CHAPTER I

INTRODUCTION

1.1 Background of the Study

Continues galvanizing line (CGL) machine is a machine that produces galvanized iron (GI) by immersing strip of coil into zinc alloy liquid. The galvanizing process of CGL machine in PT XYZ use *continuous* hot dip galvanizing as the coating process. The process convert cold roll coil material into galvanized iron coil. As the name implies, continuous hot-dip coating involves the application of a molten coating onto the surface of steel sheet in a *non-stop process* (GalvInfo Center, 2007).

To make sure that the galvanizing process in CGL runs continuously, a *welding machine* is equipped to join the tail end of the preceding coil and the head end of the succeeding coil. CGL machine uses two decoilers side by side called Pay of Reel. The pay off reel receives coil from coil car and hold the coil to feed the line. When the preceding coil is almost run out, the succeeding coil is ready to be processed.

When the line is stopped for welding, the preceding coil strip being cut at the double cut shear and the tail end of preceding coil is threaded to the welder and clamped. Then the head end of the succeeding coil is threaded to the welder, lapped and clamped. The two ends of the coil are welded by the *welding wheel.*

Double pass system is applied from the pay off reel to the welder to feed the material coils continuously. To keep the strip continues to run in the next process at CGL machine while the strip is stopped in the entry section for welding, there is delivery looping car system. Delivery looping car system will stock some length of strip for the next process while the entry section is stopped for welding. After the strip welded in entry section, the stock of strip in delivery looping car that used at welding restored its length to be used in the next welding process.

If the welding processes fails and the stock of strip in delivery looping car runs out, then the operation in CGL machine that supposed to be continuous will be stopped. The consequences if CGL machine stopped in the middle of operation is very high, the strip that still in the middle of CGL machine (annealing furnace, zinc pot, post treatment) is defect and will be classified as scrap. The time to recover and install a new strip inside the CGL machine is long enough, and it will ruin the entire schedule that has been made until Finishing Line, the impact is like chain effect that will cost PT XYZ a lot.

The welding wheel that used in welding machine, when used it will erode bit by bit until the diameter is too small to be used. So the welding wheel needs replacement when the condition is not appropriate again to produce a good quality of welding. The original welding wheel itself purchased from Japan, the price is very expensive and the lead time to buy the material takes few months to be delivered, moreover the producer in Japan consider not to produce that type of welding wheel anymore by the end of year 2010. This condition need to be solved because the welding activity is very essential to make the process in CGL machine runs continuously, without an appropriate welding wheel in welding machine the CGL machine cannot be run.

Finally, the purpose of this research is to make a new welding wheel that suite the welding machine qualification to substitute the welding wheel that produced in Japan and eliminates the issue that mentions above. So, how to make a welding wheel that suite the welding machine and other parameters that make the new welding wheel electrode have the same performance with the original Japan's made welding wheel electrode is the question that need to be answered in this research.

1.2 Problem Statement

Based on the background of the study, the problem statement of this research can be defined as follow:

1. How to make a domestic welding wheel electrode that can substitute the original Japan made welding wheel electrode?
2. Define the quality and performance of domestic welding electrode compared to the original Japan made welding electrode!
3. Define the price of domestic welding electrode compared to the original Japan made welding electrode!

1.3 Objectives of the Research

1. To make a domestic welding wheel electrode that can substitute the original Japan made welding wheel electrode.
2. To define the quality and performance of domestic welding electrode compared to the original Japan made welding electrode.
3. To define the price of domestic welding electrode compared to the original Japan made welding electrode.

1.4 Significance of the Research

After this research is done, it will give significance benefit as stated below:

1. The company can replace the original Japan made welding electrode with domestic welding electrode.
2. The quality and performance of domestic welding electrode compared to the original Japan made welding electrode is defined.
3. The price of domestic welding electrode compared to the original Japan made welding electrode is defined.

1.5 Scope of the Research

The scope of the research will be stated as follows:

1. The research placed in PT. XYZ at Continuous Galvanizing Line machine.
2. The welding wheel electrode design and parameter subjected to welding machine in Continuous Galvanizing Line Machine.
3. The welding machine made specifically to weld strip of coil.
4. The data gathered from January 27, 2010 until February 26, 2010.

1.6 Outline of the Research

In order to get a well structured research report, hence the research outline will be continued as follows:

CHAPTER II **LITERATURE REVIEW**

This chapter contains the basic theory and the theoretical review of the research problem, explanation about the basic concepts about the topic and support to the research performed, and the related works.

