THE MECHANICAL PROPERTIES & MICROSTRUCTURAL ANALYSIS OF WELDED DPS IN COMPLIANCE TO A SELECTED INTERNATIONAL STANDARD

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This report is submitted
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DECLARATION

I declare that this project report entitle “The mechanical properties & microstructural analysis of welded DPS in compliance to a selected international standard” is the result of my own except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for award of the degree of Bachelor of Mechanical Engineering (with Honours)

Signature : ....

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

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Date : ....

DEDICATION

This report is dedicated to my beloved mother and father

Norainah binti Mat Yusoff

Noorazmi bin Yahya

ABSTRACT

This researches is to characterize the effect of annealing temperature to the mechanical properties and microstructure of Dual Phase Steel (DPS) produced through heat treatment of mild steel and also to determine the suitable Dual Phase Steel (DPS) that is in compliance to a selected international standard for welding. High ductility, affordability, weld ability and good machinability characteristics of mild steel has put mild steel into the popular choice of steel for consumers. However, due to lack of alloying elements compared to those found in stainless steel means that mild steel is more prone to corrosion. On the top of that, mild steel also being in the low hit when it comes to strength capability and it restrict the usage of mild steel in applications where load bearing and strength is essential. Even though, mild steel has found its own territory in various industries, some other application needs the material used to be harder, without reducing the formability and stronger while keeping the price affordable and competitive. Dual phase steel (DPS) has been introduced to fill in the gap left by mild steel and provide better strength steel by heat treatment process. The selected for this particular project occurs in the inter critical temperature which is 740°C, 760°C, 780°C and 800°C within the α-ferrite and γ-austenite phase region from $Fe\text{-}Fe_3C$ phase diagram. Quenching was done right after austenitizing in order to produced martensite through diffusionless transformation. The volume fraction of martensite (%) was then analyze for each temperature. Characterization of the samples were done by Rockwell Hardness Test (ASTM A370-14) , morphological observation using light microscope and tensile testing is carried out using universal testing machine (UTM) of 500 KN capacity as

per ASTM code E8-09 after shielded metal arc welding SMAW process of mild steel and Dual Phase Steel. In the observation the higher intercritical temperature of annealing, the higher the percentage of the martensite volume fraction. For the hardness more volume fraction of martensite, more hardening occur in specimen. Eventhough hardness increase with the higher annealing temperature due to formation of martensite. However, at certain point it already reduces the weldability of Dual Phase Steel. The overall objective of this project has been achieved. Dual phase steel mechanical properties and microstructure analysis had been analyzed and studied, and also shielded metal arc welding. The hardness of the steel was determined from the experiment result.

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DPS	Dual Phase Steel
SMAW	Shielded Metal Arc Welding
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
FCAW	Flux Core Arc Welding
SAW	Submerged Arc Welding
ESW	Electro Slag Welding
CCT	Continuous cooling Transformation
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
MCS	Medium Carbon Steel
HCS	High Carbon Steel
HSLA	High Steel Low Alloy

LIST OF SYMBOL

T	=	Temperature
°C	=	Degree Celsius
α	=	Alpha
γ	=	gamma

CHAPTER 1

INTRODUCTION

1.1 Background

Mild steel is considered a type of steel with the amount of carbon content typically around 0.05% to 0.25% by weight. Although mild steel relatively has low tensile strength compared to other steel with higher percentage of carbon, the usage of mild steel has become very competitive in various industries due to its affordable price. Sectors where vast usage of mild steel can be found includes structural applications, automotive industry and pipelines for oil and gas.

High ductility, affordability, weld ability and good machinability characteristics of mild steel has put mild steel into the popular choice of steel for consumers. However, due to lack of alloying elements compared to those found in stainless steel means that mild steel is more prone to corrosion. On the top of that, mild steel also being in the low hit when it comes to strength capability and it restrict the usage of mild steel in applications where load bearing and strength is essential.

Even though, mild steel has found its own territory in various industries, some other application needs the material used to be harder and stronger while keeping the price fordable and competitive. Dual phase steel (DPS) has been introduced driven to fill in the gap left by mild steel and provide better strength steel without reducing the formability or reducing the costs.

Dual phase steel can be produced either by continuous annealing with the inter critical temperature range or by hot rolling. Dual phase steel produced by the continuous annealing process is considered important due to less requirement of Mn and give less variation in mechanical properties. Dual phase steel also known to have properties such as high work hardening rate and uniform total elongation that makes it a very good candidate in automotive industry for weight saving and improving fuel economy due to the good formability characteristics.

A common property that all steels should have is weld ability during the application and assembly of dual phase steel, fusion welding process such as SMAW is used as pail its joining technique. However, heat input from fusion welding can cause the martensite island to decompose into softer island of tempered martensite.

1.2 Problem Statement

Event though, the formability of high strength dual phase steel is superior to that of mild steel, higher percentage of martensite and possibility of it decomposing into tempered martensite with the application of heat during welding might introduced certain issues for the welded part. The effect of the percentage of martensite which directly relates to the intercritical annealing temperature is expected to play an important role towards a good weldability characteristic of the dual phase steel produced. The study will be looking into this aspect an analysis of the welded pail as well as its weldability performance will be done.

1.3 Objective

The objectives of this project are as follows:

I. To characterize the effect of annealing temperature to the mechanical properties and microstructure of Dual Phase Steel (DPS) produced through heat treatment of mild steel.

II. To determine the suitable Dual Phase Steel (DPS) that is in compliance to a selected international standard for welding.

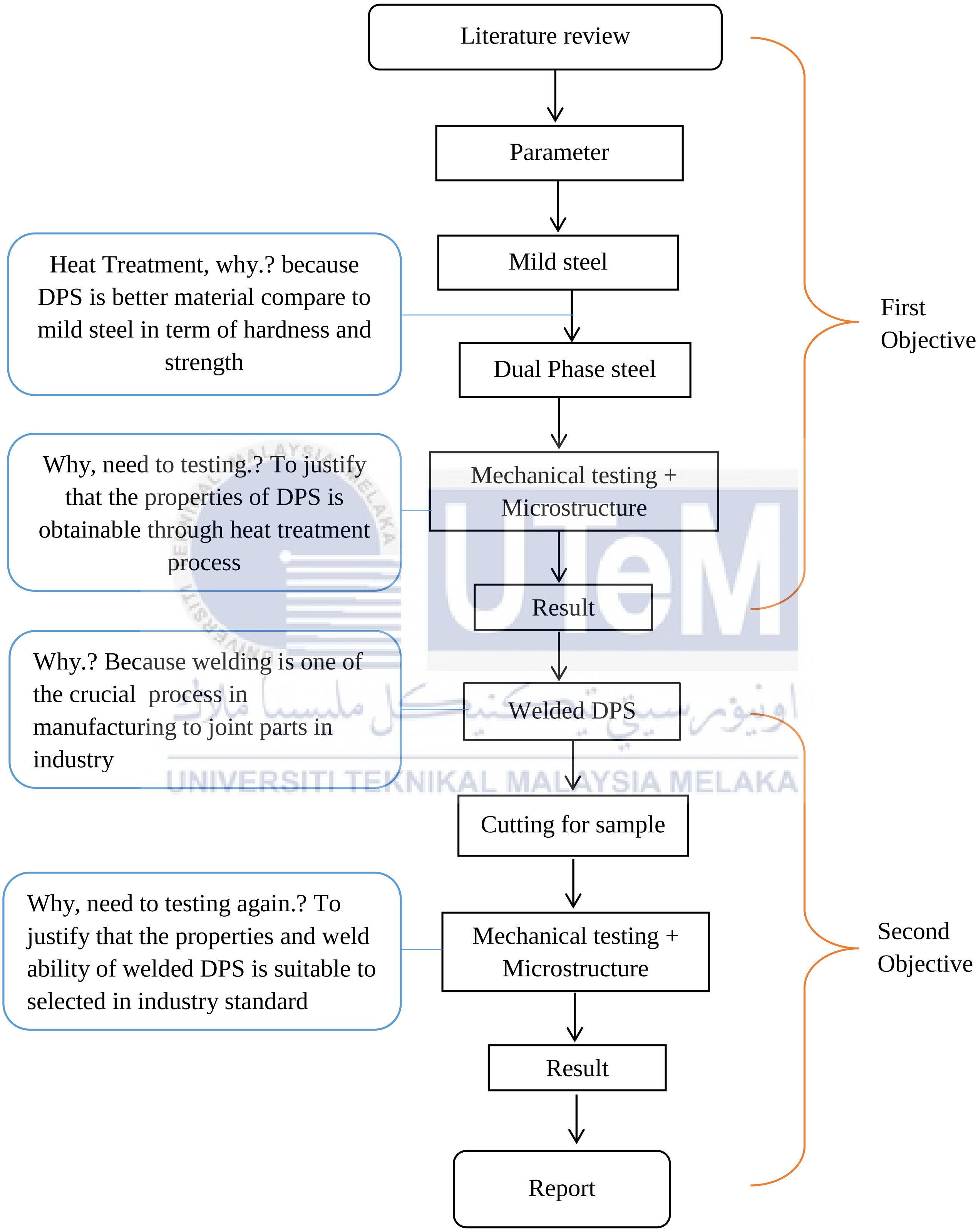
1.4 Scope

The scopes of this project are:

I. Mechanical testing to see the strength of mild steel and after transform to Dual Phase Steel (DPS) by using tensile test.

II. Development of microstructure transformation to martensite in annealing temperature.

1.5 General Methodology



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter intended to review the literature of the most about Dual Phase Steel and apply it in welding process. Microstructure view and mechanical testing which was hardness test on dual phase steel forms one of the main reasons for this project. In the previous study, research or journalism due to dual phase steel characterized by good cool-forming properties and suitable as pressed and welding parts. Great, in this study dual phase steel is the stuff where the welding will labor on.

2.2 Steel Definition

Steel is an alloy with the majority of iron and carbon between 0.2% and 2.1% by weight, rely on the grade. Carbon is most common iron alloy, but different from the used alloy element, such as manganese, chromium, vanadium and tungsten. Carbon and other element act as a hardening element, preventing dislocation in the iron crystal grid moving past each other.

The varying quantity and shape of the alloy elements in the steel (solute components, precipitated segment) direct behaviours such as hardness, ductility and tensile strength of the steel resulting. Steel with a boosted carbon content can be harder and stronger than iron, but its ductility is less than iron as well. Alloys with a carbon element higher than 2.1 percent are known as cast iron due to their low melting point and good cast capacity.

Additional steel fine tuning has been developed such as basic oxygen steel production (BOS), lower production costs while increasing metal quality. Today, with more than 1.3 billion tons formed annually, steel is one of the most common material in the world. It is a key component in buildings, infrastructure, tools, ships, automobile, machine appliance, and weapon.

2.2.1 Type Of Carbon Steel

Carbon steel also called plain carbon steel, where carbon is the main interstitial alloy element. The American iron and steel institute (AISI) derive carbon steel as: “steel is considered to be carbon steel when minimum for chromium, cobalt, molybdenum, nickel, niobium, titanium, tungsten, vanadium or zirconium, or any other element to be added to obtain a desired alloying effect. Carbon steel is divided into four classes based on carbon content.

