STRENGTH OF THE WELDED MEDIUM CARBON STEEL

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DECLARATION

I hereby declare that this thesis entitled "Strength of The Welded Carbon Steel" is the result of my own work research as cited in the references.

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APPROVAL

I declare that I have read this study report and in my opinion, this is sufficient in terms of scope and quality for the award of degree of Bachelor of Mechanical Engineering.

Signature	:	……………………….
Supervisor’s Name	:	Dr. Kamarul Ariffin Bin Zakaria
Date	:	………………………..

DEDICATION

To my beloved parents and family.

ABSTRACT

The idea to make this study is when the process of joining steel in various type of industries has been cause discontinuities to happen and this will lead to dangerous consequences. For an example, the use of medium carbon steel in railway application. If this discontinuity happens, the train can slip from the rail and causing danger to the passengers. The objective of this project is to study the effect of welding parameter to the tensile strength of the medium carbon steel. In this study, medium carbon steel type of specimen had been used. The specimens have been cut into half before it can proceed to the welding processes. For the welding processes, Metal Inert Gas (MIG) welding has been used to weld the specimens by three parameters that had been decided to be analyze and after that, the tensile test had been done using the Instron Universal Testing Machine (Model 5969). The parameter that used in this study was decided based on the MIG welding machine that being used which is WIM MIGWeld 210. One of the parameters is the weld joint. Different weld joint being tested to identify the most suitable weld joint to get the optimum tensile strength. The different weld joint includes the single transverse fillet, double transverse fillet and square butt where at the end of this study, it is proved that double transverse fillet weld joint gives the optimum tensile strength. The next parameter used is the welding feed speed. Three different welding feed speed is chosen which are 8.5 m/min, 10.2 m/min ad 11.9 m/min respectively. From the tensile test, it is concluded that, the higher the value of the welding feed speed, the higher the tensile strength of the material. Lastly, the parameter of welding voltage also used in this study where voltage of 223.3 V, 226.6 V and 229.9 V is applied and the result shows that the low voltage give better tensile strength for the medium carbon steel.

ABSTRAK

Idea untuk membuat kajian ini adalah apabila proses percantuman antara besi dalam pelbagai jenis industri telah menyebabkan ketidakpatuhan berlaku dan ini akan membawa kepada akibat berbahaya. Sebagai contoh, penggunaan besi karbon sederhana dalam aplikasi kereta api. Sekiranya kekurangan ini berlaku, kereta api boleh tergelincir dari laluan dan menyebabkan bahaya kepada penumpang. Objektif projek ini adalah untuk mengkaji kesan parameter kimpalan kepada kekuatan tegangan besi karbon sederhana. Dalam kajian ini, spesimen jenis besi karbon sederhana telah digunakan. Spesimen telah dipotong menjadi setengah sebelum ia boleh meneruskan proses kimpalan. Untuk proses kimpalan, kimpalan Metal Inert Gas (MIG) telah digunakan untuk mengimpal spesimen dengan tiga parameter yang telah diputuskan untuk dianalisis dan selepas itu, ujian tegangan telah dilakukan menggunakan Mesin Ujian Universal Instron (Model 5969). Parameter yang digunakan dalam kajian ini diputuskan berdasarkan mesin kimpalan MIG yang digunakan iaitu WIM MIGWeld 210. Salah satu parameter ialah sambungan kimpal. Sambungan kimpalan yang berbeza diuji untuk mengenal pasti sambungan kimpalan yang paling sesuai untuk mendapatkan kekuatan tegangan optimum. Sambungan kimpalan yang berbeza termasuk filet melintang tunggal, filet melintang ganda dan kotak persegi di mana pada akhir kajian ini, dibuktikan bahawa sendi kimpal filet melintang ganda memberikan kekuatan tegangan optimum. Parameter seterusnya yang digunakan ialah kelajuan suapan kimpalan. Tiga suapan kimpalan yang berbeza dipilih iaitu 8.5 m / min, 10.2 m / min ad 11.9 m / min masing-masing. Dari ujian tegangan, disimpulkan bahawa, semakin tinggi nilai kelajuan makanan kimpalan, semakin tinggi kekuatan tegangan bahan. Akhir sekali, parameter voltan kimpalan juga digunakan dalam kajian ini di mana voltan 223.3 V, 226.6 V dan 229.9 V digunakan dan hasilnya menunjukkan bahawa voltan rendah memberikan kekuatan tegangan yang lebih baik untuk besi karbon sederhana.

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First and foremost, all praise to Allah for giving me strength, determination and blessings to complete this study. With His continuous grace and mercy, I was able to survive especially during the tenure of my research.

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Next, I want to acknowledge my beloved parents and sibling wo has been giving me the moral supports to keep going in my bachelor’s degree journey. Lastly, special thanks to my close friends and housemates who have been going through this phase together and kept encourage one another. Without them all I would not be able to complete this successfully.

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LIST OF SYMBOLS AND ABBEREVATIONS

MIG	-	Metal Inert Gas
GMAW	-	Gas Metal Arc Welding
AISI	-	American Iron and Steel Institute
ASTM	-	American Society for Testing and Materials
UTS	-	Ultimate Tensile Strength
A	-	Ampere
V	-	Volt
GPa	-	Gigapascal
MPa	-	Megapascal

CHAPTER 1

INTRODUCTION

1.1 Background

Carbon steel or also known as plain carbon steel is an iron-based alloy with present of carbon which act as a powerful alloying agent. This carbon content is in amount of less than about 2% and different carbon content can give different characteristic (Gandy, 2007). The increases in carbon can make the strength and the hardness of the steel increase besides lowering the ductility of the steel (Hughes, 2014).

According to American Iron and Steel Institute (AISI), steel can be categorized as carbon steel when no minimum content is specified for cobalt, molybdenum, tungsten, nickel, titanium, niobium, chromium, zirconium or vanadium, or any other element to be added to obtain a desired alloying effect. The mechanical properties can be improved by the increase of carbon concentration that dissolved in austenite prior to quenching (Odusote, Ajiboye, & Rabiu, 2015).

Basically, there are 4 types of carbon steel which includes low carbon steel, medium carbon steel, high carbon steel and very high carbon steel. Low carbon steel or also known as mild steel composed from 0.15% to 0.45% of carbon . Due to its low carbon content, the tensile strength is lower hence it is neither externally brittle nor ductile (Jaypuria, 2008). It is a low-cost material that is easy to shape, and its surface hardness can be increase by carburizing. The other type of carbon steel is medium carbon steel which have 0.45% to 0.8% of carbon composition. Medium carbon steel is ductile and strong, with long-wearing properties. Carbon in steel reduce the tendency of atoms to slide past each other henceforth making it harder than iron and to add it up, the presence of elements such as manganese and chromium will act as the hardening agent (Ismail, Khatif, Kecik, & Shaharudin, 2016). High carbon steel in other hands, is composed with 0.8% to 1.5% carbon. It is very strong and holds shape memory well, making it ideal for springs and wire. Lastly, very high carbon steel is made from 0.96% to 2.1% carbon and because of this, it becomes an extremely strong material. This grade requires special handling due to its brittleness.

Typically, medium carbon grades are employed in conjunction with alloys such as nickel, molybdenum and chromium. Products of medium grades carbon steel are mostly in general mechanical engineering which include the gears, shafts, bearings, tools and other machine components that require optimal combinations of strength and toughness (Cambridge University, 2003). Despite the brittleness of this medium carbon steel, it has a high tensile strength and ductility compared to other forms of steel, make it the preferred choice.