CHAPTER III **RESEARCH METHODOLOGY**

This chapter contains a detailed series of steps of the research, research variable, research procedure, data collecting method, data processing method, and analysis method.

CHAPTER IV **DATA COLLECTING AND PROCESSING**

Explain about the data of the research, processing the data using the methods that detemined by the analysis result to get the final answer.

CHAPTER V **DISCUSSION**

This chapter contains result, analysis and interpretation about the data processed.

CHAPTER VI CONCLUSION AND SUGGESTION

This chapter consists about the summary of the research study that has been done, the recommendation for the company and for further research study.

REFFERENCES

APPENDICES

CHAPTER II

LITERATURE REVIEW

2.1 Hot Dip Galvanizing

Hot dip galvanizing is a form of galvanization. It is the process of coating iron, steel, or aluminum with a thin zinc layer by passing the metal through a molten bath of zinc at a temperature of around 860 °F (460 °C) (Wikipedia, 2010). It forms fairly strong material and stops further corrosion by protecting the steel below from corrosive elements. Zinc coatings prevent corrosion of the protected metal by forming a physical barrier coating, it provides a tough, metallurgically-bonded zinc coating that completely covers the steel surface and seals the steel from the environment's corrosive action. Additionally, zinc's sacrificial action (cathodic) protects the steel even where damage or a minor discontinuity occurs in the coating. Because zinc is anodic to steel, the galvanized coating provides cathodic protection to the exposed steel. When zinc and steel are connected in the presence of an electrolyte or corrosive material, the zinc is slowly consumed while the steel is protected. Zinc's sacrificial action offers protection even where small areas of steel are exposed, such as cut edges, drill-holes, scratches, or as the result of severe surface abrasion. Cathodic protection of the steel from corrosion continues until all the zinc in the immediate area is consumed, the equation for this phenomenon is: $Zn + Fe^{2+} \rightarrow Fe + Zn^{2+}$

Galvanizing forms a metallurgical bond between the zinc and the underlying steel or iron, creating a barrier that is part of the metal itself (American Galvanizers Association, 2000). During galvanizing, the molten zinc reacts with the iron in the steel to form a series of zinc/iron alloy layers. Figure 2.1 is a photomicrograph of a galvanized steel coating's and shows a typical coating microstructure consisting of three alloy layers and a layer of pure metallic zinc. The gamma, delta and zeta alloy are actually harder than the base metal itself. The temperature at bonding activity between base steel and zinc must be at least 800 °F (427 °C) or the bonding cannot occur.

Figure 2.1 Photomicrograph of Galvanized Coatings. Adapted From American Galvanizers Association (2004)

Electrons will naturally gravitate towards zinc and consume it. The thicker the layers, the longer it will take to corrode. The base steel is covered with four different levels of hot dip galvanization. The hardest, strongest level starts out at the bottom, closest to the steel. The thickness of the galvanized coating is the primary factor in determining the service life of the product (American Galvanizers Association, 2004). The thicker the coating, provide higher corrosion protection. Although galvanizing will prevent corrosion in the base steel, corrosion will be inevitable, especially if the environment is acidic or contain salt material. For example, sea environments also lower the lifetime of galvanized iron roofs and similar products, because the high electrical conductivity of sea water encourages and increases the rate of corrosion. Galvanized steel products can last longer if further protected by a paint layer.

2.2 Continues Galvanizing Line Machine

Continues galvanizing line (CGL) machine is a machine that produces galvanized iron (GI) by immersing strip of coil into zinc alloy liquid in the process. The galvanizing process of CGL machine in PT XYZ use *continuous* hot dip galvanizing as the coating process, it convert cold roll coil into galvanized iron coil. As the name implies, continuous hot-dip coating involves the application of a molten coating onto the surface of strip of coil in a *non-stop process* (GalvInfo Center, 2007). The strip of coil is passed as a continuous ribbon through a bath of molten metal at speeds up to 183mpm, in the molten metal bath, the steel strip reacts (alloys) with the molten metal to bond the coating onto the strip surface. As the strip emerges from the molten bath, it drags out excess liquid metal (zinc). Using a gas-wiping process, a controlled thickness of coating, usually expressed as weight (mass) of coating per unit area, is allowed to remain on the strip surface.

The material that processed in Continuous Galvanizing Line machine called Cold Rolled Coil (CRC), which is an unannealed, low carbon steel without coating. The specifications of the CRC that processed in CGL machine are:

-Thickness = 0.20 – 1.20 mm

-Width = 762 – 1,219 mm

-Weight = max 20 ton

-Inner diameter = min 508mm

-Outer diameter = min 1000mm – max 2000mm

Based on the technology of the production system, hot dip galvanizing in PT. XYZ is categorized as modern continuous hot dip galvanizing (coil to coil) that use NOF system for its furnace (Rachmat, 2006). Because the production system is coil to coil and must run continuously, a welding machine is installed to join the strip of the coil to make it run continuously. The illustration of CGL machine shown in figure 2.2.

