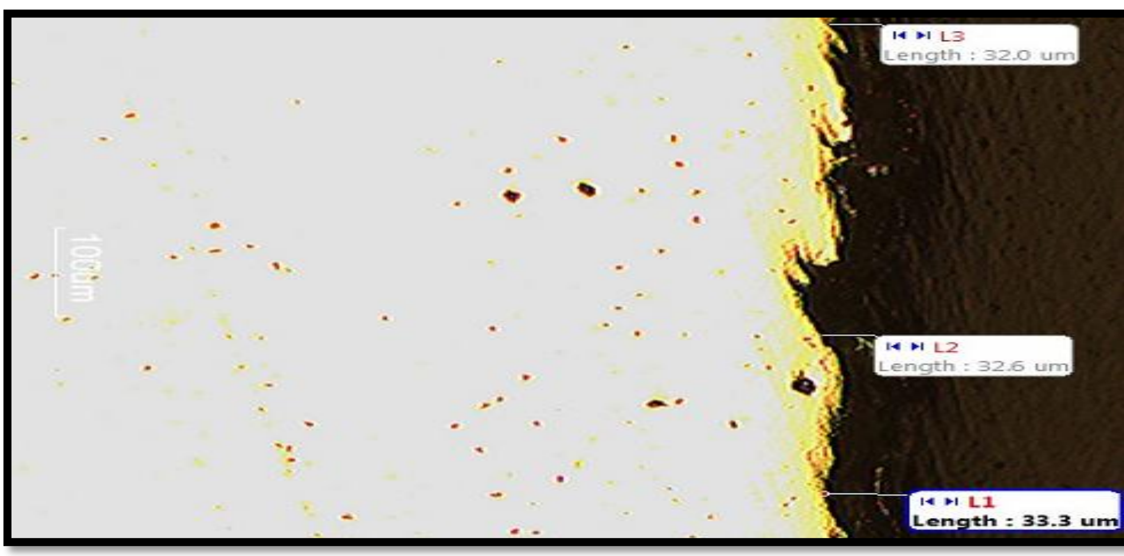

Figure 4.8: Microstructure analysis result for Experiment 3 (850°C, six hours)

Table 4.3: Data for microstructure analysis

Condition (Carburization)	**Carbon Coated Thickness (μm)**	**Carbon Coated Average (μm)**
Experiment 1 (850°C, two hours)	1) 25.1 2) 23.2 3) 25.7	24.667
Experiment 2 (850°C, four hours)	1) 29.5 2) 28.2 3) 29.5	29.067
Experiment 3 (850°C, six hours)	1) 32.0 2) 32.6 3) 33.3	32.633