Low carbon steel – Mild steel is the most common form of steel because it has a relatively low value while offering material properties that can be used in many applications. Low carbon steel has an approximate carbon content of 0.05-0.25 percent and mild steel contains 0.16-0.29 percent carbon; it is therefore fragile or ductile. The tensile strength of mild steel is virtually low, but it is cheap and bendy; surface hardness can be increased by carburizing. It is often the case that large quantities of steel, such as structural steel is approximately 7.85 g/cm^3 (7850 kg/m^3) and the young’s modulus is 210 GPa (30,000,000 psi). The experience of low carbon steels from yield point runs out where the material has two yield points. The first point (top yield) is greater than the second point and yield decreases dramatically after the upper yield point.

Medium carbon steel – The carbon content is approximately 0.30 – 0.59 percent. Balance ductility and strength and good wear confrontation for larger components, forging and automotive components.

High carbon steel – The carbon content is approximately 0.6 – 0.99 percent. Very powerful physically, used in springs and high - strength wires.

Ultra high carbon steel – The carbon content is approximately 1.0 – 2.0 percent. To great stiffness, steel can be raged. Used for specific purposes, such as axles and punches.

2.3 Mild Steel

Mild steel is type of carbon steel with a low the quantity of carbon, it also called as "low carbon steel". Although degrees range depending on the source, the quantity of carbon generally discovered within slight metal mild steel is 0.05% to 0.25% by weight. (McHenry and Laughlin, 2014) whereas the content of higher carbon steel are usually described as having a carbon content from 0.30% to 2.00%. If any extra of carbon than to that amount is added, the steel would stand labelled as cast iron. Mild steel is not an alloy steel and consequently does not contain large amounts of other elements besides iron. The calculated average industry grade mild steel density is 7861.093 kg/m3. Its Young's modulus, a measure of its stiffness is around 210,000 MPa.

Less carbon means that mild steel is usually more ductile, machine able, and welding able than high carbon steel and other steel. However, that additional capability such is nearly not possible with to harden and strengthen through heating and quenching. The low carbon content also means it has very little carbon and other alloying elements to block dislocations in its crystal structure, typically resulting of much less tensile strength than high carbon and alloy steel. Mild steel also has a high iron and ferrite content, which makes it magnetic. Lack of alloying elements such as those found in stainless steels means that the iron in mild steel is subject to oxidation (rust) if not properly coated. However, the negligible amount of alloy elements also makes mild steel relatively affordable compared to other steels. The affordability, weldability, and machinability make it a popular consumer choice of steel. Such as it provides high surface hardness and a soft core to parts that include worms, dogs, pins, liners, machinery parts, special bolts, ratchets, chain pins, oil tool slips, tie rods, anchor pins, studs, and others (Covered and Composition, 2012).

However, due to the lack of alloy elements like in stainless steel, mild steel is more susceptible to corrosion. In addition, mild steel is also low in strength and restricts the use of mild steel in applications where load bearing and strength are essential. Therefore, dual phase steel (DPS) has been introduced, where DPS offer higher strength without reduced formability compared to conventional high steel low alloy (HSLA).

2.4 Dual Phase Steel (DPS)

Dual phase steel (DPS) steel urbanized in the mid-seventies (Granbom, 2010) in order to gratify the increasing weight reduction and improved crash performance and keeping the manufacturing costs at easing levels. Dual phase steel grades having a more range of chemical compositions and being produced with various processing methods.

Based on the report by Hayami and Furukawa, DPS essentially contained ferrite and martensite as its major microstructure. However, other microstructure such as bainite, pearlite and retained austenite might also exist in a smaller amount. Regardless of the exact composition of the mild steel, dual phase ferrite martensite microstructure occurs in the inter critical temperature within the $\alpha + \gamma$ two phase region from the Fe-Fe_3C phase diagram. Accompanied by rapid cooling (quenching) in order to allow martensite conversion. (Ghosh *et al.*, 1991)

Soaking time of steel in the inter critical temperature was normally keep around 3 hours to ensure homogeneity before being followed by quenching. The term “dual phase” steel or DPS, refers to a class of high strength steel which is composed concerning of two phase; normally a ferrite matrix and a dispersed second phase of martensite, retained austenite and bainite. The driving force for the development of DPS was due to the urge of producing new high strength steel without reducing its formability and at a relatively low cost compared to other steels such as MCS or HCS. The automotive industry, in particular, has demanded steel grades with excessive tensile elongation in conformity with assure formability, high tensile strength. DPS show superior properties as shown in **Figure 2.1**.

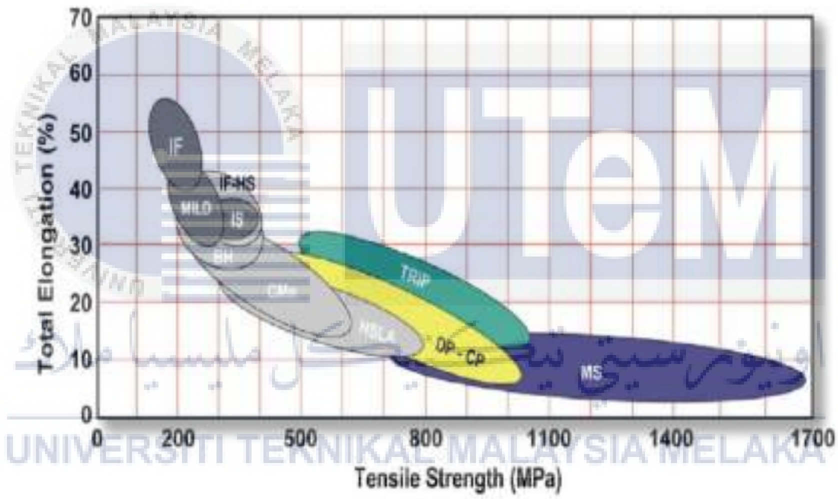


Figure 2.1 : Schematic picture showing advanced high strength steels (shown in colour) compared to low strength steels (dark grey) and traditional HS steels (grey)

Source : (Granbom, 2010)

The Continuous Cooling Transformation (CCT) are determined by measuring some physical properties during continuous cooling. Normally these are specific volume and magnetic permeability. However, the precedence about the work has been done through specific volume change by dilatometric method. This method is supplemented by using metallography and hardness measurement. These diagrams are more useful than Time Temperature Transformation (TTT) because it is more convenient to cool material at a certain rate than to cool quickly and hold at certain temperature (Van Aken, 1999) The critical point is the “correction” of the CCT diagram to involve the presence of strain in autenite (to simulate the real process condition). In continuous heat treating lines three type of cooling are utilize. For example water quenching, gas jet cooling and air cooling (Ebner *et al.*, 2018). Producing of DPS is easy and economical production by using water quenching. The common heat cycle involves intercritical heat treatment and water quenching suppression to form a ferrite martensitic microstructure.

By entering the intercritical two-phase region, austenite nucleates extensively in the pearlite or neighbourhood of the cementite element and grow widely until liquefied carbides. Slower extension of austenite to ferrite are prolonged at a rate initially managed by carbon diffusion in austenite and finally by manganese diffusion in austenite until the equilibrium state of the system has been achieved. **Figure 2.2** shows an intercritical annealing of the fraction of austenite and ferrite in dual phase steel.

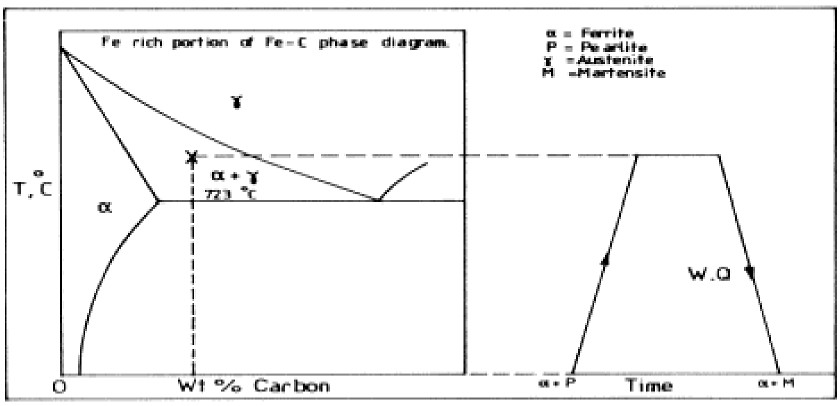


Figure 2.2 : Production of DPS by annealing. The fractions of austenite and ferrite as well as their carbon content at annealing temperature can be estimated by applying the lever rule. (source : Kalpakjian, Schmid, Manufacturing Engineering and Technology, 2011)

Dual phase steel is high strength steel that has a ferritic-martensite microstructure. Dual phase steel consist of ferrite and second phase of hard martensite, in ratio of about 20% or more than 10% by volume (Ennis *et al.*, 2018). Dual phase steel are produced from low or medium carbon steel that are quenched from annealing temperature determined from continuous cooling transformation diagram. Therefore, the overall behaviour of dual phase steel is governed by the volume fraction, morphology for example size, aspect ratio interconnectivity and others (Caprili *et al.*, 2018).

Dual phase steel with increased formability are of growing importance in the automotive industry such as, car body panels (Ennis *et al.*, 2018). The existence of martensite in DPS microstructure gives rise to its strength while soft ferritic microstructure ensures high formability. Phase like a bainite, perlite and residual austenite may also be present in little quantities. Properties such as continuous yielding behaviour, uniform plastic deformation then excessive elongation, excellent strength and formability combinations were among the characters of DPS making it very promising substrate materials for mild steel (Caprili *et al.*, 2018).

The desire to produce high strength steels with formability greater than micro alloyed steel. Dual phase steel microstructure allows tensile test at value 400 – 1200 Mpa. DPS microstructure is more advantageous than advance high strength steel, for example the strength of dual phase steel can be designed by the volume fraction of martensite.

Dual phase steel experienced high strain hardening, especially at the beginning of plastic deformation, they can be strengthened by static or dynamic strain through a drying effect called bake hardening effect. Dual phase steel with low carbon content exhibit excellent defence from spread of crack. in dual phase steel, martensite is produced by quenching process from autenite phase or from two phase ferrite plus austensite phase during annealing treatment inter critical step.

2.5 Application

The growing vehicle market has developed a new vehicle design based on the design concepts to offer a steel-based structural platform that meets the obligations of the automotive markets and benefits from the high-strength steel. The application of superior high strength steels promotes both high strength and excellent structure capability provides the special option or unique option of combining weight reduction (by the using thinner gauges of sheet material) together with improved inert safety, optimized environment act and manufactured opportunity at affordable cost.

2.6 Welding

Welding is a fabrication or sculptural process that joins material. Welding is a process of connecting metal or non-metallic materials using heat or pressure. Commonly metals or thermoplastic, by grounding coalescence. This is frequently done by melting the work parts and put a filler material to create a pool of molten material (the weld pool) that cools to develop into strong joint. Where the pressure sometimes used in combination with heat, or by itself, to create the weld. This is in compare with soldering and brazing, which engage melting lower melting point stuff between the work parts to form a link between them, without melting the work parts.

Welding is widely used in different sources, as well as a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While frequently in manufactured process, there are many difference in the environment that can be done through the welding process, including in open air, under water, and in and in outer. Welding is a high-risk safety work on physical and mental, that why security measures or precaution should be taken, so that such hazards, a burn, an electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to severe can be avoided.

Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering. In the late twentieth century, the first welding process was are welding and fuel welding, and electric resistance welding followed soon after. Welding technology advanced quickly during the early 20th century as World War I and World war II drove the demand for reliable and inexpensive joining methods.

Following the war, some modern welding techniques have been created, including manual methods like Shielded Metal Arc Welding (SMAW) now one of the most popular welding methods, as well as semi-automatic and automatic process such as Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Flux Core Arc Welding (FCAW), Submerged Arc Welding (SAW) and Electro Slag Welding (ESW). Enhanced innovation with the creation of a laser beam welding, electron beam welding, electromagnetic pulse welding and friction stir welding in the latter half of the century. Now, the science continue to more advance, the use of welding robots in the industry is commonplace, and researchers continue to develop new welding method and gain a better understanding of welding quality and characteristics.

2.6.1 Shielded Metal Arc Welding (SMAW)

Welding arc is a welding process used to unite two metals into metal by using of an electric current to achieve sufficient heat to melt the metal, and then the molten metal when cool result in a binding of the metal. This welding type is uses welding power supply, to produce electric arc between the electrode and the base material to melt metals at the point-of-contact. The common arc welding circuit is an alternating current (AC) or direct current (DC) power source. Arc welding is frequently applied to form built-up high strength steel (Jiang *et al.*, 2018).

Shield metal arc welding starts when the electric current is passed from the welding machine through the electrode touch which is one other terminal. The resistance prevailing during electrode conduction (electricity) through electrode distance will produce a high arc. High heat will continue to melt the electrode and base metal or work piece and then unite as weld boundaries. Ionized lines of gas appear to complete circuit (Circuit, no date). The schematic diagram SMAW is show in **Figure 2.3**

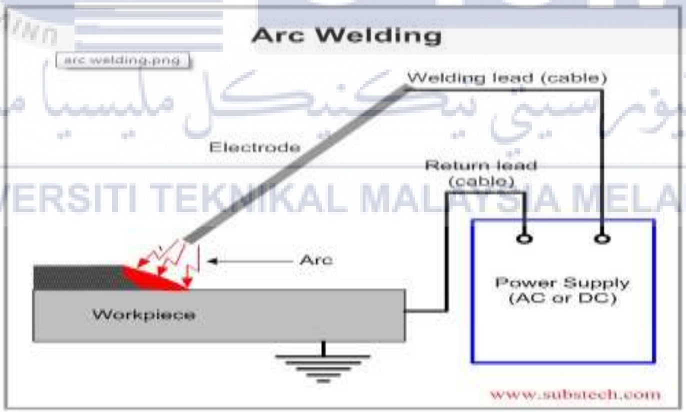


Figure 2.3 : Basic welding circuit

At the end of the electrode or between the ends of the electrode and work piece, the temperature is about 3600°C to dilute part of the welded metal and part of the electrode (Circuit, no date). This makes a pool of molten metal that cool and hard behind the electrode because it is goes along the connection line. There are two kinds of electrodes. Firstly, are consumable electrodes tips liquefy, and liquid metal droplet and combine into the weld pool. Secondly, are non consumable electrodes do not melt. Instep, filler metal is liquefied into the joint from a isolated rod or wire (Circuit, no date).

The quality and strength of the weld is diminished when metals at high temperature respond with oxygen and nitrogen become oxides and nitrides. Most arc welding processes reduce contact between the molten metal and the air with a shield of gas, vapour or slag. Granular flux, for illustration, includes deoxidizers that make a shield to ensure the molten pool, thus changing into a better or quality weld (Circuit, no date).

2.6.2 Welding Power Supply

Shielded metal arc welding can be used alternating current (AC) or direct current (DC), but in either case, the control power source chosen must be of the consistent current sort. This sort of control power source will convey a moderately consistent amperage or welding current regardless or arc length varieties by the operator. The amperage decides the total of the heat at the arc and since it will stay generally steady, the weld beads create will be uniform in estimate and shape. Whether to utilize an AC, DC or AC/DC supply source depends on the sort of welding to be done and the electrode use (Circuit, no date).

2.6.3 Electrode

electrodes are an additive metal in arc welding. It is coated with lath which is a mixture of certain type of material and has a variety of function during welding work. In another sense it describes an electrode that is the material used as a conductor in contact with non-metallic parts or media from a circuit, for example semiconductor, electrolyte or vacuum. This word phase was created by scientist michael faraday from the greek (article, bagnoli and livi, 2018),(ii and pustaka, no date).

2.7 Microstructure Analysis

Microstructure is the exceptionally little scale structure of a material, characterized as the structure of an arranged surface of material as uncovered by a magnifying instrument over 25x magnification. Heat treatment methods can produce microstructure of ferrite martensite from mild steel, they can be analysed using optical microscope with image analyser, scanning electron microscope (SEM). There is a delta ferrite and austenite in the microstructure analysis. The used of optical microstructure is the most suitable equipment for this research to achieves microstructure analysis. Steel is attained when small amount of carbon include.

2.7.1 Formation Of Martensite

Transformation austenite to martensite **Figure 2.4** is commonly as thermal diffusion less change, happening when the austenite is rapidly cooled underneath the Ms temperature. By this exposure, martensite contains the same chemical composition as its parents austenite. Due to the diffusion of martensite formation, carbon molecules will be enclosed within the octahedral site of a bcc structure (Granbom, 2010). The volume increment through the austenite to martensite change is clearly obvious in a dilatation curve. **Figure 2.5.**

Figure 2.4 : Formation of epitaxial ferrite and martensite. 1 is new ferrite.

2 is retained ferrite. 3 is martensite.

source : (Granbom, 2010)

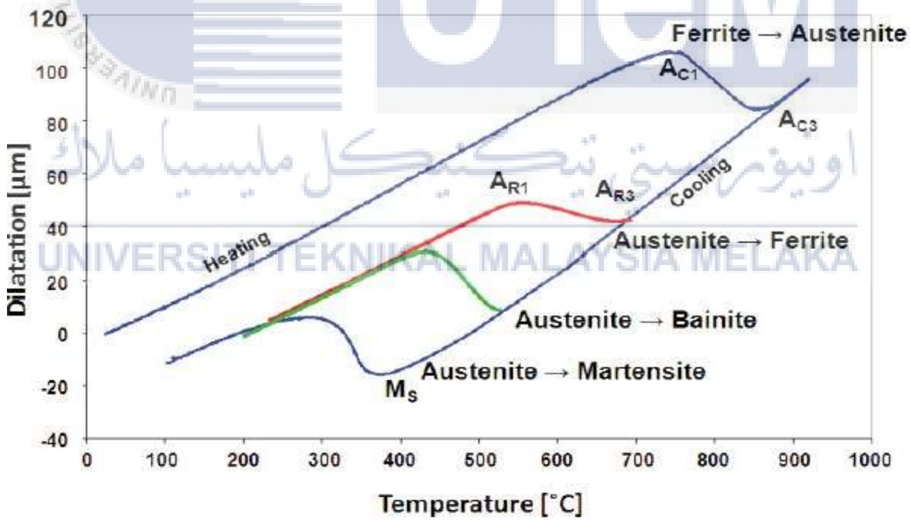


Figure 2.5 : Schematic dilatation curve

source : (Granbom, 2010)

2.8 Mechanical Testing

Materials testing considers the conduct of material beneath different load. In specific, the relationship between the acting forces and the coming about deformation and the constrain stresses that lead to disappointment of component are considered. The characteristic value gotten from the testing process are utilized for material improvement, planning components and in quality confirmation. There is a range of standardised testing strategies to characterise the mechanical properties of materials as accurately as conceivable (Stan-, 1998).

2.8.1 Tensile Test

The tensile test is the foremost vital testing method in destructive materials testing. A standardised example with a know cross segment is stacked consistently with moderately low increasing constrain within the longitudinal direction. An uniaxial stress situation occurs in the specimen until the contraction begins. The proportion of stress to strain can be appeared from the plotted load extension. The stress-strain diagram clearly the different conduct of the material and gives the characteristic values for tensile strength Rm, yield strength Re, proportional limit Rp, elongation at fracture A and the elastic modulus E. [23] As a show in **Figure 2.6.** 1 is a hooke's straight line, 2 is a luders strain, 3 is strain hardening region, 4 is start of contraction and 5 is a fracture. **Figure 2.7**. it is show the standard size for tensile test specimen.

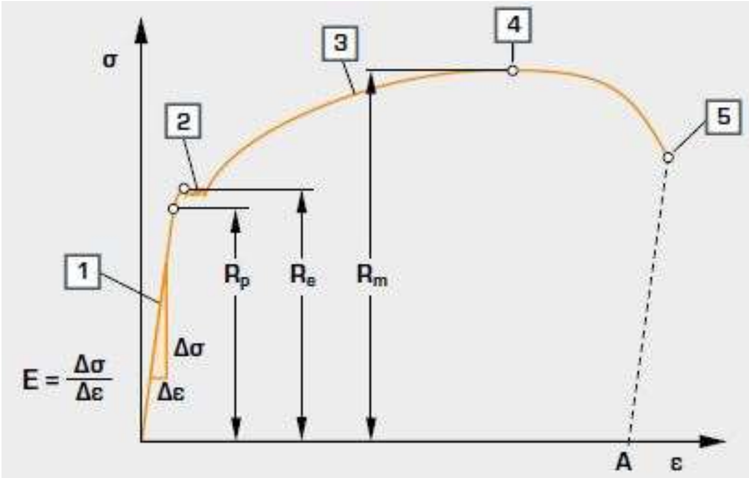


Figure 2.6 : The stress-strain diagram

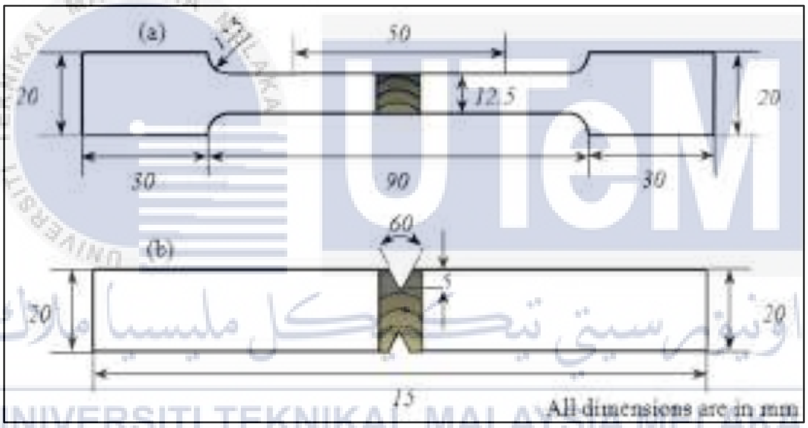


Figure 2.7 : Tensile test specimen

2.8.2 Hardness Testing

The Rockwell hardness test method is to use a diamond cone or hardened steel ball indenter to indent the test material. The indenter is usually 10kgf forced into the test material under a small preliminary load F0 (A). When equilibrium has been reached, an indicating device, which follows the movement of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position.