CGL

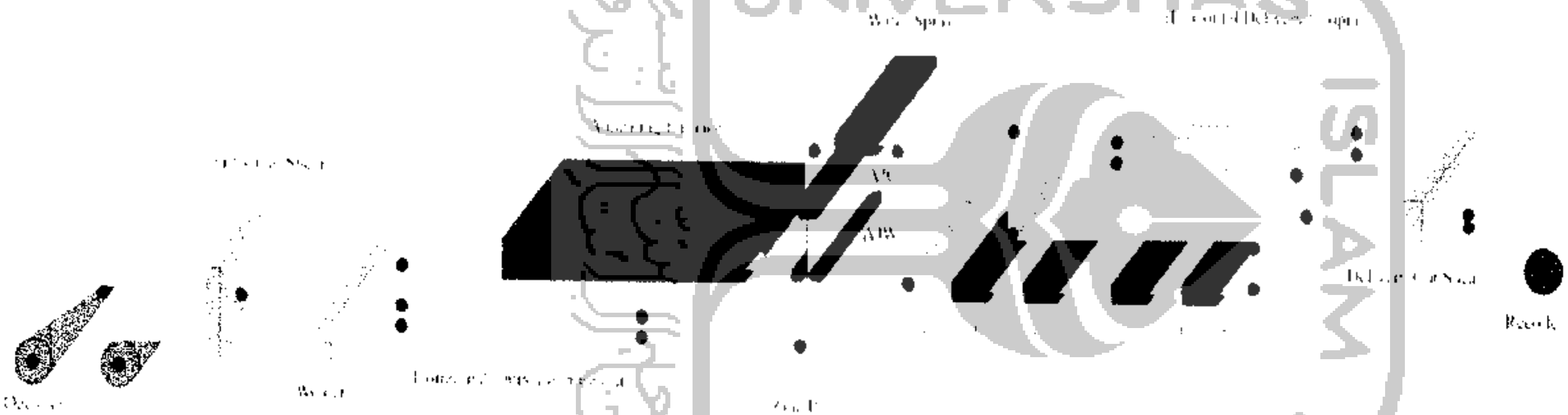

Figure 2.2 Continuous Galvanizing Line Machine

The CGL machine itself consists of 8 sections, which are:

1. Entry section

Material coil transferred from the entry coil yard is placed on the entry coil skid by the overhead travelling crane. The transferred coil is then transferred by the entry coil car and inserted into the pay off reel after height and width are aligned manually. The top end of the coil on the pay off reel is led to the pinch roll by manual and threaded to the double cut shear. The double cut shear cuts the top and tail end (off gauge and defect) of the strip for welding and then the scraps are removed by manual. The top end of the succeeding is transferred to the welder and welded to the preceding tail end of the strip. Double pass system is applied from the pay off reel to the welder to feed the material coils continuously.

2. Entry looper section

A horizontal type looper is installed to store the required length of the strip due to the continuous furnace operation when the entry section is stopped for welding.

3. Annealing Furnace section

The annealing furnace is off horizontal type, consist of Pre-heater, Non Oxidizing Furnace, Radiant Tube Furnace, Slow Cooling Section, Jet Cooling Section and Turn Down Section. (each of which is referred to as PH, NOF, RTF, SC, JC, TD). Strip first enters into PH & NOF which heat the strip up to proper temperature and remove rolling oil by means of direct firing up to 650° C. PH is located prior to NOF to recover the heat of waste gas from NOF. NOF is conducted by direct burning using fuel gas under atmospheric gas without Oxygen (O_2). The O_2 is purged by N_2 and H_2 gas from before the process start and in the process of burning for better corrosion resistant.

The strip next enters into RTF which heat the strip up to final annealing temperature up to 1,200° C depend on the GI coil specification expected by means of indirect radiational heating utilizing fuel gas fired radiant tube. Another function of RTF is to reduce the strip surface which is weakly oxidized in previous direct fire section, the microstructure formation of the strip is change in the reductive atmosphere of this section. And next, the strip is slow cooled in SC section to avoid the deterioration of the strip shape and also to complete the reduction of the strip surface. For this purpose, radiational cooling utilizing cooling tube and additional electrical heating is adopted. Finally, the strip is rapid cooled in JC section down to appropriate temperature for successive coating by means of circulation gas jet cooling. After JC section, the strip goes to coating pot through TD section, in which the strip pass is turned down to sink roll in the pot, and furnace atmosphere is sealed by snout which covers the strip into molten zinc.