As stated earlier, the carbon content of medium carbon steel is between 0.45% to 0.80% . After fabrication, this type of steel may be heat treated and may be used for general machining. Depending on the carbon content and the thickness of the steel, it should be preheated from 300 to 500°F (149 to 260°C). There is various kind of welding method that can be used to weld medium carbon steel. It can be welded with any of arc, gas and resistance welding ("Welding of Medium carbon steels | Welding , Hardfacing , Cladding and Cutting of metals," n.d.).

One of the welding methods that can be used to weld the medium carbon steel is by using the Metal Inert Gas (MIG) welding. MIG welding which also be known as Gas Metal Arc welding (GMAW) is a process of joining two base materials together, where a continuous solid wire electrode is fed through a welding gun and into the weld pool. To protect the weld pool from contamination, a shielding gas is also sent through the welding gun (“MIG Welding: The Basics for Mild Steel | MillerWelds,” n.d.). The solid MIG wire does not withstand rust, dirt, oil and other contaminations very well unlike stick and flux-cored electrodes which have higher amounts of special additives. So, in order to solve this problem, use a metal brush or grinder and clean down to bare metal before striking an arc. This is because, any electrical impedance will affect wire feeding performance.

1.2 Problem Statement

Medium carbon steel may often be used in structural steel and railway application. The parts in this application requires high tensile strength to resist the problem that might happen in future. For example, in railway application, wheels, rails and other steel parts associated with the suspension of rail cars which all of them is made from medium carbon steel need to have high tensile strength to confront the changing force of the rail’s cars on the rails. This also applied to the structural beams, joiner plates and other shape associated with building that need to withstand the torque and pressure of buildings and bridges.

However, discontinuities developed during the process of joining the steel may affect the performance of the parts and can be dangerous. In order to meet such condition satisfactorily, the different joining method should be conducted, and, in this project, the medium carbon steel is experimented with different method of joining them using same type of welding.

1.3 OBJECTIVE

The objectives of this project are as follow:

1. To investigate the tensile strength of the medium carbon steel.
2. To investigate the effect of different type of joint to the tensile strength of the medium carbon steel.
3. To study the relationship between different application of voltage with the tensile strength of the medium carbon steel.
4. To study the effect of the different application welding feed speed to the tensile strength of the medium carbon steel.

1.4 Scope of Project

The scopes of this project are:

1. This project only used medium carbon steel as the specimens.
2. Metal Inert Gas (MIG) welding is used to connect the joint.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain on all the topics that are related and used in this study. This includes the type of material that used and other basic knowledge about the topic related to this project such as the welding type and others.

2.2 Carbon Steel

Carbon steels are used in various applications throughout the industrialized world. For examples in the marine application, nuclear/fossil fuel power plants, chemical processing and construction (Zarras & Stenger-Smith, 2014).This is because of its relatively low price, ready occurrence and easy formability (Loto & Loto, 2018). Carbon steel is made up from iron and carbon with carbon content ranges from 0.12% to 2.0%. Some other elements such as manganese, silicon and copper are allowed in carbon steel with low maximum percentage.

According to (Jaypuria, 2008), in order to soften the metal, to modify the structure of the material, to relieve the stress set up in the material after hot and cold working or to change the grain size, the heat must be treated to the carbon steel. Heat treatment is a combination of timed heating and cooling to produce certain microstructure and desired mechanical properties which includes hardness, yield strength, Young's modulus, toughness, ultimate tensile strength, percentage elongation and percentage reduction (Fadare, Fadara, & Akanbi, 2011). In other words, it is a controlled process of heating and cooling of metal to change the physical and mechanical properties of the metal itself without changing the shape of the product (Singh & Bajwa, 2016). This include heating the material and then let them cool in the brine, water and oil. Due to manufacturing processes such as welding or forming that either heat or cool, heat treatment sometimes is done inadvertently (Varma, Kashyap, & Singh, 2012).

As we compare carbon steel with the stainless steel, we can see that the carbon has lower ability to resist corrosion. This is because stainless steel has added chromium in it, even though they both contain iron which oxidizes when exposed to the environment. Despite its low corrosion resistance, carbon steel used in large range in marine applications, fossil fuel power plants, nuclear power, transportation, petroleum production, chemical processing and refining pipelines, mining, construction and metal-processing equipment (Kadhim, 2011).

In power plants, chemical and petrochemical processing and oil refining, carbon steel is extensively used for high temperature applications. There are some examples of components that made of mild steel which are boiler tubes in power plants, reactor vessels in process industries, heat treating fixtures and exhaust train piping (Khanna, 2012).

2.3 Types of Carbon Steel

Generally, carbon steel can be divided into three groups. This grouping is made based on the carbon content. This grouping includes low or mild carbon steel, medium carbon steel and high carbon steel and the classification of the carbon shown in the Table 2.1.

Table 2.1 : Different Type of Carbon Steel

Type of Carbon Steel	**Carbon Composition**	**Explanation**
Low/Mild	0.05 – 0.25	• A low-cost material. • Easy to shape. • Surface hardness can be increase by carburizing.
Medium	0.29 – 0.54	• Ductile and strong. • Stronger than low carbon steel. • Long-wearing properties.
High	0.55 – 0.95	• Strong and holds shape memory well. • Ideal springs and wire. • Very difficult to cut, bend and weld. • Extremely hard and brittle one heat was treated.

2.4 Heat Treatment

Generally, various heat treatment processes always applied in engineering practice include annealing, normalizing, hardening, austempering, martempering and tempering. All of this will give an impact to the microstructure of the material (Rashed & Bazlur Rashid, 2016).

2.4.1 Annealing

Annealing is one of the heat treatments that use in altering the physical and chemical properties of a material. This annealing is done when we need to increase the ductility of the material by refining the grain structures and reduce its brittleness ("Annealing | heat treatment | Britannica.com," n.d.). Basically, annealing is used for steel, however, a process called solution annealed is subjected to other metals This metal includes copper, aluminum and brass ("Difference Between Annealing and Tempering | Metal Supermarkets - Steel, Aluminum, Stainless, Hot-Rolled, Cold-Rolled, Alloy, Carbon, Galvanized, Brass, Bronze, Copper," n.d.).

During the process of annealing, the recrystallization occurs when the metal is heated to a specific temperature. Any defect that caused by deformation are repaired at this stage. For a fixed period of time, the metal is held at that temperature. After that, it is been cooled down to room temperature. This cooling process is done very slowly. This is needed to produce a refined microstructure and maximizing the softness. Usually, this is done by putting the hot steel in the ashes, and other substances with low heat conductivity. It also can be done by allowing the cooling of the steel with the furnace after switching off the oven ("Learn About Annealing in Metallurgy," n.d.). In the case of carbon steel, full annealing requires the material to be heated to the temperature of 845–900ºC for 1 hour 30 minutes for every additional 25.4 mm above 25.4 mm thickness (Gandy, 2007).

2.4.2 Normalizing

Another heat treatment process is normalizing which is a process to regulate internal material stress ("What is Normalizing? - Definition from Corrosionpedia," n.d.). It will make the material softer but does not produce the uniform material properties of annealing ("Normalizing Heat Treatment - Surface Finishing - Engineer's Handbook," n.d.). Besides that, normalizing only applicable only to ferrous metal. Just like annealing process, normalizing requires the metal to be heated up to a higher temperature but differ from the annealing where the metal will be removed from the furnace for air cooling purpose.