While the preliminary lower load is still applied, an additional major load is applied with an increased penetration (B) resulting. The additional major load is removed when equilibrium is reached, but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration as shown in **Figure 2.8**. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

The Rockwell hardness method's advantage includes the re-reading of the direct Rockwell hardness number and rapid testing time. The disadvantages include many non-related arbitrary scales and possible anvil supporting effects from the specimen. It shows the Rockwell hardness scale with a different type of indenters, load, application to be used and the material used in **Table 2.1** and **Table 2.2**.

HR = E – e

- F0 = preliminary minor load in kgf
- F1 = additional major load in kgf
- F = total load in kgf
- e = permanent increase in depth of penetrating due to major load F1 measured in units of 0.002 mm
- E = a constant depending on form of indenter : 100 units for diamond indenter, 130 units for steel ball indenter
- HR = Rockwell hardness number
- D = diameter of steel ball

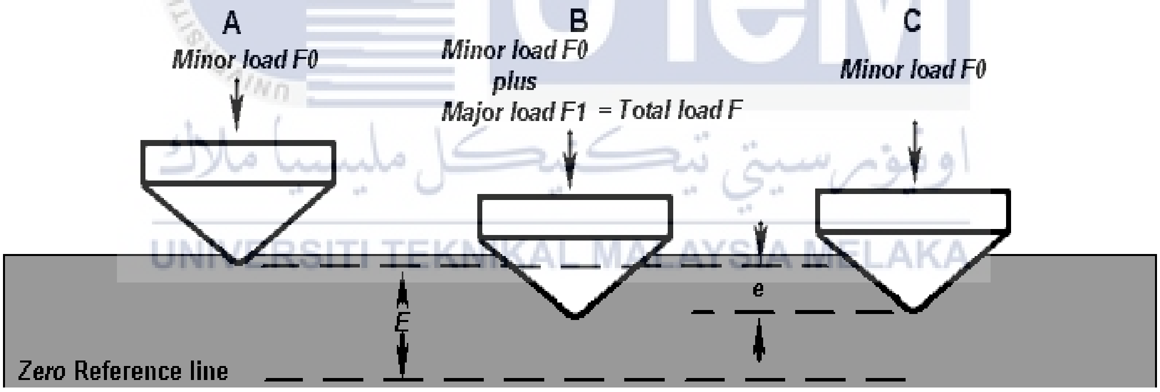


Figure 2.8 : Rockwell hardness test principle. Preliminary load (A), penetration (B)

(Source: https://www.gordonengland.co.uk/hardness/rockwell.gif)

Table 2.1 : Rockwell hardness scale with different type of indenter and loads

(Source: https://www.gordonengland.co.uk/hardness/rockwell.gif)

Scale	Indenter	Minor Load F0 kgf	Major Load F1 kgf	Total Load F kgf	Value of E
A	Diamond cone	10	50	60	100
B	1/16" steel ball	10	90	100	130
C	Diamond cone	10	140	150	100
D	Diamond cone	10	90	100	100
E	1/8" steel ball	10	90	100	130
F	1/16" steel ball	10	50	60	130
G	1/16" steel ball	10	140	150	130
H	1/8" steel ball	10	50	60	130
K	1/8" steel ball	10	140	150	130
L	1/4" steel ball	10	50	60	130
M	1/4" steel ball	10	90	100	130
P	1/4" steel ball	10	140	150	130
R	1/2" steel ball	10	50	60	130
S	1/2" steel ball	10	90	100	130
V	1/2" steel ball	10	140	150	130

Table 2.2 : Rockwell hardness scale with different type of application and material

(Source: https://www.gordonengland.co.uk/hardness/rockwell.gif)

Rockwell Scales	Application
HRA	Cemented carbides, thin steel and shallow case hardness stee;
HRB	Copper alloys, soft steel, aluminium alloys, malleable irons, etc.
HRC	Steel, hard cast iron, case hardened steel and other material harder than 100 HRB
HRD	Thin steel and medium case hardened steel and pearlitic malleable iron
HRE	Cast iron, aluminium and magnesium alloys, bearing metals
HRF	Annealed copper alloys, thin soft sheet metals
HRG	Phosphor bronze, beryllium copper, malleable irons
HRH	Aluminium, zinc, lead
HRK	
HRL	
HRM	
HRP	Soft bearing metals, plastics and other very soft materials
HRR	
HRS	
HRV	

2.9 Non-Destructive Testing (NDT)

Non-destructive testing may be a wide gather of inspection techniques used in science and technology industry to assess the properties of material, component or system without causing harm. The terms non-destructive examination (NDE), non-destructive review (NDI) and non-destructive assessment (NDE) are too commonly utilized to portray this technology. Since NDT does not for all time modify the article being assessed, it may be a profoundly profitable method that can save both cash and time in item assessment, investigating, and research. There are six commonly used NDT methods, such as visual testing, penetrant testing, magnetic particle testing, ultrasonic testing, eddy current testing, and radiographic testing (Inspection, Particle and Current, 2010).

However, all of these techniques in particular requiring standard operator and translating results may be difficult because the result can be subjective. NDT can be performed on metal, plastic, ceramics, composite, cermet, and coatings in order to identify cracks, internal voids, surface cavities, delamination, incomplete or defective welds and any type of imperfection that seem lead to untimely disappointment (Inspection, Particle and Current, 2010).

2.9.1 Penetrant Testing (PT)

Penetrant testing is one of the broadly utilized non-destructive assessment method. Let is see why this penetrant testing is very widespread and popular, because it is easy to use and its flexibility. The method is based on the capacity of a fluid to be drawn into a "clean' surface breaking imperfection by capillary action. This technique is a cheap and helpful technique for defect detected on the surface. The weakness of the technique of penetrating liquid includes not being able to examine the weakness of the inner surface. Liquid penetrant testing is commonly used on nonmagnetic material. For example, aluminium, copper, steel, and titanium. Liquid penetrant is utilized to examine of imperfection that break the surface of the test such as fatigue cracks, quench cracks, grinding cracks, overload and impact fractures, porosity, laps seams, pin holes in weld, lack of fusion or braising along the edge of the bond line (Inspection, Particle and Current, 2010),(Guirong *et al.*, 2015).

2.9.2 Ultrasonic Testing

Ultrasonic are the sound waves whose frequency is between 0.5 and 15 kHz. Due to the high frequency they have great entering control (Kogias, 2007). When sound waves propagate from one medium to another a half of the sound energy is restored and the other half is transmitted on the interface separating the two media. The waves are produced by utilizing either a piezoelectric energised crystal cut in a specific design to create the specified wave mode or an electromagnetic acoustic transducer. If the ultrasonic wave propagates from a medium of higher density into a medium of lower density than the maximum reaction of intensity takes place at the interface separating the two media.

There are several functional units, for example pulses/receivers, transducers, and display devices in this inspection. A pulses/receiver is device that produces high voltage electric pulses. Driven by pulsers, the transducer generates high frequency ultrasonic energy. Pulse approach and amplitude scan (Bernieri *et al.*, 2018). The resulting of sound energy and then transmitted through material in the form of waves. If there is a defective surface in the wave path, sounds energy will be reflected back from the flaw surface. The reflected wave signal is changed into an electrical signal by the transducer and is shown on a screen (Kogias, 2007). This process shown in **Figure 2.9.**

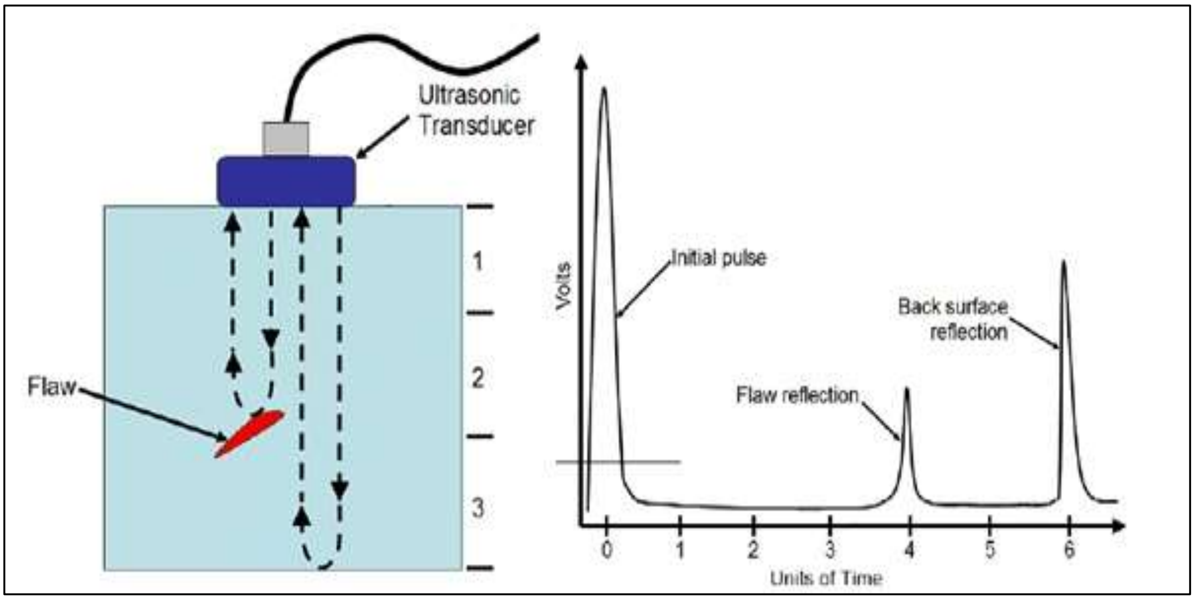


Figure 2.9 : Travel of wave

CHAPTER 3

METHODOLOGY

3.1 Introduction

The purpose this chapter is to detail the description about how the project can be implemented to full fill the task given. Each aspect of project implementation is discussed. The chapter begins with a description of overall implementation process. Investigation of microstructure and hardness or strength of Shielding Metal Arc Welding (SMAW) is explained thoroughly. The desire to compare both high productivity of welding in term of microstructure analysis and mechanical characteristic process forms one of the main reasons for the increasing interest in. in the present study, dual phase steel is an advanced high strength steel plate, with a ferrite martensitic microstructure. It was subjected to both welding. The selection of adequate filler metal and heat input with respect to weld metal and strength will be discussed, and microstructure and mechanical properties process used with both welding processes, as well as heat treatment where our dual phase steel made. Finally, the appearance of our study material will be studies into, ore detail in the next chapter.

3.2 Flow Chart

The project flow chart can be a diagram of a sequence that explains the flow of activities from the beginning to the end of the project. This flow chart can accurately describe the method involved and ensure that the ultimate outcome can achieve the project's objective.

