Effect of Welding Parameters on Mechanical Properties of Welded Carbon Steel

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ABSTRACT

The main purpose of this project is to study effect of welding parameter on mechanical properties of welded carbon steel. Current problem is cracking happen on the bridge frame after a long time period being used and welding process need to be used to joint back the cracking. The objective of this study is to study the effect of welding parameter such as speed, current and voltage to the mechanical properties of carbon steel. Tensile test, microstructure view, hardness test and optical measurement view is used to define the mechanical properties for welded specimens and as received specimen. The welded specimen being compared with unwelded to study the change of metal before and after welded process. Metal Inert Gas (MIG) welding is used and the liner type was mild steel liner. The hardness study was conducted using a Vickers Hardness Tester MMT-X7 to analyze the conditions change at each region which are weldment zone, heat affected zone and base metal zone area. Low carbon steel show increased in hardness test especially on fusion zone following by heat affected zone due to heating process by the welding. There is a change on microstructure view where the base metal changing and create dendrite shape at weldment area and columnar at heat affected zone area. Optical measurement view test shown the depth of penetration affect the tensile test result. This project is significantly to show that different parameter setup will give different strength and must be the important considered by the welder.

ABSTRAK

Tujuan utama dari projek ini adalah untuk mempelajari kesan kajian bahan parameter kimpalan ke atas sifat mekanikal keluli karbon yang dikimpal. Masalah masa pada masa kini adalah keretakan berlaku pada rangka jambatan selepas tempoh masa yang lama digunakan dan proses kimpalan perlu digunakan untuk menyambung semula keretakan yang berlaku. Objektif kajian ini adalah untuk mengkaji kesan parameter kimpalan seperti kelajuan, arus dan voltan kepada sifat-sifat mekanikal keluli karbon. Proses kimpalan telah dijalankan untuk mengimpal bersama dua logam keluli karbon. Ujian tegangan, pandangan mikrostruktur, ujian kekerasan dan pandangan ukuran optic dijalankan untuk menentukan sifat-sifat mekanik untuk bahan yang dikimpal dan bahan yang diterima seadanya. Spesimen yang dikimpal dibandingkan dengan specimen yang diterima seadanya untuk mengkaji perubahan logam sebelum dan selepas proses kimpalan. Inert Gas (MIG) proses digunakan dan jenis pelapik yang digunakan adalah pelapik keluli lembut. Kajian kekerasan telah dijalankan menggunakan Vickers Hardness Tester MMT-X7 untuk menganalisa perubahan keadaan di setiap kawasan iaitu zon kimpalan, zon haba yang terlibat dan kawasan zon logam asas. Keluli rendah karbon menunjukkan peningkatan dalam ujian kekerasan terutama pada zon kimpalan diikuti zon haba yang terlibat hasil dari proses pemanasan kimpalan. Terdapat perubahan pada pandangan mikrostruktur di mana perubahan logam asas dan mewujudkan bentuk dendrite di kawasan hasil kimpalan dan kolumnar di kawasan terkesan haba. Ujian pandangan ukuran optik menunjukkan kedalaman penembusan yang mempengaruhi keputusan ujian tegangan. Signifikan projek ini adalah untuk menunjukkan bahawa persediaan parameter yang berbeza akan memberi kekuatan yang berbeza dan mesti menjadi keutamaan untuk dipertimbangkan oleh pengimpal.

TABLE OF CONTENTS

CHAPTER 3 METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percent
B.C	Before century
C	Carbon
P	Phosphorus
Mn	Manganese
S	Sulphur
Fe	Ferum
kg	Kilogram
m	Meter
Mpa	Mega pascal
Gpa	Giga pascal
mm	Milimeter
F	Force
d	Diameter
°	Degree
N	Newton
Cr	Chromium
Al	Aluminium
Cu	Cuprum
V	Voltage
A	Ampere
s	seconds
min	Minutes

