STRENGTH OF THE WELDED MEDIUM CARBON STEEL

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A report submitted
in fulfilment of the requirements for the degree of
Bachelor of Mechanical Engineering

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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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.

Signature	:	………………………..
Name	:	Norliana Izaty Binti M. Noorawi
Date	:	………………………..

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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	:	………………………..

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DEDICATION

To my beloved parents and family.

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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.

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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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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

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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

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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 500ºF (149 to 260ºC). 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

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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.

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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.

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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

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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.

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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).

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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

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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 -

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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.

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