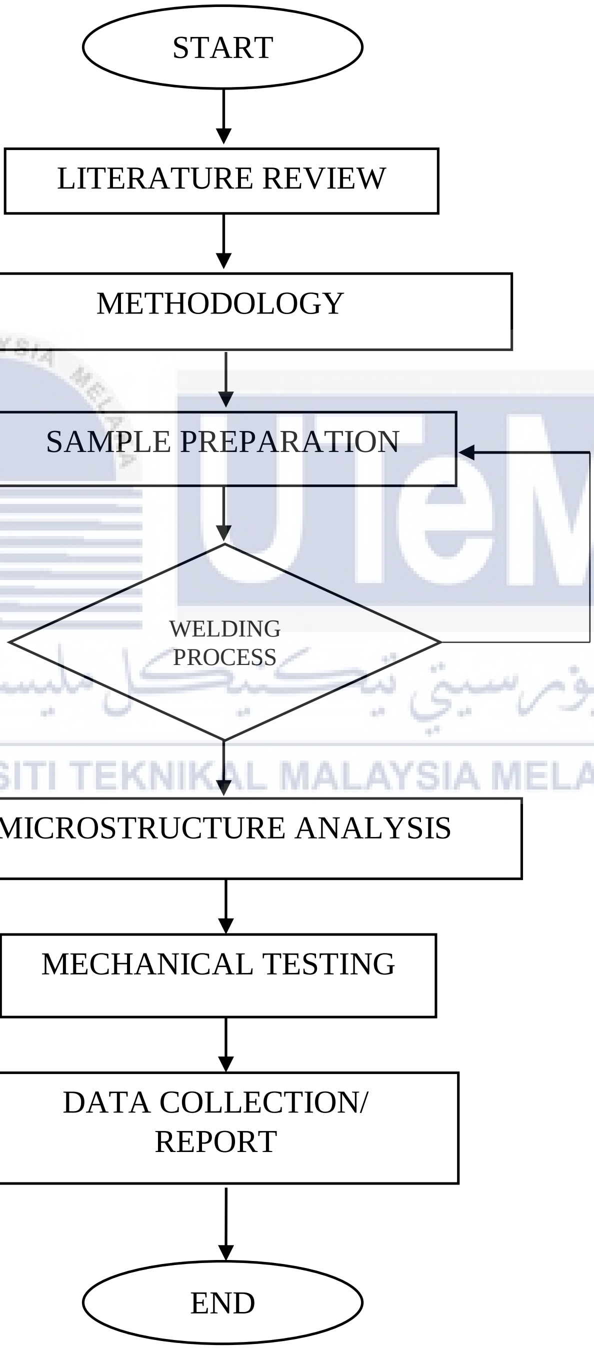


Figure 3.1 : Project flow chart

3.3 Gantt Chart

Table 3.3 : Gantt chart table

No	Task	Week														
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Received and discuss title with supervisor	■	■													
2	Searching article at internet and library	■	■	■	■											
3	Discussion progress report			■	■											
4	Preparation progress report				■	■										
5	Submission of progress report						■									
6	Meeting	■	■	■				■				■	■	■		■
7	Preparation chapter 2							■	■	■						
8	Discuss about literature review								■	■	■	■				
9	Checking literature review												■			
10	Preparation chapter 3											■	■			
12	Edit Psm 1 report													■	■	
13	Submission Psm 1 report														■	
14	Seminar															■

3.4 Sample Project

Material used for this project is mild steel. Divided into two characterize of specimen which is original mild steel and other characterize is the specimen will undergo heat treatment process in order to change the structure of the mild steel to become dual phase steel. The both of characterize will be used in the welding process. **Figure 3.2** shows specified for original mild steel and dual phase steel plate will be used in welding and then cutting the plate as shows in **figure 3.3** for the sample to testing in based on microstructure and mechanical properties.

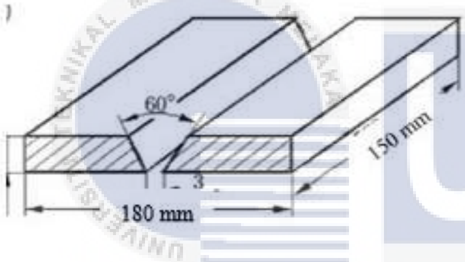


Figure 3.2 : Mild steel plate

Figure 3.3 : Sample

3.5 Sample Preparation

3.5.1 Cutting

Long mild steel is cut into desired length with 90mm x 150mm x 10mm as shown in **Figure 3.4** into to two set using band saw. First set is used for analysis microstructure and mechanical testing without dual phase steel and the second set is used for analysis microstructure and mechanical testing with dual phase steel. The both set is testing after welding process. Mild steel in both set also have several process before the welding process. The process are squaring and bevelling.

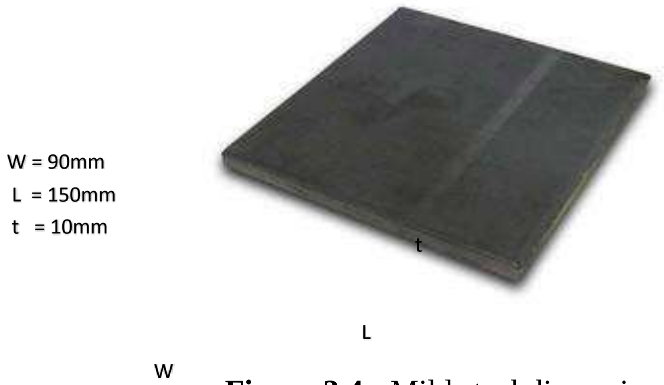


Figure 3.4 : Mild steel dimension

3.5.2 Bevelling

The bevel groove weld, in which the edge of one of the piece is chamfered and the other is left squared. The bevel symbol's perpendicular line is always drawn on the left side, regardless of the orientation of the weld itself. The arrow points toward the piece that is to be chamfered. This extra significance is emphasized by a break in the arrow line. For the experiment, the angle for bevelling is 30°. Bevel is done by using chamfering machine for automatically, but it can also use manually by using grinding. Bevel is done only at one edge. Bevel is done so that later when after welding process, the produced weld will be strong and it will not break under small force.

This preparation of butt joints plays an important role when the hardness testing for example tensile test (Prasad and Lingaraju, 2017). There are several types of bevel preparation before welding start, such as single V, single Y and double V. This research considers only on single Y for the groove bevel. as shown in **Figure 3.5.**

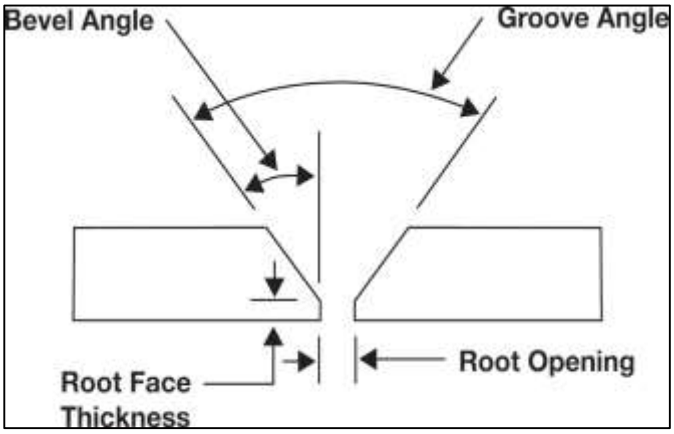


Figure 3.5 : Single Y groove

3.5.3 Heat Treatment

Heat treatment cycle restores ductility to a work piece allowing it to be worked further without breaking. Ductility is important in shaping and creating a more refined piece of work through process such as rolling, drawing, forging, spinning, extruding and heading. The piece is heated to a temperature typically below the austenizing temperature, and held there long enough to relieve stress in the metal. The piece is finally cooled slowly to room temperature. It is then ready again for additional cold working. Heat treatment is a combination of timed heating and cooling operation applied to a metal or alloy in the solid state in such ways as to produce certain microstructure and desired properties. For this experiment, the specimen will be heated at T_1 = 740°C , T_2 = 760°C, T_3 = 780°C, and T_4 = 800°C for 40 minutes in furnace respectively. After finish heating, the specimen will undergo quenching a raping cooling process using water as the medium. At the end of the heat treatment process, the specimen mild steel will transform into dual phase steel with improved strength and mechanical properties.

3.5.4 Welding Process

For this research, only one type of welding are considered on SMAW. The welding parameter for the process are show in **Table 3.2** below ;

Table 3.2 : Welding parameter

TYPE OF WELDING	SMAW
CURRENT TYPE	DIRECT
POLARITY	REVERSE
CURRENT INPUT (AMP)	90 – 120
ELECTRODE	E6013

Table 3.1 shown, there are four main variable for process welding which are the current type, polarity, current setting, and electrode. Type of current used at SMAW is direct current (DC). DC is utilized since it gives the specified welding scope's parameter. One is more important aspect in welding is welding polarity because it is sets the electron path. It has two option such as straight polarity or reverse polarity. For this research, the reverse polarity are considered for SMAW because it work well with the DC current and type of welding filler electrode. Current setting is between 90 – 120, over current input may cause defect on work piece for example under cut (Type, no date),(Baughurst, 2011), while less input current also will cause defect for such as lack of fusion during the melting process (Baughurst, 2011).

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Result and Discussion

4.1.1 Analyze microstructure of mild steel

Metallography or microscopy consists of the microscopic study of the structural characteristic of a metal or an alloy. Microscopic study depends largely upon the care taken in the preparation of the Mild steel. The ultimate object is to produce a flat, scratch free, like mirror surface. **Figure 4.1.** Etching need to apply before workpiece are seen on the microscope. The purpose of etching is two-fold grinding and polishing operating produce a highly deformed, thin layer on the surface which is removed chemically during etching. Secondly, the etchant attacks the surface with preference for those sites with the highest energy, leading to surface relief which allows different crystal orientations, grain boundaries, precipitates, phases and defects to be distinguished in reflected light microscope.

After etching operation our workpiece is ready for inspection. This time we used optical microscope plus screen image to view the microstructure of mild steel.

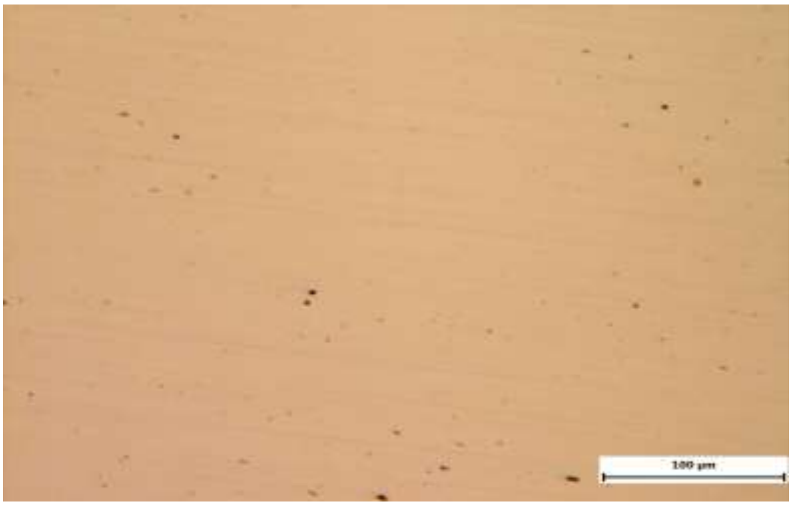


Figure 4.1 : Image mild steel like of mirror surface by using optical microscope (50x magnification)

4.1.2 Analyze microstructure of Dual Phase Steel

The critical temperature of the steel annealing was estimated using the equation of Andrew. The intercritical temperature were approximated as 740° C, 760°C, 760°C and 800°C. To study the effect of temperature on martensite formation, four specimens were selected. Specimens were heated for 40 minutes at different intercritical temperatures in the furnace and quenched in cold water to transform the austenite into martensite. The martensite formation involves coordinated atom movement. Martensite in steels is a supersaturated solid solution of carbon in ferritic iron. Martensitic transformation is diffusionless so the change in crystal structure is achieved by a homogeneous deformation of austenite. Stabilization means a reduction in the amount of austenite to martensite transformation resulting from processes that interfere with nucleation and growth of the plates. The first specimen was heated at a lower intercritical temperature of 740°C and for the following specimens the temperature is increased by 20°C until the upper intercritical temperature is reached. All specimen microstructure will be observed after the intercritical annealing process. Before the observation, specimens will be polished to obtain a shining surface.