μ	micron
gf	Gram force

LIST OF ABBREVIATIONS

ASTM	American Standard Testing Method
AISI	American Iron and Steel Institute
MIG	Metal Inert Gas
GMAW	Gas Metal Arc Welding
HAZ	Heat Affected Zone
FZ	Fusion Zone
CJP	Complete Join Penetration
CNC	Computer Numerical Control
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
BCC	Body Centered Cubic

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Steel is a metal alloy created from a mixture of iron and carbon. Iron is a key component in steel and carbon content in the steel which varies between below than 0.2% until above 0.5% mass depending on the grade of steel. Metal alloys are also commonly known as cast iron because of the carbon content in which it affects the low melting point and easy to be poured into molds.

Steel is commonly used in building construction, infrastructure such as bridge, tools equipment, machinery, ship, vehicle components and weapon. This is because the mechanical properties of ductile steel which is easy to set up and cost-effective, high work hardening rate, high yield strength, resistance to impact loading, and has a very goods surface (Sacks and Bonhart, 2005). Researchers have done a deeper study for steel material about the grain refinement which to increase the yield strength for steels and the toughness simultaneously.

Low carbon steel is a type of metal that has an alloying element made up of a relatively low amount of carbon. Typically, it has a carbon content that ranges between 0.05% and 0.30% and a manganese content that falls between 0.40 and 1.5% (William, 2006). Since it has a low amount of carbon in it, the steel is typically more malleable than other kinds of steel. As a result, it can be rolled thin into products like car body panels and also in used as low carbon steel pipe to transmitting substances such as gas and oil (Sack and Bonhart, 2005).

Low carbon steel has better mechanical properties of steel in terms of high hardness, high wok hardening rate, yield strength of the end, and on the high forces. This factor causes the material of low carbon steel is mostly used in industries at this moment especially in construction industry, automotive and oil and gas industry. In construction industry, this material is used to build the bridge. This is because of the the material properties which is ductile, can hold high impact load and effective cost cause of the common material (Karadeniz, 2007).

Low carbon steel have high ductility. Then it will effect in the process of formation. In addition, the end result of the formation process of high carbon steel is also very good because of the final surface is flat and does not required a machining. Sometimes, this material also will crack and need to be weld to make sure the crack will not continued. But at which condition the welding process is good enough to make sure it can hold the crack by changing the parameters to weld (Gural, 2007).

1.2 PROBLEM STATEMENT

The bridge construction industry activities are carrying out actively from day to day not only in the city but even in village areas. This is to prevent rural communities from left behind about current development progress. Safety factor is a major factor to be concerned in construction activity because it will involves lives of the bridge user. From this, the factor of safety in depends on the type and quality of materials used in build a strong bridge frame. High quality materials that have good mechanical properties and the ability to withstand high loading forces in build the bridge frame to make sure it will not collapse easily during and after it was built (Mark Rossow, 2009).

Figure 1.1: Bridge frame using low carbon steel

Source: Mark Rossow (2009)

Most of bridge frame normally will be used low carbon steel material as shown in Figure 1. The biggest bridge need to be build, the larger force that need to be hold by the frame bridge. As the aged of bridge increased, some defects will happen and one of it is crack. To patch the crack, welding process need to be done but at which parameter the welding process will be the best to hold the crack. Because of that, low carbon steel that being used as a bridge frame construction will be analysed by running the tensile test, hardness test, and microstructure deform after the welding process between two parts of low carbon steel plate. The parameter will be changed such as the speed, voltage and current to see which parameter will effect the material and also will causes the material to fail.

1.3 OBJECTIVE OF PROJECT

The objective for this analysis is purposely to study the effect of welding parameter such as speed, current and voltage to the mechanical properties of low carbon steel.