The benefits that we can get from this normalizing process of heat treatment, the mechanical properties of the metal can be improved as the normalizing permits the refinement of a metal's grain size. It gives a uniform and fine-grained structure to the steel. Beside that normalizing is less expensive compare to annealing process. The normalizing temperature for carbon steel usually 55ºC above the upper critical temperature (Gandy, 2007).

2.4.3 Hardening

Neutral hardening which also can be called as martensitic or quench hardening, is a process of heat treatment that used to obtain high hardness/strength on steel. In order to retain a tempered martensite or bainite structure, this process consists of austenitising, quenching and tempering ("Neutral hardening - Hardening and tempering - Bodycote Plc," n.d.). This process is typically neutral which means that it is not intended to change the chemical composition of the steel surface of the parts.

Firstly, the steel is heat up in stages to the hardening temperature. This temperature is depending on the steel type itself which between 800 and 1220°C. Carbon steel material is heated to the temperature of 815–870ºC (Gandy, 2007). The step after that is to hold at that hardening, austenitising temperature. This is to fully equalise the temperature of the parts. Besides that, it also allows the transformation of the microstructure into the austenite. Finally, the part is being quenching from the austenitising temperature in a cold medium. Usually, this step use water, liquid salt, oil or high pressure nitrogen as the quench medium, depending on the type of the steel and also the dimensions of the part ("Neutral hardening -

Hardening and tempering - Bodycote Plc," n.d.). To prevent the material from becoming into the original soft structure, the quenching speed must be high enough (Banerjee, 2016).By this hardening process, optimal combination of high strength and toughness can be given to heavy loaded parts and by that, lighter and stiffer parts can be made due to higher strength. Overall, for the tool steels, hardening can give the desired properties if high hardness, heat resistance, wear resistance and machinability.

2.5 Welding

According to (Vural, 2014), welding can be defined as the joining of materials with the use of heat and/or force in the welding zone. It can be done with or without filer metal. It also can be facilitated by shielding gas, welding powders or pastes, and the energy requires is supplied from the outside. Basically, welding can be known as the art and science of joining metals which includes various kind of fusion such as welded, brazed and soldered joints as the formation of metallurgical bonds (David, Babu, & Vitek, 2016).

For the combination of steel, welding is the major mode. Welding techniques are important as well as the welding materials and the weldability of steel. This is because, the quality of welding depends on that criteria (Reemsnyder, 2004). Weldability is also can be said as joinability which means the ability to be welded. It often impacted by the content of chemical in that material. For example, when the material has more than 0.3% carbon content in it or there is more sulfur, the weldability will decrease. Same goes when the material is high in the alloy elements content or high in the impurity content. Both will result in the decrease of the weldability.

2.5.1 Metal Inert Gas (MIG) Welding

Metal Inert Gas (MIG) welding is a process joining metals by heating them and causing them to melt using an electric arc forms between an electrode and a metal workpiece. Electrode is an electrical conductor that being used to contact a nonmetallic part of a circuit which includes a semiconductor, a vacuum, air or an electrolyte. Figure 2.1 shows the example of electrodes that used in arc welding. MIG welding also can be known as Gas Metal Arc Welding (GMAW). GMAW and Tungsten Gas Arc Welding (TGAW) are two most common methods of arc welding, but in any special cases or any limited applications, there are many other forms of arc welding methods that can be used (Mallick, 2010).

Figure 2.1 :Example of Electrodes Used in Arc Welding

(“A Guide to Welding Electrodes on Ships - Part 1,” n.d.)

To protect the arc and the weld pool, GMAW or MIG employs a continuous consumable solid wire as both electrode and filler metal with an inert shielding gas (Lathabai, 2010) . Figure 2.2 below shows the schematic illustration of GMAW Process.

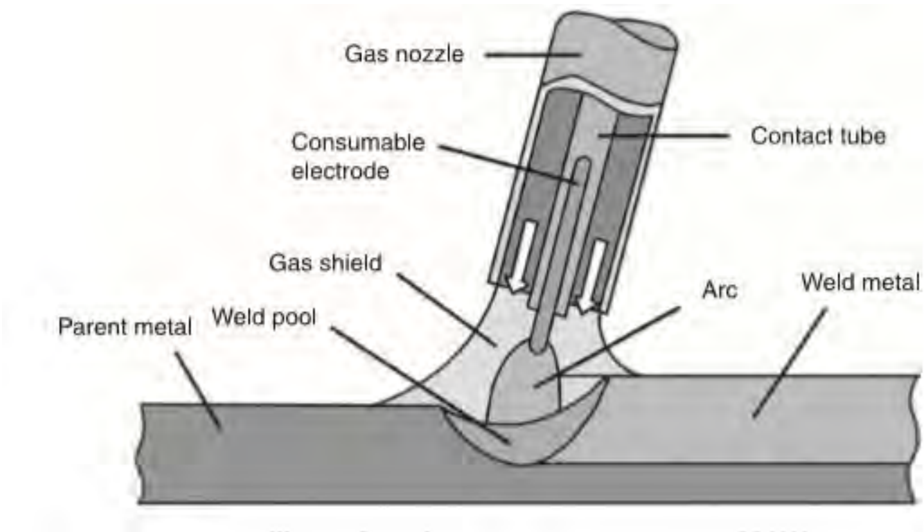

Figure 2.2 : Schematic Illustration of GMAW Process (Lathabai, 2010)

There are many advantages that we can get in using this MIG or GMAW compared to others. One of them is this type of welding can produce higher productivity. This can make the job a lot easier as the welder does not have to change rods constantly or chip away slag. They also did not need to brush the weld repeatedly and this will make the work faster and cleaner. Besides that, better weld pool visibility also can be provided by MIG welding and the auto-feed wire od MIG makes the process more simple and better control to produce a great looking weld. The welding speed also can be improved as well as the quality of the weld and overall control because the continuously fed wire keeps both hands free for MIG welding (“Mig Welding Advantages, Disadvantages,” n.d.).

There is also some limitation of this MIG method where the equipment is more complex and because of that, it became less portable (Weman, 2011). The illustration for the equipment of MIG welding is shown in Figure 2.3. Besides that, it also not suitable for outdoor working since shielding gas is used to protect the purity of the weld and the wind can impact the quality of the weld as it will disturb the shielding gas. Another disadvantage is limitation in position. Because of the high heat input and the fluidity of the weld puddle, it cannot be used in the vertical or overhead welding positions ("Advantages of MIG Welding / RodOvens.com Blog," n.d.). Figure 2.4 shows one of the MIG welding model.

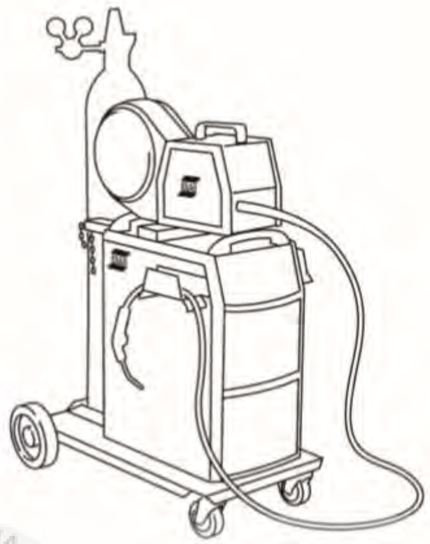

Figure 2.3 : Illustrated Equipment for MIG welding (Weman, 2011)

Figure 2.4 : One of The MIG welding model (Toothman, n.d.)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the methodology that used in this project. The flow chart of this project is shown in Figure 3.1. Generally, in order to fulfil this project, many steps and methods have been made which starting by doing the literature review. This literature review basically requires a lot of readings from journals, articles or any other sources that related.