Then, the etching process is done using etching solution suitable for steel which is 2% Nital to reveal the microstructures on the surface of the steel. The microstructure of the dual phase steel has been characterized as shown in **table 4.1.** Every micrograph's magnification is 50x. The micrographs in each temperature show the different percentage of martensite. The **Figure 4.2** is show the martensite form.

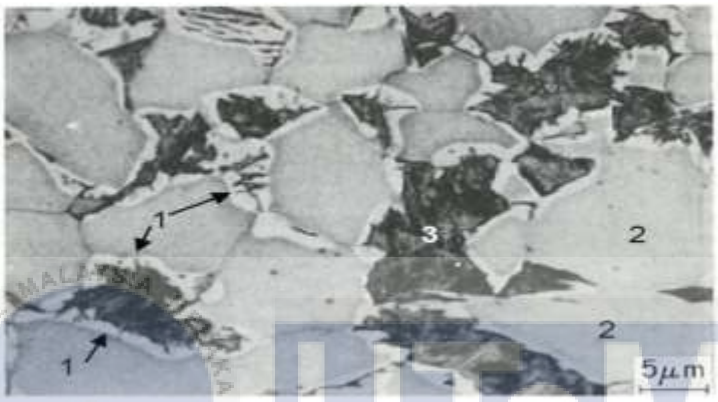
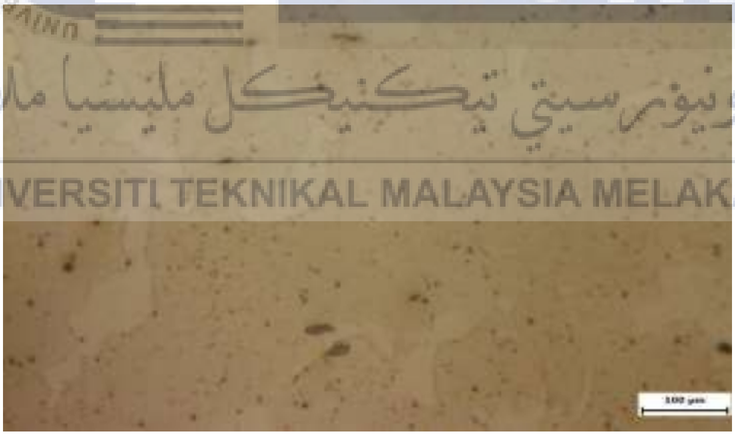


Figure 4.2 : Formation of ferrite and martensite. 1 is new ferrite. 2 is retained ferrite. 3 is martensite.

source : (Granbom, 2010)

Table 4.1. : Microstructure of dual phase steel with different intercritical annealing temperature

Temperature (°C)	Microstructure of DPS	Volume fraction of martensite (%)
740		5.5
760		9.0

780		14.0
800		19.7

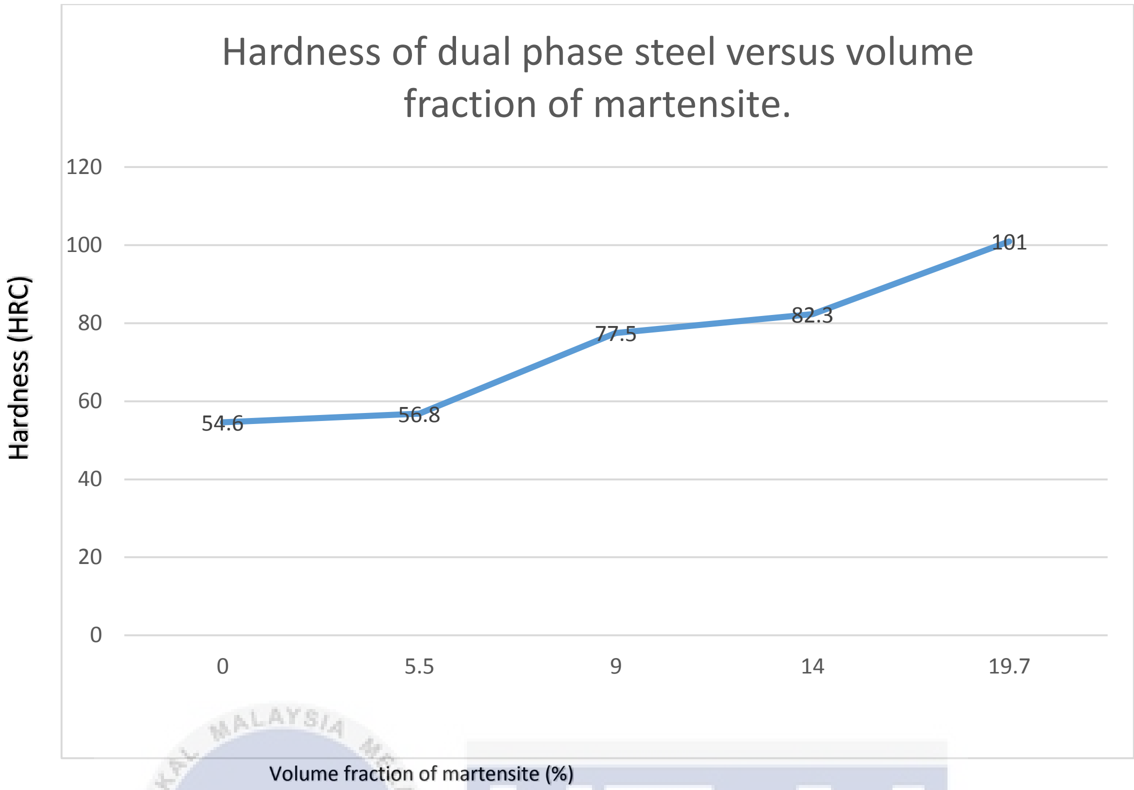
Ferrite is a solid solution of carbon in body centered cubic iron (BCC), pearlite is a dual phase microstructure resulting from austenite transformation of eutectoid composition and consist of alering layers or lamella of α ferrite cementite. The micrograph shows that there are two phase, ferrite (white region) martensite (dark area). The percentage volume fraction of martensite in Dual phase steel is influenced by variation in the temperature of the intercritical annealing. The higher intercritical temperature of annealing, the higher the percentage of the martensite volume fraction obtained in dual phase steel. This is because more pearlite will change to austenite when the intercritical annealing temperature increases. Austenite is then transformed by rapid cooling into martensite.

4.1.3 Analyze of hardness testing

The indentation is done in Rockwell hardness tester for determining the hardness of the quenched materials. It’s performed in accordance to ASTM A370-14 standard. To find hardness, the "C scale" is taken. Rockwell Hardness is probably the most common method of hardness testing since it is simple and self - contained. An indenter was used with the 120° diamond cone. For penetration, the load of 150 kg is applied. Durability is measurement at 3 or 4 different locations of each test sample and then average value is taken. The experimental results at **table 4.2** show that dual phase steels have excellent mechanical properties in terms of hardness.

Table 4.2 : Result of hardness testing on how many volume fraction of martensite

Temperature (°C)	Volume Fraction of martensite (%)	Hardness (HRC)
0	0	54.6
740	5.5	56.8
760	9.0	77.5
780	14.0	82.3
800	19.7	101.0



The graft above shows the hardness value of dual phase steel and low carbon steel. The hardness of the dual phase steel are increase by increasing the percentage of martensite. The hardness of dual phase steels is higher than the low carbon steel is due to the formation of martensite after quenching which will increase the strength of the mild steel from the hardness testing. The dual phase steel has better hardness properties as it consists of ferrite and martensite structures. Steel is ‘austenitic’ and has Face-Centered Cubic (FCC) structure. At this temperature it transforms to ‘ferrite’ which has Body-Centered Cubic (BCC) structure. When carbon is sitting in between these Fe atoms during the phase change, the Fe atoms will try to rearrange themselves from FCC to BCC , and carbon will diffuse out and form Fe_3C or that is call cementite. When cooled quickly (quenched) the carbon does not have enough time to diffuse out to form cementite, and martensite, a Body-Centered Tetragonal (BCT) structure is formed instead of ferrite which has 0.2 wt % carbon and is actually very solf. Martensite is incredibly brittle because BCT is essentially a shared state of BCC, and can exhibit a lot of stress and more hardness. Martensite is a metastable iron phase supersaturated in carbon that is the product of a diffusion less transformation of austenite. The hardness in martensite is the result of severe lattice distortions produced by its formation, since the amount of carbon present is significantly higher than in solid solution.

4.1.4 Analyze of welding zone

The microstructure of dual phase steel for welding were the same. From **Figure 4.3 (a)** seen that the transition period between the base metal and the welding. The transiting was called the heat affected zone (HAZ). The SMAW welding there were some defects detected which was porosity and slag. As for the SMAW welding the difference between welding area and the base metal was clearly seen because the welding electrode used was E6013 which don't carry the dual phase steel properties.

Figure 4.3 : Seen that the transition period between the base metal and the welding. Welding area (1), HAZ (2), base metal (3)

One the microstructure of the welding, size of the welded area SMAW is almost the same like base metal and darker more to welded area. **Figure 4.4**. Welding heat influenced the grain sizes of the welding and indirectly influenced the material's hardness. Welding technique plays an important role in finding the results and achieving a specification as follow in standard. The current polarity and welding polarity play important roles in producing a strong weld.

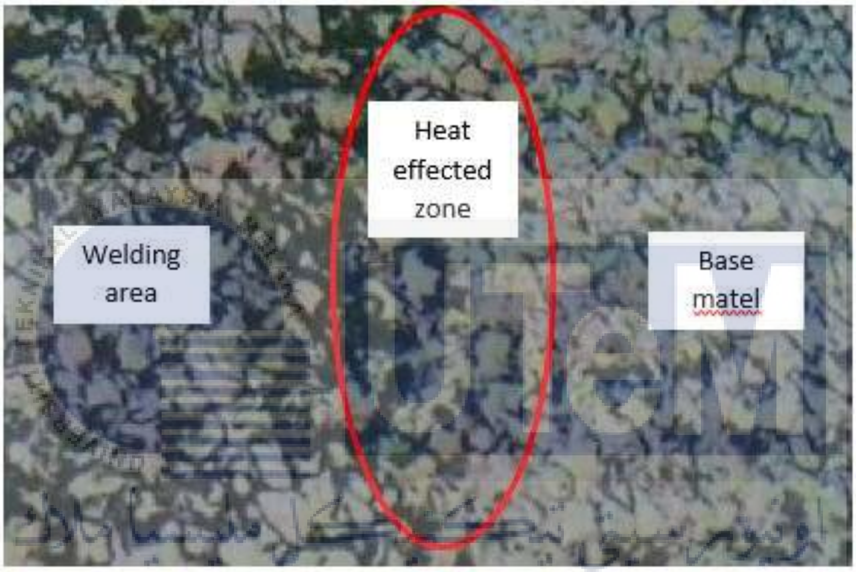


Figure 4.4 : Magnification of 200x

4.1.5 Analyze of welding fracture

Weld quality assurance is the use of technological methods and measures to test or ensure weld quality, and secondarily to confirm the presence, location and cover of welds. Welds are used to join two or more metal surfaces in the manufacturing process due to the fact that these connections may encounter loads and fatigue during the lifetime of the product, there is a chance that they may fail if not created according to proper specification. Fatigue is material weakening due to repeated loads. It is the progressive and localized structural damage that happens when a material is cyclically loaded. The nominal maximum stress values that cause such damage can be significantly lower than the material strength typically quoted as the ultimate tensile stress limit, or the yield stress limit. **Figure 4.5** is specimen after tensile test and **Figure 4.6** cross section of fracture.