1.4 SCOPES OF PROJECT

In order to achieve the objective, it should have proper arrangement of scopes project. The lists of scopes are as followed:

i) Sample preparation including raw material preparation and cutting process
ii) Compositional analysis before and after welding process
iii) Welding process with different welding speed, voltage and current using Metal Inert Gas (MIG) process to the mechanical properties of low carbon steel.
iv) Tensile test, hardness test and microstructural analysis test.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Steel in other name is refined pig iron or an alloy of iron and carbon. Steel is made up of carbon as important composition, silicon, sulfur, phosphorus and manganese. At this time, low carbon steel can be obtain easily in most local industry especially in construction industry and one of it can be found in bridge construction industry. Other than that, it can be found in ships, tank, pipes, railroad cars and automobiles (Sacks and Bonhart, 2005). There are lots of methods and studies have been conducted to increase the performance and the ability of low carbon steel to make sure the utilization can be improved to others applications that more sophisticated. In bridge construction application, the low carbon steel is used a lot on bridge because of the hardness and strength at low carbon steel and a good material in absorbed the forces that being given. To increase the strength or high performance of bridge frame material, the carbon content in steel must be less which ensure the toughness and weldability (Guo et al, 2009).

2.2 LOW CARBON STEEL

The first recorded use of iron was the ancient Assyrians about 3700 B.C. This given them an advantage compares to other nation since it was in making weapons (Sacks and Bonhart, 2005). Low carbon steel is steel that contain fine grain and it started being designed since years of 1960. Low carbon steel can be classified when the carbon content is lower than 0.2 percent (American Society for Testing and Materials). Low carbon steel is widely used in fabrication industry due to excellent to weight ration and one of the applications are in automobile industry (Khodabakhshi *et al*, 2011). This material is suitable to use in automotive industry because it can absorb high impact force without cracking. This happen because it has low carbon which make it as ductile material compare to high carbon steel that more brittle and easy to crack although it have more strength.

The used of low carbon steel is not limited just on creating the frame for bridge construction or building construction only but low carbon steel also is used a lot in making car chasis for automotive industry because of the high strength, brittle and easily to welding. This material also good in weight because it reduces the weight of material that being used which can help to reduce oil consumption at once decrease the gas emissions and improves crash safety (Naderi *et al*,2011).

Now through studies and sophisticated technology will expand the application of low carbon steel in the used for bridge construction industry. Low carbon steel is used as a bridge frame. Low carbon steel also work as a link for bridge construction in many way purposely for strengthen the bridge frame structure to make sure it will not easily deflected or strain experienced because of high loading force. Other than that, it also will be welding between two part of low carbon steel is carried out to combine and usually strengten the frame of bridge.

Low carbon steels contain up to 0.15% carbon (William, 2006). The largest category of this class of steel is flat-rolled products which is sheet or strip usually in the cold-rolled and annealed condition. The carbon content for these high formability steels is very low, less than 0.10% with up to 0.4% manganese. Typical uses are in the automobile body panels, tin plate and wire products. This material also used for stampings, forgings, seamless tubes and boiler plate where the carbon the containing may be increased to approximately 0.30% with higher manganese up to 1.5% for rolled steel structural plates and sections (American Society for Testing and Materials). Table 2.1 show the chemical composition for low carbon steel with more detailed according to ASTM.

Table 2.1: Chemical composition low carbon steel

C (% Mass)	P (% Mass)	Mn (% Mass)	S (% Mass)	Fe (% Mass)
0.05-0.15	<0.04	0.30-0.60	<0.05	99.18-99.62

Source: American Society for Testing and Materials (ASTM)

The added elements in the steel is purposely to increase the hardness, strength and chemical reaction for low carbon steel.

2.3 PROPERTIES FOR LOW CARBON STEEL

Low carbon steel is a steel that contain fine grain with ferrite phase structure. The mechanical properties for low carbon steel is better because of soft matric ferrite with good ductility. This become the factor to low carbon steel to have good mechanical properties which is from the high in yield and tensile strength and also high absorption foce.

Other than that, mechanical properties for low carbon steel is depends on others various factor such as ferrite mechanical properties which contains carbon and fine grain size (Qu et al, 2008). The added others element alloy into low carbon steel such as molybdenum with the quantity between 0.1-0.2% mass will produce grain structure that more soft and also increase the effect of precipitate hardening through elements of others alloy.