3.2 Material Used

This project used medium carbon steel AISI 1045 as the specimen. This AISI 1045 composed by 0.43-0.50% of carbon, 0.60-0.90% of manganese, 0.040% max of phosphorus and 0.050% max of sulphur ("AISI 1045 Carbon Steel - AISI 1045 Medium Carbon Steel | All Metals & Forge Group," n.d.). Usually this medium tensile steel like AISI 1045 is supplied in the black rolled or sometimes in normalised condition with the Brinell hardness range from 170 to 210 and the strength range between 570 and 700 MPa ("1045 Medium Tensile Carbon Steel Bar | Interlloy | Engineering Steels + Alloys," n.d.). This medium carbon steel AISI 1045 has the characteristic of good machinability, good weldability and high strength and impact properties in either the normalized or hot rolled condition ("AISI 1045 Medium Carbon Steel," n.d.). The welding of AISI 1045 will follow the ASTM E8-16a.

Figure 3.1 : Specimens of AISI 1045 Medium Carbon Steel

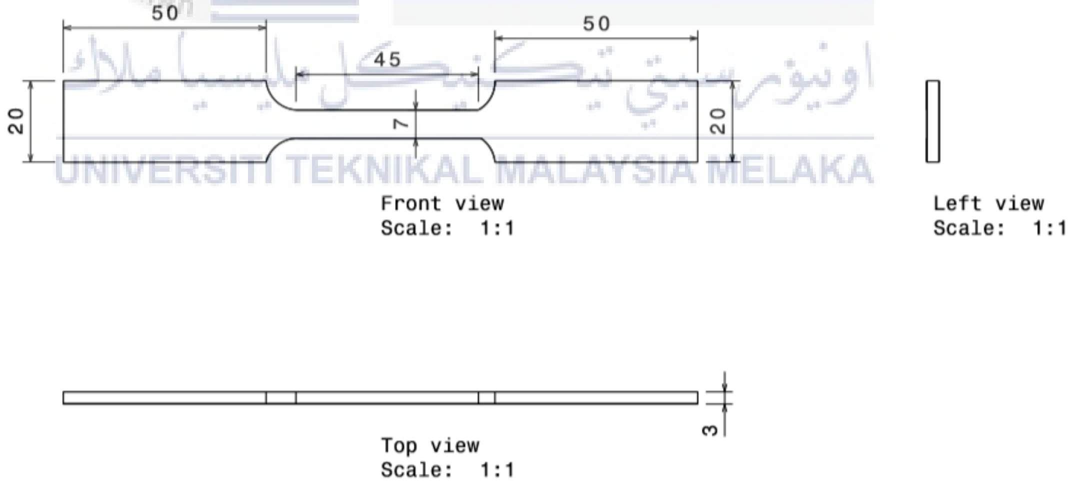

Figure 3.2 : Specimen Geometry and Dimension

3.3 Preparing Test Samples

Different parameters have been decided to be applied during the welding of the specimen. This is to investigate on how the different parameters of welding can affect the tensile strength of the specimen which is AISI 1045 medium carbon steel. Three different parameters have been selected and under each of them, there will be three different value and type. The welding had been done by using WIM MIGweld 210 as shown in Figure 3.3.

Figure 3.3 : MIG Welding Used

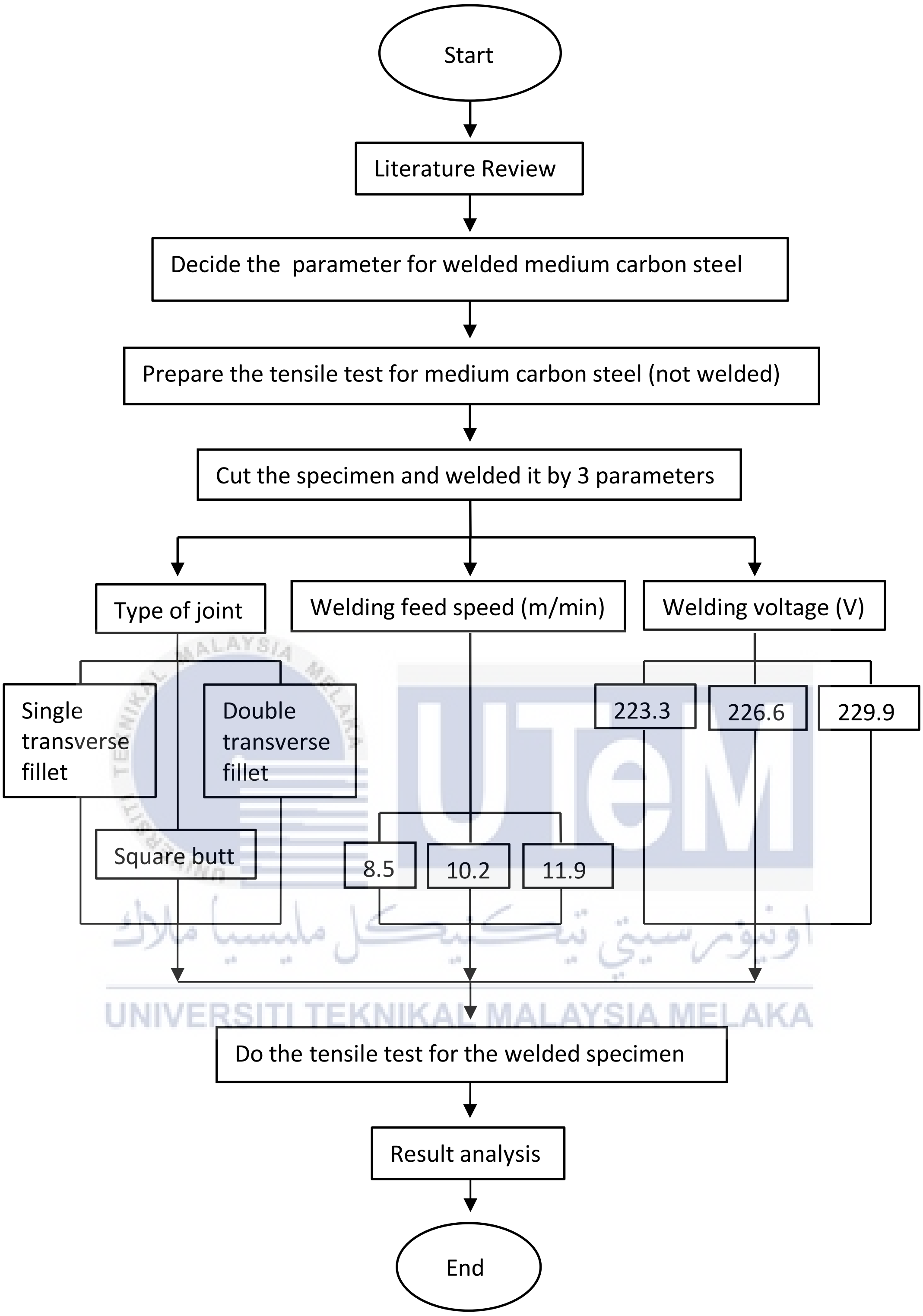

Figure 3.4 : Flowchart of Project

3.3.1 Type of Joint

Three different type of joint have been selected which includes single transverse fillet, double transverse fillet and square butt as we can see from the Figure 3.8. The illustration of the welding joint is shown in Figure 3.5, Figure 3.6 and Figure 3.7 respectively according to the parameter. Single transverse fillet and double transverse fillet are grouped under lap weld. According to ("What is a Lap Weld? - Definition from Corrosionpedia," n.d.), basically, a weld that made on a lap joint is called a lap weld which consist of two or more overlapped material. The edge of one material is melted and fused with the surface of another material. This type of weld usually used in welding processes that involve automation. Gas Metal Arc Welding (GMAW) or as well can be called as Metal Inert Gas (MIG) welding is one of the popular methods that used for this fillet or lap weld.