Figure 4.5: Specimen fracture

Figure 4.6: The cross section of fracture

4.1.6 Analyze of weldability using tensile test

Tensile test specimens are prepared in accordance with the standard ASTM E8-09. Tensile tests are performed using Universal Testing Machine (UTM) of 500 KN capacity. Tensile strength of SMAW of mild steel with butt joint for each observation. Tensile strength of welded test specimen depending upon the welding condition. 10 mm thick with single Y groove. The tensile strength using Y groove surface preparation is found more than simple butt joint without surface preparation. This is due to high depth of penetration of molten metal in the joint. The results as show in **Table 4.3**

Table 4.3 : Results of tensile

Specimen	Volume Fraction of martensite (%)	Maximum Load (KN)	Tensile stress at Maximum Load (Mpa)	Tensile strain (Extension) at Maximum Load (mm/mm)	Modulus [Chord – Cursor] (MPa)	Modulus [Automatic Young's] (Mpa)	Modulus [E-modulus] (Mpa)
Mild Steel (A5)	0	79.77	7977.31	0.071	534992.279	638655.303	562006.101
740°C (A4)	5.5	75.89	7588.98	0.041	585084.900	671112.417	576116.572
760°C (A3)	9.0	82.32	8232.4	0.060	540897.458	622417.793	570091.658
780°C (A2)	14.0	68.73	6873.08	0.021	476682.803	579590.379	510007.021
800°C (A1)	19.7	70.01	7001.43	0.019	517288.296	634258.387	564365.975

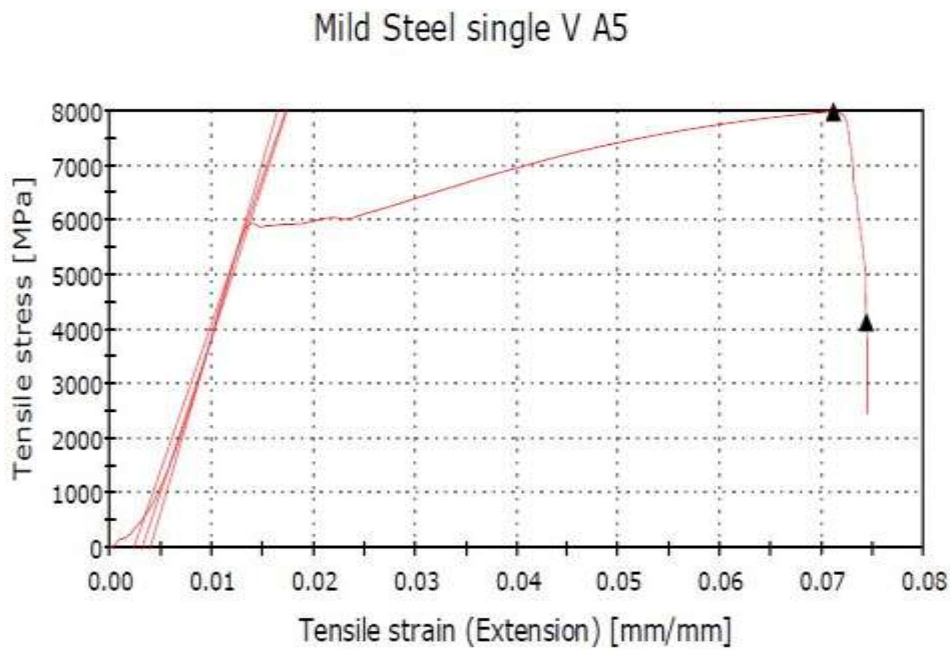


Figure 4.7 : Graph stress strain curve for (A5)

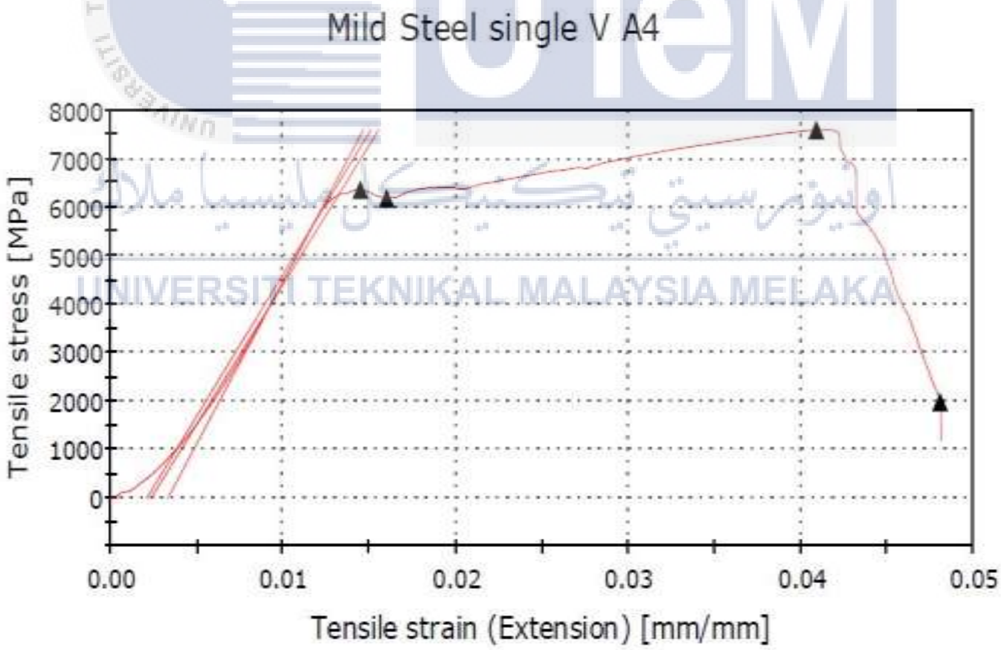


Figure 4.8 : Graph stress strain curve for (A4)

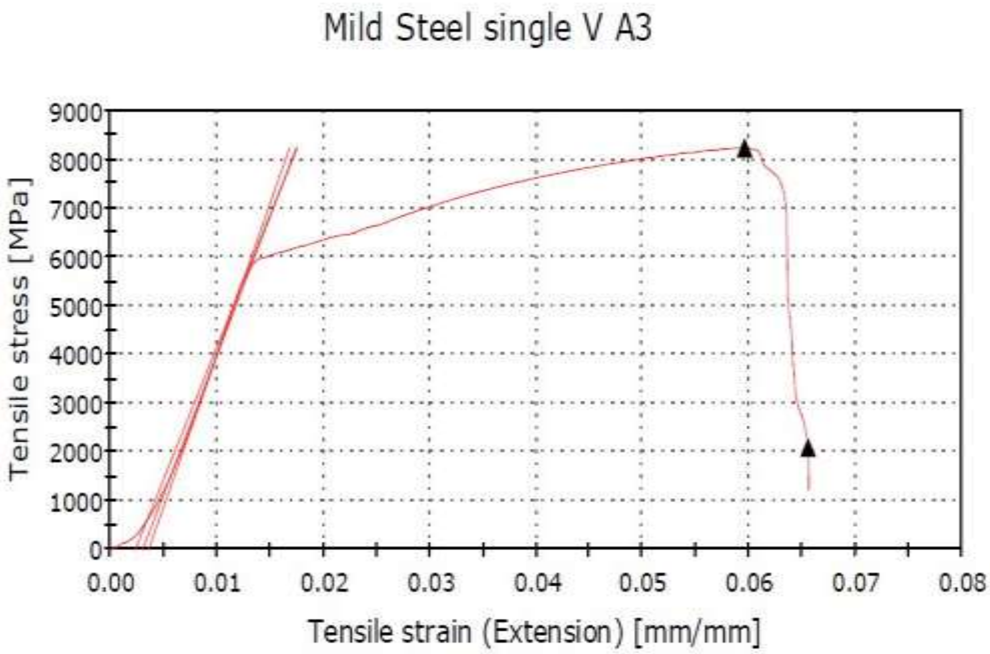


Figure 4.9 : Graph stress strain curve for (A3)

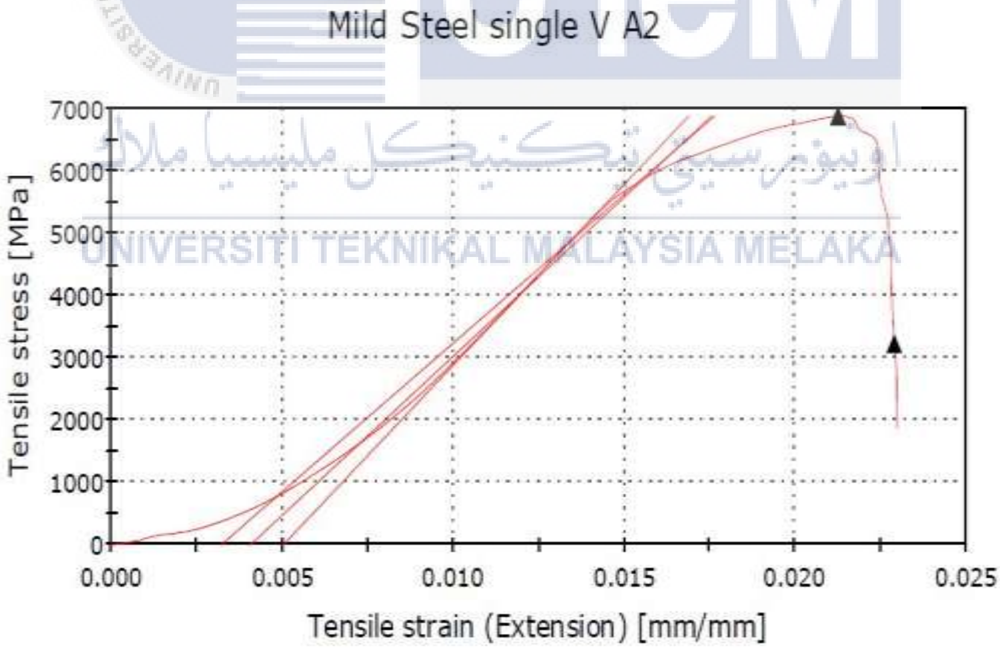


Figure 4.10 : Graph stress strain curve for (A2)