Final strength for ferrite structure is determined through the decrease of carbon content in the material (Qu et al. 2008). The reduction of carbon indirectly will increased the elongation of low carbon steel when there is a tensile load. This show that ductility properties of the material is increased. The ductility of the low carbon steel is also being influence by the increment of fraction grain boundaries which will increase the number of dislocation sources which in turn would increase the frequency of the dislocation density and high strength carbon steel (Calcagnotto et al. 2010).

Low carbon steel will be able to absorb a high shock impact and this mechanical properties is really needed in construction industry to absorb any force that being given to the bridge frame to make sure the structure of bridge always in strong condition and did not collapse easily (Sack and Bonhart, 2005).

Welding process that created on the low carbon steel material is a one of the factor that influence the change in mechanical properties because this process will control the material phase size, volume fraction and others phase formation in low carbon steel material. This is because, welding process will created heat which is being called heat affected zone (HAZ). The heated given on low carbon steel will come from welding process which change the ferrite phase to and austenite phase and back into ferrite phase. This will increased the strength of material but the ductility will decreased because of hardness material is increased. Next it will decreased the level of absorption shock that being given to the material. **Table 2.2** and **table 2.3** show the physical properties and mechanical properties for low carbon steel.

Table 2.2: Physical properties of low carbon steel

Physical properties	
Density	7870 kg/m^3

Source: www.matweb.com

Table 2.3: Mechanical properties for low carbon steel

Mechanical properties	
Final tensile strength	>=380 MPa
Yield strength	205MPa
Elongation before fracture	25.0 %
Shear Modulus	80 GPa
Bulk modulus	140 GPa

Source: www.matweb.com

Low carbon steel is produce for various applications such as in automotive industry and construction industry. Mechanical properties for low carbon steel is greatly influenced by the phase structure of the material and others alloy elements that being added into low carbon steel. The content in low carbon steel influenced the ferrite phase structure in the material. Figure 2.1 show the microstructure ferrite phase and pearlite for low carbon steel (Gural, 2007).