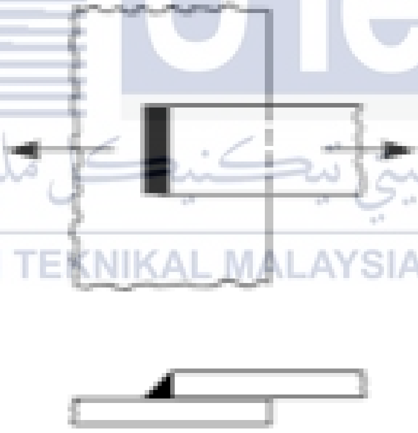

Figure 3.5 : Single Transverse Fillet (Irawan, 2009)

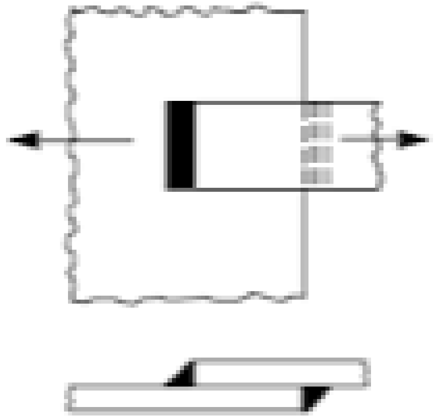

Figure 3.6 : Double Transverse Joint (Irawan, 2009)

In other hands, square butt welded joint is the most common type of joint applied in the fabrication of welded pipe systems . It also employed for valve, flanges, fittings and other equipment. This butt welding joint also can be called as a square grove weld which is the easiest and common welding which consists of two flat material that parallelly side by side (The Welding Master, n.d.).

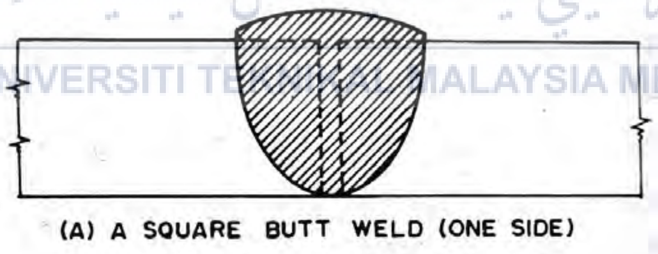

Figure 3.7 : Square Butt Welded Joint ("Design of Structures: LESSON 7. Welded Connection," n.d.)

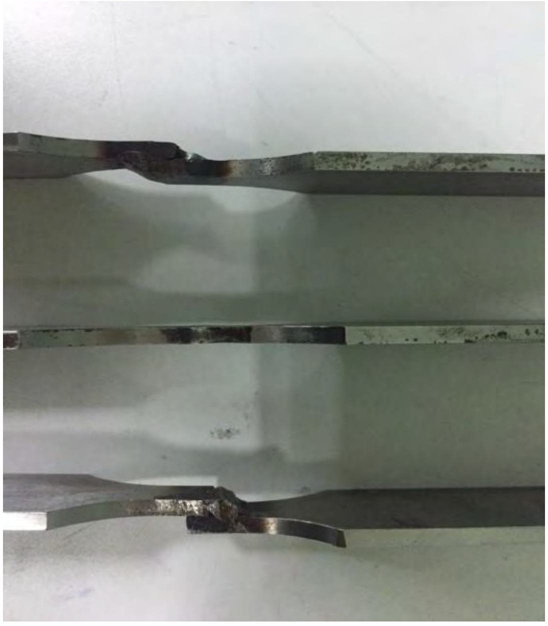

Figure 3.8 : Three Different with Type of Joint

3.3.2 Wire Feed Speed

One of the parameters that have been chosen to this project is wire feed speed. This wire feed speed controls the amount and the speed of the wire being feed into the weld joint ("How To Set Up a MIG Welder - Welder Settings, Gasses and Electrodes," n.d.). Increase in wire feed speed will result in wider weld bead. When the wire feed speed is too high, it will lead to an excessively wide weld bead, poor penetration and excessive spatter. Meanwhile when the wire feed speed is too low, it will result in narrow and convex bead besides poor tie-in at the toes of the weld that marks insufficient amperage ("MIG Welding: Setting the Correct Parameters | MillerWelds," n.d.).

For this project, three different wire feed speed have been finalised to be the parameter. This includes 8.5 m/min, 10.2 m/min and 11.9 m/min.

3.3.3 Welding Voltage

The last parameter that will be used in this project is welding voltage. The welding voltage that have been decided are 223.3V, 226.6V and 229.9V. Welding voltage will affect the weld bead whereas the voltage increases, the width-to-depth ratio will also increase, and the weld bead will flatten out more. These changes will not affect the weld penetration as the welding current will not change. As we can see in Figure 3.9, the weld beads are clearly widened when we increase the voltage.

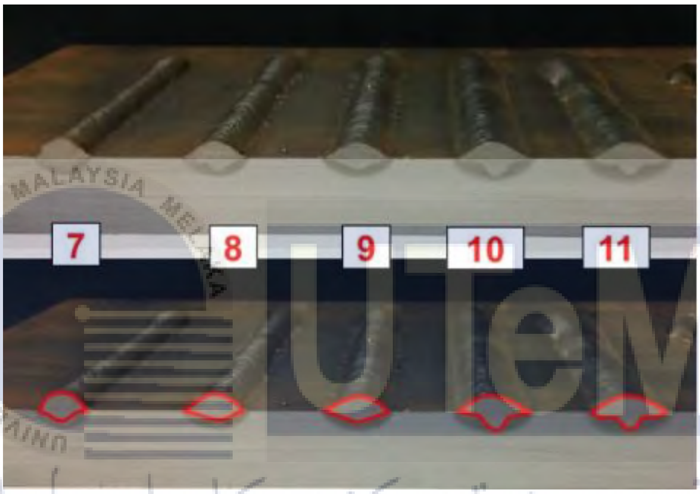

Figure 3.9 : Widening of the Weld Beads as the Voltage Increased ("Gas Metal Arc Welding Basics: Welding Current & Welding Voltage - EWI," n.d.)

3.4 Tensile Test

The most common form of material test is probably tensile testing. Tensile test can be understood as the maximum tensile stress that can be sustain by a material without causing fracture (Vallin, Jonsson, & Knechtel, 2015).This may include smooth bar, plane strain specimen and notched bar . Mechanical properties such as yield strength, total elongation, ultimate strength and reduction in cross-sectional area can be assessed from this tensile test (W.E. Luecke et al., 2005).The tensile test is conducted using Instron Universal Testing Machine (Model 5969) that shown in Figure 3.10 while the process of the tensile test is shown in Figure 3.11.

Figure 3.10 : Instron Universal Testing Machine (Model 5969)

Figure 3.11 : Ongoing Tensile Test

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The welding of the specimens has been done before proceeding to the tensile test. Three specimens were prepared for each parameter including three specimens for non-welded. From this tensile test, we discussed three main properties which are the Ultimate Tensile Strength, the yield point and the Young's Modulus of the specimen. This testing had been conducted using the Instron Universal Testing Machine as Figure 3.10.