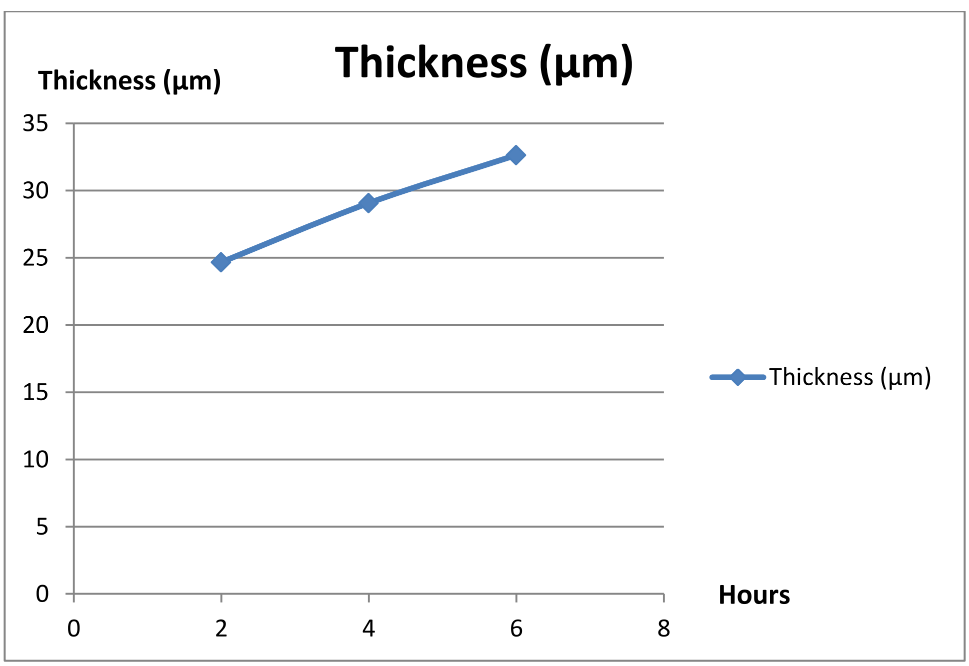

Figure 4.9: The effects of carburizing time on the thickness of carbon layer

Table 4.3 shows that the data for microstructure analysis for mild steel at different time of carburizing process, two hours, four hours and six hours. In figure 4.10, the graph shows the effects of carburizing time on the thickness of carbon layer. From two hours carburizing time with the carburizing temperature of 850°C, the thickness of carbon layer that coated the mild steel is 24.667µm. For four hours carburizing time with constant temperature, 850°C, the thickness is increased to 29.067 µm. For carburizing temperature, 850°C with carburizing time of six hours, the effects of carburizing time on the thickness of carbon layer were increased to 32.633µm. This shows that, the thickness is increased due to the increased of carburizing time. Depending on the amount of time and temperature, the affected area can vary in carbon content. Longer carburizing times and higher temperatures lead to greater carbon diffusion into the part as well as increased depth of carbon diffusion. (http://en.wikipedia.org/wiki/Carburizing)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter discuss on the conclusion which are made based on the analysis of the result that shown in previous chapter. It also has recommendation for future works to make the research better than before.

5.2 CONCLUSION

The study of carbonizing process effect to the properties of the material at the various times was successfully conducted and fulfills the first objective that is to study the influence of carburization process for mild steel.

For second objective, there is to study the material performance such as tensile test, hardness test and microstructure analysis after carburization process. The result gain from the experiment was shown in the chapter 4, where it shown there had effected to the mechanical properties. Comparisons were made from specimen at the various times, shown that the tensile strength will be reducing with time; hence the optimum time is 4 hour (541.41096 MPa). For Young's modules results, it shows that the longer of treatment time it will affected to the value where it will become brittle. This is due to the carbon content in the material were increase. For hardness test, it show that the hardness will increase when the time increase. The maximum hardness was shows at 6 hours carburization (578.4 VHN). The thickness of carbon coated is shown on the microstructure analysis. The higher thickness is 32.633μm were getting from 6 hours carburization. This shows that, the thickness is increased due to the increased of carburizing time.

5.3 RECOMMENDATION

As the recommendation for this experiment, there should be more parameter involve such as time should be more various others that 3 various that using in this experiment. Others are such as the carbon ingredient, temperature, as well as the quenching material that will be use, because these also have the effect to the mechanical properties of the material that will be treated. Besides that, different material can be used for this experiment such as stainless steel and aluminum. This will be more reliable to the industries to use as the reference for their project.