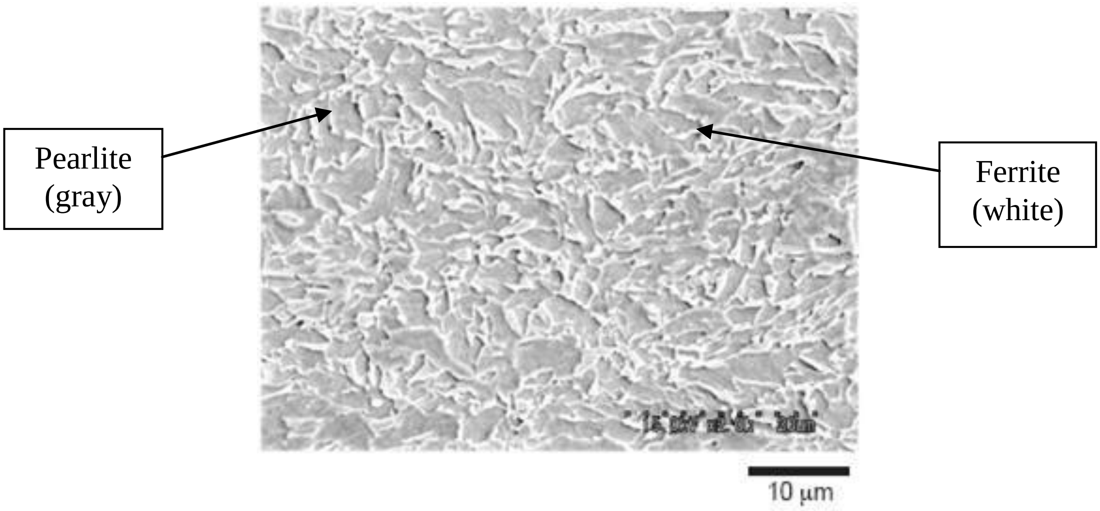

Figure 2.1: Microstructure low carbon steel

Source: www.keytometals.com/

2.4 METALLOGRAPHIC EVALUATION

In order to investigate the microstructure, Scanning Electron Microscopy (SEM) is used (Li Zhuang, 2009) by using a QUANTANA600 microscope. This process is to study the mechanical properties of the low carbon steel. There are several process needed to be done before the mircrostructure can be analyzed which is sectioning, grinding and polishing and etching. Finally the specimen were ready to be viewed on the SEM. Images being scanned on a digital imaging system by computer enhancement or be taken by using an attached camera. The solution is be used to etched the material is natal solution which is combination between ethanol and acid nitric (Li Zhuang, 2009). Sectioning is involved the cutting process which taken the best part to be analyzed. Grinding and polishing is a process to clean the surface and make the microstructure more cleared before etching process taken the place.

2.5 TENSILE TEST FOR LOW CARBON STEEL

One of the methods to evaluate the mechanical properties of one material is by using tensile test. Tension test that has been conducted on low carbon steel has given information about mechanical properties that material. Tension test for low carbon steel given the high and lower yield strength which is influenced by the dislocation associated with carbon and nitrogen contains in the material but this theory not yet approved for metal that has body-centered-cubic (bcc) and face-centered-cubic (fcc) structure .

Yield strength, tensile strength, uniform elongation of material and work hardening exponent can be obtained through tension test to know the effect onto material deformation (Hwang & Lee, 2010). Other than that, tension test also can determine whether that material is fail in brittle or ductile behaviour. This can be known through material fracture surface experiment after going the tension test.

Brittle material will not experienced elasticity deformation but it will experience plasticity deformation. Elongation and deformation for brittle material would not so obvious. This is because material dislocation is limited. The surface fracture for brittle material is the same as in figure 2.2. Metal that has hexagonal-closed position is brittle due to number of slip system are at least 3.

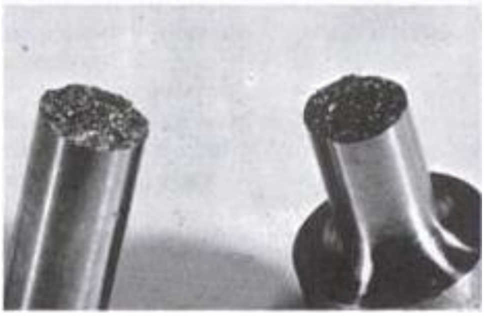

Figure 2.2: brittle fracture

Source: www.sv.vt.edu/

For ductile material, it elastic deformation will occur before plastic deformation. It is the ability of material to stretch by loading and finally fracture (Sacks and Bonhart, 2005). Before the material fail or fracture, material cross section area will decrease. This shown, the dislocation occur on decreasing cross section area. The surface fracture for ductile material is in the shape of cup and cone. Metal with body-centered cubic structure is the most ductile because of the number of the slip system were 48 (William, 2006).

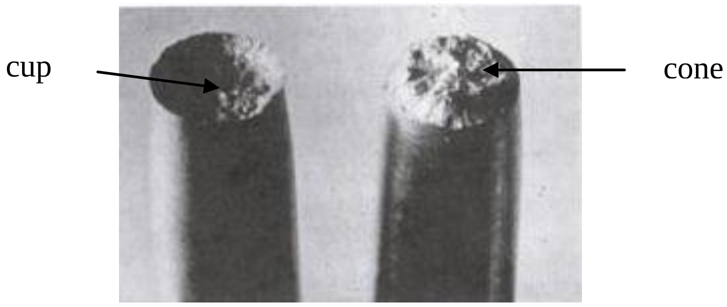

Figure 2.3: Ductile fracture

Source: www.sv.vt.edu/

In tension test, ductile material is different to brittle material. The strain force for ductile material is greater due to area of ductile material has elastic area and the energy needed by material to avoid deformation. For brittle material, strain force contained is