4.1.1 Ultimate Tensile Strength

Ultimate Tensile Strength (UTS) or also called as Tensile Strength is the maximum stress that can be handled by a specimen during the test before begins to elongate, stretch and neck. It can be calculated by dividing the maximum load which also the load at failure with the original cross sectional area.

$$\sigma_{max} = P_{max}/A_O \tag{4.1}$$

where, the P_{max} is the maximum load while the Ao is the original cross sectional area.

4.1.2 Modulus of Elasticity

Modulus of Elasticity is one of the most important properties of solid materials that calculated to measure the stiffness of the specimen in the elastic region only where it shows the ability of the specimen to resist the elongation when undergo tension. According to (5. Modulus of Elasticity, n.d.), when a material undergo deformation elastically, for a given stress, the strain is always the same, but the amount of deformation depends on the size of the material. The stress and strain are related by Hooke's Law where the stress is directly proportional to the strain.

$$\sigma = E.\varepsilon \tag{4.2}$$

where σ refer to the stress while the E and ε is a modulus of elasticity and strain respectively.

From the Hooke's Law, the modulus of elasticity is defined as the ratio of the stress to the strain. It also can be obtained from the slope of the straight-line portion of the stress-strain curve (Stress-Strain Relationships, n.d.). The stress can be obtained from the calculation of force per unit area and the strain is the ratio of elongation over initial length of the specimen.

$$E = \frac{\sigma}{\varepsilon} = \frac{F/_A}{(L-L_O)/_{L_O}} \tag{4.3}$$

where F is the value force and the A is the area. L and L_0 is referring to the new length and the original length respectively.

4.2 Non-Welded Specimens

For the non-welded specimen, three same type of specimens have been used where the specimens were does not being cut and welded. The tensile test had been done onto the specimens to measure the strength of the medium carbon steel that does not being welded and to be compared with the welded specimens.

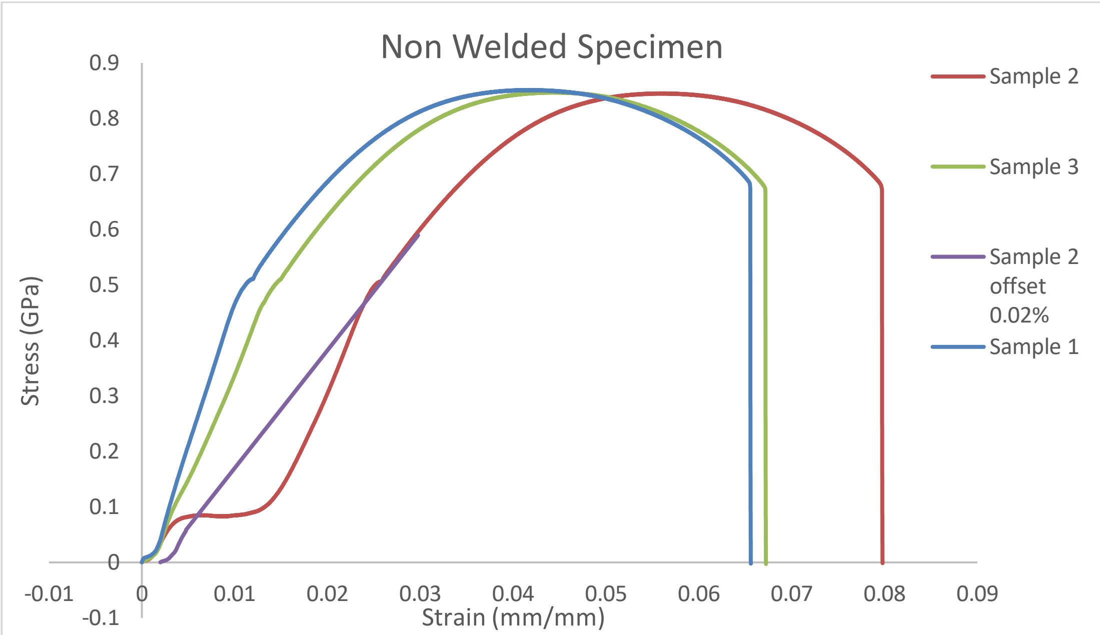

Figure 4.1 : Stress-Strain Curve for Non Welded Specimens

As we can see in the stress-strain curve in Figure 4.1, the trend of the graph is almost the same as the specimens are not varies. For the sample 2, the graph slightly dragged at the beginning and this might happen because of the slippage during of the tensile test. This slippage may due to the axial misalignment where it can misrepresent the measurement (Kevin Connelly, 2017). Hence, offset of 0.02% had been made. From the curve, we can get to know the UTS of the material by identifying the highest point of the stress-strain curve. From the Table 4.1, based on the result of the tensile test, we can calculate the average of the UTS for these three non-welded specimens where the average UTS is 848.02 MPa. Consistent tensile strength throughout the body in a medium carbon steel structure (martensite) is due to the combination of specific range of carbon through process of quenching for example cooling the steel from the outer surface to the inner, and tempering (Tribe, n.d.) . High UTS in medium carbon steel make it more preferable choice for steel. According to (Rods et al., 1991), typically, the tensile strength of medium carbon steel that supplied in the black hot rolled or occasionally in the normalised condition is in the range between 570-700 MPa but for the medium carbon steel up to 16mm that hardened by water quench at 820ºC-850ºC or oil quench at 830ºC-860ºC and tempered between 540ºc-680ºC, the range of the UTS is between 700-850 MPa. Another source said that C1045 which supplied as forged or normalized will through harden to 63mm with a tensile strength of 620-850 MPa (“AISI 1045 Carbon Steel - AISI 1045 Medium Carbon Steel | All Metals & Forge Group,” n.d.).

Table 4.1 : Tensile Test Result for Non Welded Specimens

Specimen	**Max Load (N)**	**Ultimate Tensile Strength (MPa)**	**Elastic Modulus (GPa)**
1	17881.66	851.51	52.16
2	17751.95	845.33	29.58
3	17791.70	847.22	38.66

As explained earlier, modulus of elasticity mainly representing the stiffness of the materials and by that, high elastic modulus material shows that it is a stiff material where it only changes its shape slightly under elastic loads. High loads are required to elastically deform the material. Meanwhile the average modulus of elasticity or elastic modulus of non-welded specimen is 40.13 GPa. Theoretically, the elastic modulus of steel is 200 GPa (Mahendran, 1996) and this difference between theoretical and experimental might be happened due to the several factors such as the wrong set up of the specimens and the void and impurities that can occur during the treatment of the steel.

4.3 Different Type of Joint Specimens

Three different specimens had been welded by three different type of joint which includes the single transverse fillet, double transverse fillet and square but. Then, these three specimens undergo the tensile test to identify which joint have the strongest tensile strength.