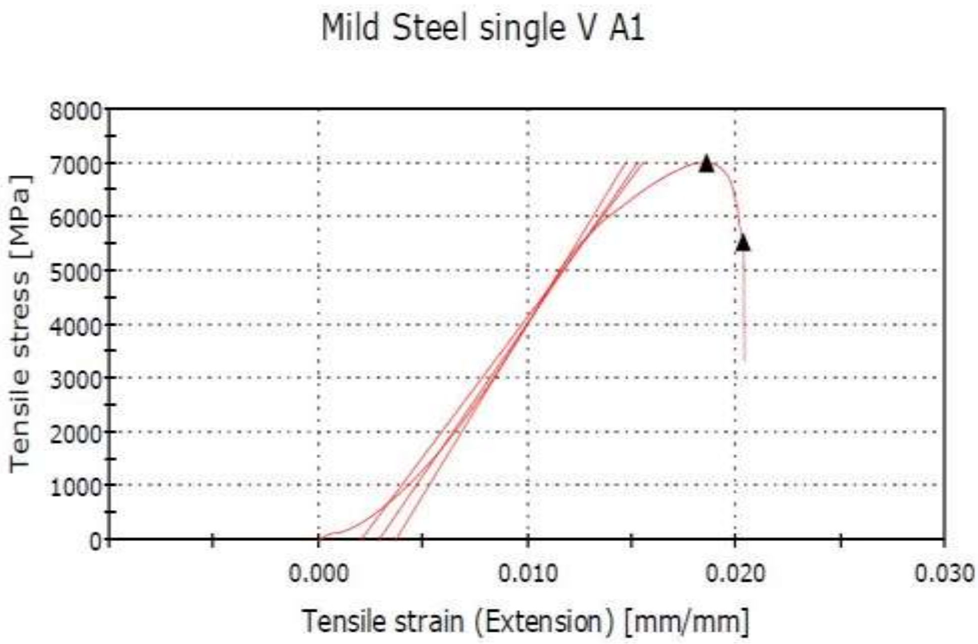


Figure 4.11 : Graph stress strain curve for (A1)

From the **Table 4.3** show the higher tensile stress is specimen A3. The value tensile strength is 8232.4 Mpa with 9.0% of volume fraction of martensite. While the lower value of tensile stress is 7001.43 Mpa but A1 have a lot of volume fraction of martensite which is 19.7%. This testing we conclude the highest temperature, the highest of volume fraction of martensite. It will affect the tensile result because the volume fraction of martensite is too much. So the specimen is more brittle and low the weldability characteristic. In this observation the hardness increase with high annealing temperature due to formation and volume fraction of martensite at the certain point it already reduces the weldability characteristic of Dual Phase Steel. However, the hardness increase with high annealing temperature due to formation of martensite.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The overall objective of this project has been achieved. Dual phase steel mechanical properties and microstructure analysis had been analysed and studied, and also shielded metal arc welding. The hardness of the steel was determined from the experiment result.

In term of microstructure observation there was quite difference in percentage of martensite while in difference annealing temperature. There was quite same in grain size between the welded area and the base metal.

Based on the course of the project, the knowledge on welding process was gained especially on microstructure, shielded metal arc welding and metal hardness with difference temperature annealing. The knowledge on the production of dual phase steel was gained from the heat treatment process. For the microstructure analysed use good etching to see clearly of microstructure.

The exact result of the experiment can be improved in some ways. First is the specimen's preparation. Before joining, the welding area must be clean and bevelled (for butt joint). It must be done thoroughly for polishing until all the rust and scratches are gone. Finally, in order to get a better reading of the scale, the hardness test material needs to be precisely flat and free of rust. Finally, this study already achieved all its objective. The mechanical properties and microstructure belongings were discovered. Some improvements can be made to improve this research.

5.2 Recommendation

Several improvements need to be made for future research in order to achieve better results. Suggestion for improvement are as follows :

- Using a better cleaning solvent, the specimen must be clean and free of dust and scratches, an example diamond paste to ensure that there is no impurity on the material surface before microscopic view.
- Welding needs to be improved because the most critical part of this experiment was the welding point.
- welding parameters such as feed rate, current, and voltage need to be adjusted. Therefore, in order to produce better welding, the feed rate will affect the microstructure either slowly or quickly.
- A better view of microstructure, scanning electron microscope (SEM) or transmission electron microscope can be used.
- The exact heat treatment temperature must be followed in accordance with the time required to prevent overheating and quenching in a better heat stand case must be done as quickly as possible.
- The indenter chosen to hardness test must be accurate with the material used and the scale also follows.

REFERENCES

1) McHenry, M. E. and Laughlin, D. E. (2014) Magnetic Properties of Metals and Alloys. Fifth Edit, Physical Metallurgy: Fifth Edition. Fifth Edit. Elsevier B.V. doi: 10.1016/B978-0-444-53770-6.00019-8.
2) Nadlene, R. et al. (2011) 'Study on the Effect of Volume Fraction of Dual Phase Steel to Corrosion Behaviour and Hardness', 5(2), pp. 393–396.
3) Caprili, S. et al. (2018) 'A new generation of high-ductile Dual-Phase steel reinforcing bars', Construction and Building Materials. Elsevier Ltd, 179, pp. 66–79. doi: 10.1016/j.conbuildmat.2018.05.181.
4) Tasan, C. C. et al. (no date) 'An Overview of Dual-Phase Steels : Advances in Processing and Micromechanically Guided Design'. doi: 10.1146/annurev-matsci-070214-021103.
5) Covered, T. and Composition, C. (2012) 'AISI 1018 Mild / Low Carbon Steel', pp. 1–4.
6) Silvestre, E. et al. (2015) 'International Journal of Mechanical Sciences Comparison of the hardening behaviour of different steel families : From mild and stainless steel to advanced high strength steels', International Journal of Mechanical Sciences. Elsevier, 101–102, pp. 10–20. doi: 10.1016/j.ijmecsci.2015.07.013.
7) Pérez, M. (2017) 'Materials Science & Engineering A Impact of annealing treatments on the softening and work hardening behaviour of Jethete M152 alloy for subsequent cold forming processes', Materials Science & Engineering A. Elsevier B.V., 690(March), pp. 303–312. doi: 10.1016/j.msea.2017.03.012.

8) Ghosh, P. K. et al. (1991) 'Weldability of Intercritical Annealed Dual-Phase Steel with the Resistance Spot Welding Process', Welding Journal, 70, pp. 7–14.

9) Ennis, B. L. et al. (2018) 'Work hardening behaviour in banded dual phase steel structures with improved formability', Materials Science and Engineering A. Elsevier B.V., 713(December 2017), pp. 278–286. doi: 10.1016/j.msea.2017.12.078.

10) 'Belt Linishing Machine' (no date).

11) Granbom, Y. (2010) Structure and mechanical properties of dual phase steels – An experimental and theoretical analysis, School of Industrial Enginnering and Management - Division on Mechanical Metallurgy.

12) Van Aken, D. C. (1999) 'Continuous cooling transformation diagrams', Industrial Heating, 66, p. 20. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-77950093625&partnerID=40&md5=6a35ad90383ac5fbe4938af1caf3823c.

13) Ebner, S. et al. (2018) 'Microstructure and mechanical properties of a low C steel subjected to bainitic or quenching and partitioning heat treatments', Materials Science and Engineering A. Elsevier B.V., 735(August), pp. 1–9. doi: 10.1016/j.msea.2018.08.026.

14) Address, I. T. O. (no date) 'CHAPTER 9 : Phase diagrams The Solubility limit'.

15) Jiang, J. et al. (2018) 'Effect of welding and heat treatment on strength of high-strength steel columns', Journal of Constructional Steel Research. Elsevier Ltd, 151, pp. 238–252. doi: 10.1016/j.jcsr.2018.09.027.

16) Circuit, B. W. (no date) 'Arc-Welding'.

17) Article, H., Bagnoli, F. and Livi, R. (2018) 'Michael Faraday: a virtuous life dedicated to science', 2, pp. 121–134. doi: 10.13128/substantia-45.

18) Ii, B. A. B. and Pustaka, T. (no date) '2(g) +', (C), pp. 5–17.

19) Granbom, Y. (2010) Structure and mechanical properties of dual phase steels – An experimental and theoretical analysis, School of Industrial Enginnering and Management - Division on Mechanical Metallurgy.

20) Stan-, A. (1998) ‘Mechanical Testing : Methods’, p. 80.

21) Inspection, V., Particle, M. and Current, E. (2010) ‘Non-Destructive Testing’, *Instrumentation Reference Book*, pp. 567–592. doi: 10.1016/B978-0-7506-8308-1.00031-0.

22) Guirong, X. *et al.* (2015) ‘Analysis and Innovation for Penetrant Testing for Airplane Parts’, *Procedia Engineering*, 99, pp. 1438–1442. doi: 10.1016/j.proeng.2014.12.681.

23) Kogias, G. (2007) ‘Introduction to Non-Destructive Testing Techniques’, *High frequency ultrasonic testing*, 4, pp. 1–36.doi:10.1016/B978-0-12-391916-8.00026-1.

24) Bernieri, A. *et al.* (2018) ‘Ultrasonic NDT on aluminum bars: An experimental performance comparison of excitation and processing techniques’, *Measurement: Journal of the International Measurement Confederation*. Elsevier, 128(October 2017), pp. 393–402. doi: 10.1016/j.measurement.2017.10.040.

25) Prasad, V. V. and Lingaraju, D. (2017) ‘Effect of Different Edge Preparations on the Tensile and Hardness Properties of Gtaw Welded 6082 Aluminum Alloy’, *Materials Today: Proceedings*. Elsevier Ltd, 4(2), pp. 157–165. doi: 10.1016/j.matpr.2017.01.009.

26) Test, B. H. (2015) ‘Mechanical properties laboratory practice guide Hardness test methods’, pp. 1–13.

27) Load, S., Tester, S. and Tester, S. (no date) ‘No Title’.

28) Type, W. (no date) 'Causes and Cures of Common Welding defects Defect : Blow Hole'.

29) Baughurst, L. (2011) 'Welding Defects , Causes & Correction', (October).

APPENDICES

Gantt chart table PSM I

No	Task	Week														
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Received and discuss title with supervisor							M								
2	Searching article at internet and library							I								
3	Discussion progress report							D								
4	Preparation progress report							T								
5	Submission of progress report							E								
6	Meeting							R								
7	Preparation chapter 2							M								
8	Discuss about literature review															
9	Checking literature review							B								
10	Preparation chapter 3							R								
12	Edit Psm 1 report							E								
13	Submission Psm 1 report							A								
14	Seminar							K								

Gantt chart table PSM II

No	Task	Week														
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Cutting the material	■								M						
2	Material polishing		■					■	■	I				■		
3	Discussion/ preparing progress report			■	■					D						
4	Heat treatment					■	■			T						
5	Submission of progress report							■		E						
6	Meeting	■			■					R	■			■		■
7	Hardness testing									M	■	■				
8	Microstructure analysis			■								■				
9	Weld the joint									B		■	■			
10	Tensile test									R				■		
12	Preparing/Edit Final PSM report				■	■	■	■		E				■	■	
13	Submission Final PSM report									A					■	
14	Final Seminar									K						■