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APPENDIX 1

GANTT CHART FYP 1

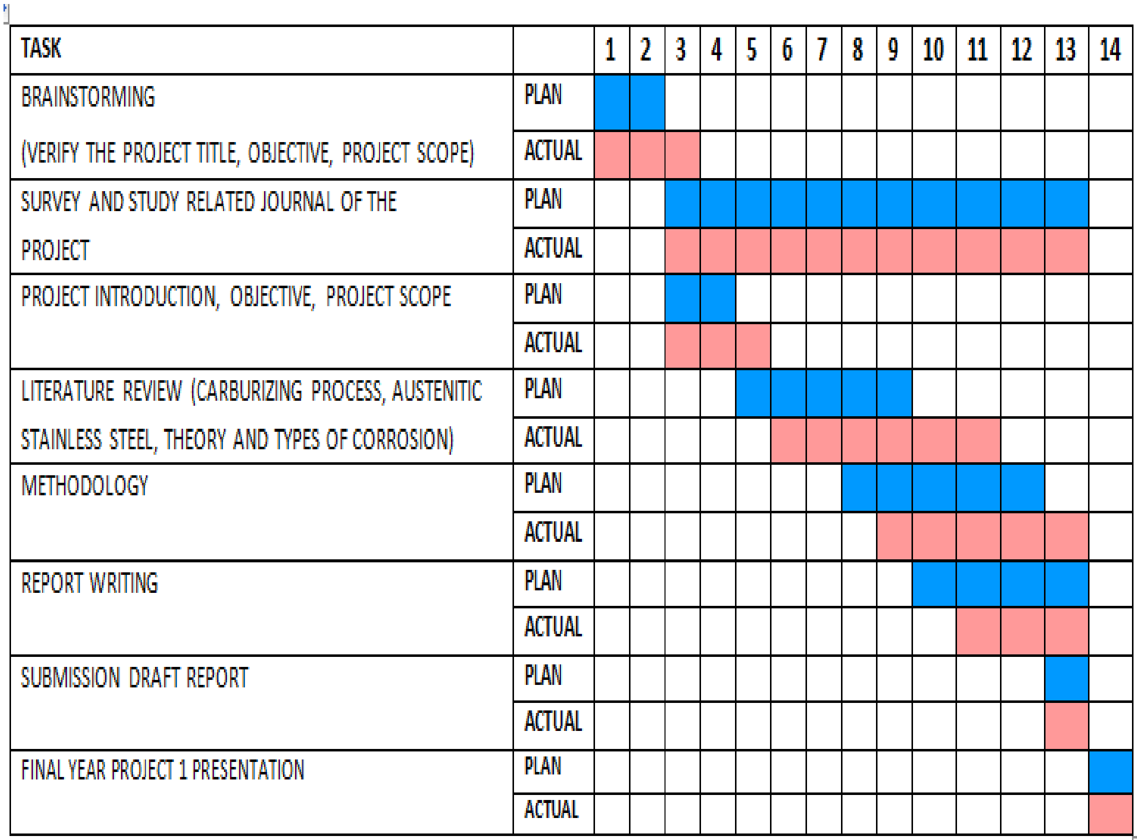

Figure 6.1: Gantt chart FYP 1

APPENDIX 2

GANTT CHART FYP 2

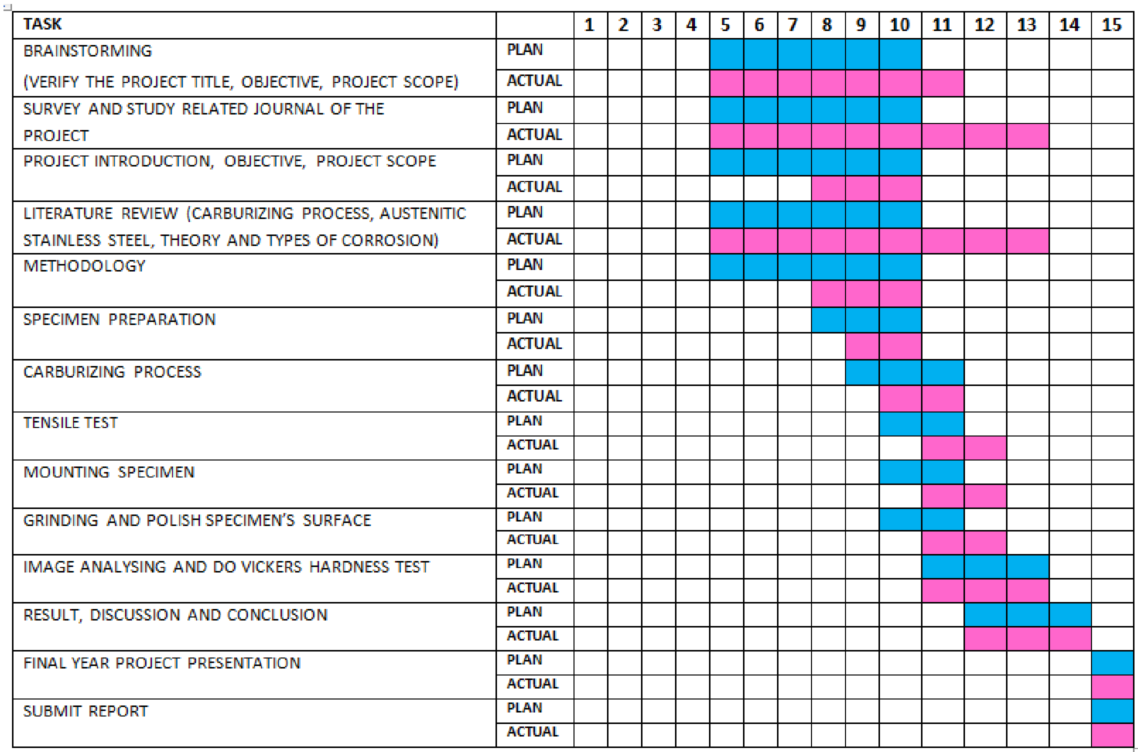

Figure 6.2: Gantt chart FYP 2