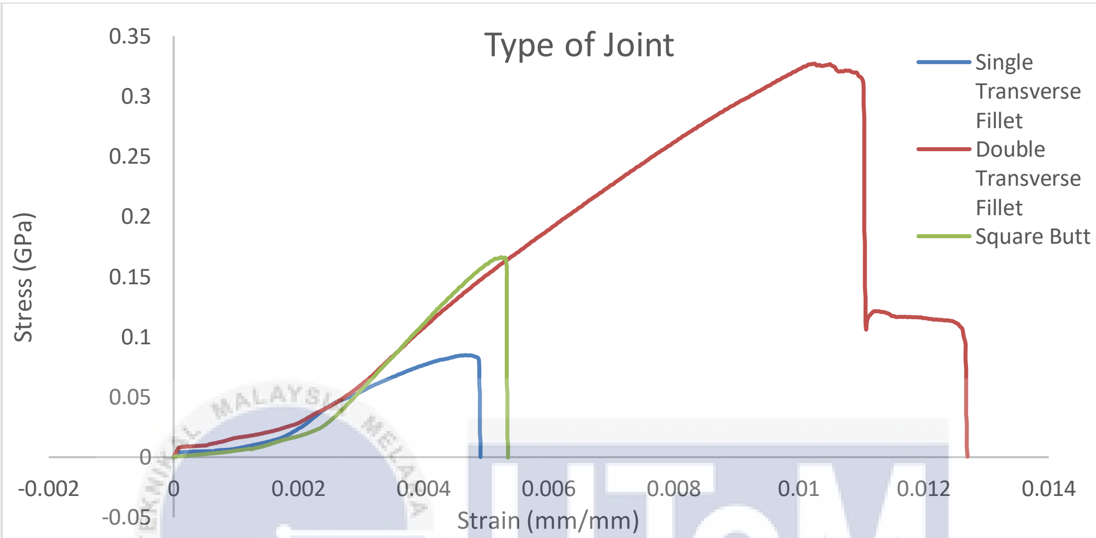

Figure 4.2 : Stress-Strain Curve for Different Type of Joint Specimens

From Figure 4.2, it is shown that there is no uniform trend of the graph between the three specimens. This shows that, different type of welded joint will result in different strength and elasticity. Firstly, for the single transverse fillet welded joint, the UTS of the specimen is 84.84 MPa. Meanwhile the UTS for the other two type of welded joint which are double transverse fillet and square but are 327.12 MPa and 166.20 MPa respectively. The results are shown in Table 3 below. From that, we know that the UTS for the double transverse fillet is the highest among all the tree different welded joint.

The UTS's difference between single transverse fillet and double transverse fillet is huge. This is because in single transverse fillet, the edge of the plate that is not welded can warp out of shape lead to easily deflect lower plate. Besides that, the minimum area of the weld at the edge of the plate also effect the tensile strength of the specimen (Design of

Machine Members-I Contents: Design of Welded Joints, n.d.). Single transverse fillet weld has lower minimum area of the weld as it only weld at one side of the joint while double transverse fillet joint weld at the both sides. Higher minimum area of the weld at the edge of the plate results in higher tensile strength hence proving the reasons why the UTS of double transverse fillet weld is higher that the UTS of single transverse fillet. As for the square butt weld, it has higher tensile strength than the single transverse fillet but lower than double transverse fillet.

Table 4.2 : Tensile Test Result for Different Type of Joint Specimens

Type of Joint	**Max Load (N)**	**Ultimate Tensile Strength (MPa)**	**Elastic Modulus (GPa)**
Single Transverse Fillet	1781.66	84.84	25.02
Double Transverse Fillet	6869.51	327.12	40.99
Square Butt	3490.11	166.20	17.85

From the Table 4.2, the value of the elastic modulus for double transverse fillet weld joint also has the highest value among the three different weld joints which is 40.99 GPa while single transverse fillet has the second highest value of elastic modulus which is 25.02 GPa. The lowest elastic modulus is in the square butt weld joint which is 17.85 GPa. Based on the result, double transverse fillet weld joint is the stiffest among the three which means, if we use the double transverse fillet weld joint as the joining method, higher amount of force needed to achieve certain deformation. Differ with the other two specimens which result in lower elastic modulus. The stiffness of the specimens is lower and by that the material's resistance to being deformed is low resulting to easy deformation of material. This shows that, single transverse fillet weld joint and square butt joint are not suitable to application that using higher forces.

4.4 Different Welding Feed Speed Specimens

Moving on to the next parameter that been used in this project is welding feed speed. Three different welding feed speed have been set up and used to weld three different specimens which are 8.5 m/min, 10.2 m/min and 11.9 m/min. This value of parameter is selected based on the welding machine's guideline.

Based on the Figure 4.3, we can clearly see that the highest stress-strain curve is the specimen with welding feed speed of 11.9 m/min which also means the fastest among those three. This automatically indicates that it has the highest UTS followed by the welding feed speed of 10.2 m/min and 8.5 m/min. We can conclude that, the higher the welding feed speed, the higher the UTS of the specimen.

Low welding feed speed or travel speed causing longer heating time hence provide larger beads and higher heat input to the base metals but it is differ when the welding feed speed is higher, narrower bead with less penetration will be produced while less weld metal gets deposited with lower heat (Bhatt & Mehta, n.d.). The increase in welding penetration will cause decrease in weld strength which is the UTS ("Weld Fusion vs. Weld Penetration," n.d.). That proved on how increase in welding feed speed can increase the UTS.

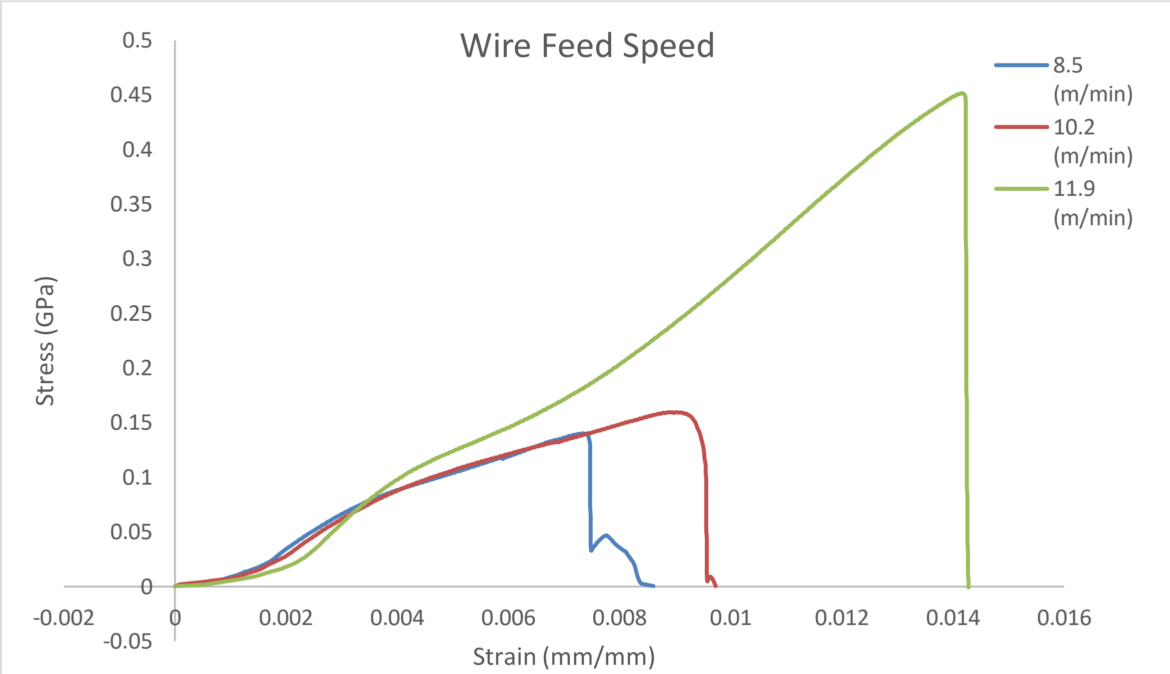

Figure 4.3 : Stress-Strain Curve for Different Type of Welding Feed Speed Specimens

Table 4.3 shows the result of the tensile test including the value for the modulus of elasticity. For the highest value of welding feed speed which is 11.9 m/min, highest value of elastic modulus had been produced. Highest value of elastic modulus tells that the welding speed makes the material stiffer and hard to be deform. Meanwhile, the lowest elastic modulus produced is by the welding feed speed of 10.2 m/min which is 22662.86 MPa. Consequently, lower value of elastic modulus will make the material becomes easier to break and lower load needed to deform it since the elastic region of the material is smaller than the one that have higher value of elastic modulus.

Table 4.3 : Tensile Test Result for Different Type of Welding Feed Speed Specimens

Different Welding Feed Speed (m/min)	Max Load (N)	Ultimate Tensile Strength (MPa)	Elastic Modulus (GPa)
8.5	2946.14	140.29	26.28
10.2	3351.38	159.59	22.66
11.9	9481.15	451.48	28.33

4.5 Different Welding Voltage Specimens

As for the voltage parameter, three different specimens had been used. The specimens being cut at the middle, then being welded by square butt joint using Metal Inert Gas (MIG) welding. The three different voltage are 223.3 V, 226.6 V and 229.9 V. The parameter for this different welding voltage also selected by following the welding machine's guideline.

The arc voltage in the MIG welding has various effect upon the penetration, the bead reinforcement and bead width. From the experiment, the result is as stated in Table 4.4. As for the UTS, the UTS for the voltage of 223.3 V is 131.81 MPa which when compared to both others voltage, it gives the lowest UTS. Low voltage produces shorter arc length causing to more focused arc and narrower arc cone which mean decrease in the width and size of the arc cone. The results for that is the bead, which is narrower and ropier, resulting in decrease of the welding penetration. However, an excessive low of welding voltage used will cause porosity and overlapping to be happened at the edges of the weld bead.

Conversely, when higher voltage is used, the arc length will increase, which lead to wider arc cone and broader arc. As the result, the weld bead become wider and flatter and the welding penetration will increase. The lower the welding voltage, the lower the welding penetration that will cause higher UTS of the specimen but excessive low of welding voltage will cause the UTS to be decreased. It is shown in the Figure 4.4 below.

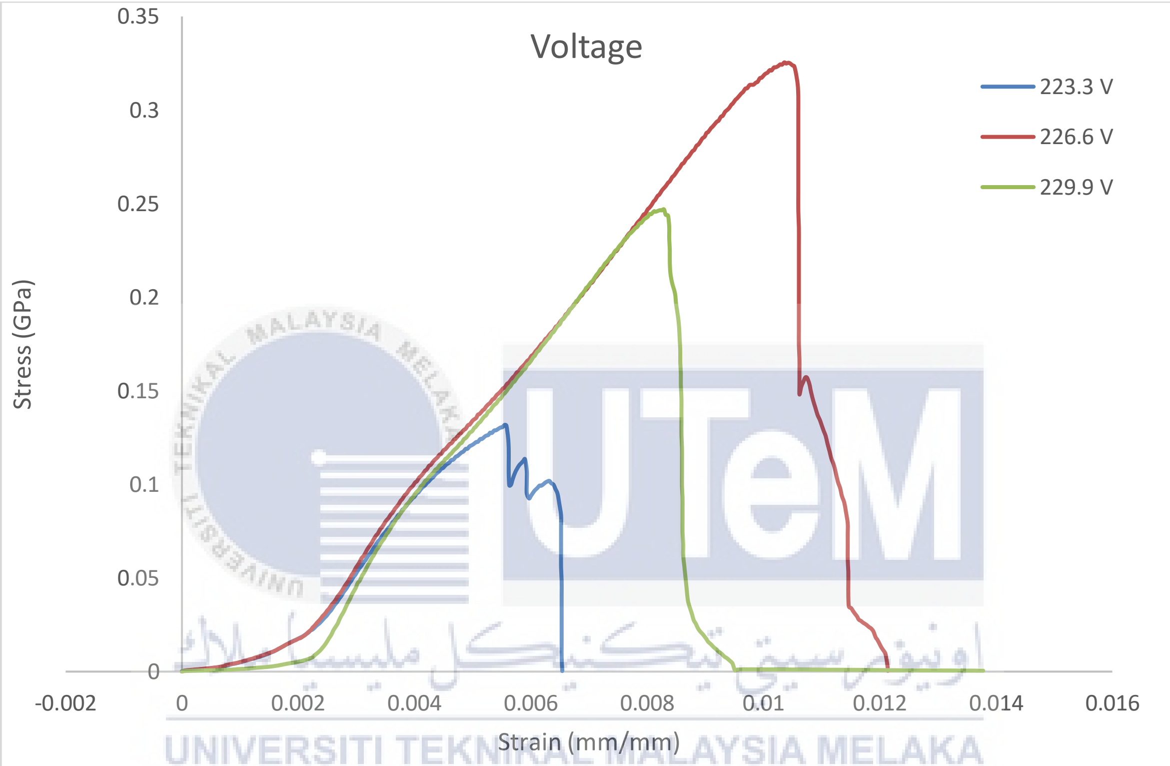

Figure 4.4 : Stress-Strain Curve for Different Type of Welding Voltage Specimens

The trend of the elastic modulus result in welding voltage parameter is almost the same with the previous parameter, welding feed speed where the highest value of the welding voltage had been given the highest value of the elastic modulus. The material with the welding voltage of 229.9 V is the stiffest among the other because it results in highest elastic modulus which is 40345.52 MPa. The welding voltage of 226.6 V had been given elastic modulus value of 36589.68 which is the lowest among the three different value of welding voltage. Lower load required to deform the material because of the lower elasticity of the material.

Table 4.4 : Tensile Test Result for Different Type of Welding Voltage Specimens

Different Welding Voltage (V)	**Max Load (N)**	**Ultimate Tensile Strength (MPa)**	**Elastic Modulus (GPa)**
223.3	2767.91	131.81	38.89
226.6	6834.78	325.47	36.59
229.9	5185.55	246.93	40.35

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a summary, medium carbon steel AISI 1045 specimens were prepared and welded by three different parameters where each parameter consists of three different value and characteristic before being tested by the tensile test to know the effect of the different parameters on the tensile strength of the medium carbon steel. Three non-welded specimens also had been tested in order to identify the tensile strength of the medium carbon steel. The test was done according to ASTM E8-16a. The parameters used were type of weld joint that include the single transverse fillet, double transverse fillet and square butt, welding feed speed which consist of 8.5 m/min, 10.2 m/min and 11.9 m/min and lastly the welding voltage of 223.3 V, 226.6 V and 229.9 V.

From the tensile test that have been made, for the parameter of type of weld joint, it can be concluded that double transverse fillet gives the highest tensile strength compared to the other two type of joints. In the case of the welding feed speed, it can be concluded that as the welding feed speed increase, the tensile strength also will be increase hence from the result that obtained, 11.9 m/min will result in biggest value of tensile strength which was 28328.54 MPa. As for the welding voltage, lower voltage will result in higher tensile strength but excessive low of voltage will cause porosity and decrease the tensile strength of the specimen.

5.2 Recommendation for Future Works

This medium carbon steel material has great potency to be explore further. Other mechanical testing can be done other than tensile test such as flexural test, compression test and impact test. For the tensile test itself, the mechanical properties can be analysed more for example in terms of yield strength and yield point of the material. The tensile test also can be done using an appropriate grip to aid in the sample placement. To help the upper grip self-align under load, swivelling adapter can be used during the tensile test (Kevin Connelly, 2017).

In addition, the amount of specimen used can be increase from one to three specimens for each value in each parameter. This is to enable the results to be taken in average, therefore the result for the project will be more accurate.

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