The temperature for each zone in annealing furnace section is different, the temperature will also be different in different product type. The temperature cycles will be explained in figure 2.3.

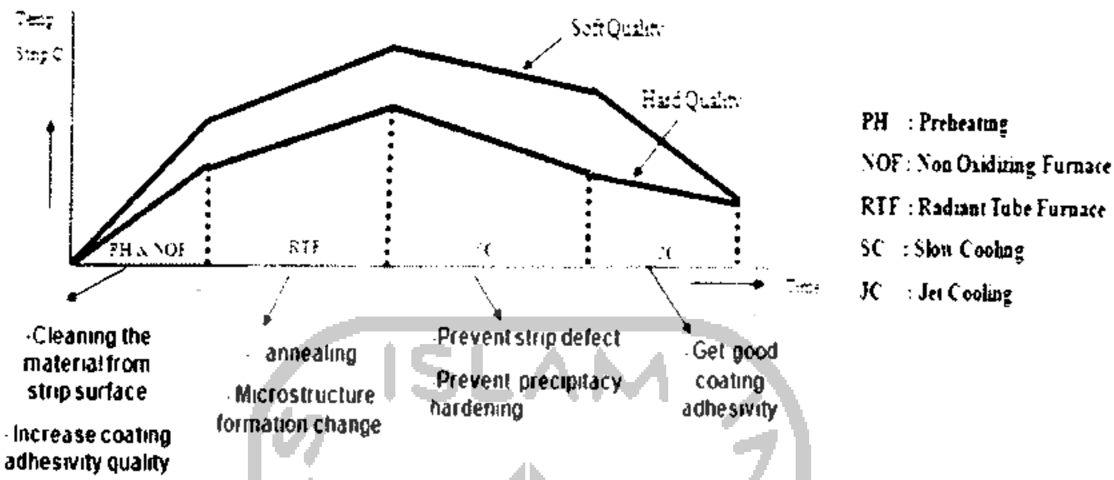

Figure 2.3 Temperature Cycles in Annealing Furnace. Adapted From Rachmat (2006)

4. Coating section

The strip is led into a molten zinc iron pot through the furnace snout, and galvanized while strip passes in it through. The temperature of zinc bath in iron pot is controlled to about 460'C by electric resistance heater. Molten zinc deposited on the strip while it passes the zinc bath is wiped off to the specified coating weight by air jet wiping (AJW) device. A few roll units is arranged to deflect the strip run from the furnace through the zinc pot to the vertical pass line at coating equipment. Motor driven support roll is arranged in zinc bath to prevent the vibration of the strip to make uniform coating possible.

5. Cooling equipment with air jet cooler (AJC) and water spray cooler

The strip passes over a cooling tower to cool the coatings which is flowering fine spangle in the strip. Cooling tower consist of an air jet cooler which blow pressured air and a water spray cooler to cool down the zinc.

6. Post treatment section

After cooling, the strip is passed through Skin Pass Mill (SPM), to press the strip under rough surfaced roll to make the surface smoother. After SPM the strip is corrected in shape by Tension Leveler (TLV), the purpose is to improve product flatness by stretching all of the longitudinal structures in the metal strip to equal length. After the tension leveler, Chromate equipment is installed to improve resistance against the white rust corrosion and the coatability of galvanized strip of galvanized steel. The dryer system is installed just after the spraying tank to dry the strip surfaces with hot air.

7. Delivery looper section

A horizontal type looper is installed to store the required length of the strip due to the continuous furnace operation when the delivery section is stopped for the coil dividing.

8. Delivery section

The coil went out of the delivery loop car is divided and cut off the portion of the welded area by the delivery shear. The product coil wound by the tension reel is carried off by the delivery coil car. The head of the succeeding coil is fed and wrap by the belt wrapper to the tension reel mandrel. The edge coil can be wound uniformly by an edge position control system. The product coil is transferred to next process by the overhead crane.

2.3 Limited Over-Lap Seam Welding Machine

2.3.1 General

This welding machine is designed and manufactured to join the leading and travelling coil strip by seam welding in Continuous Galvanizing Line machine. The operations are to overlap two strips, clamp together and seam-weld them by a pair of *wheel electrodes*.

Figure 2.4 Limited Over-Lap Seam Welding Machine

2.3.2 Welding Capacity

Material to be weld	: cold rolled, non-annealed, low carbon steel JIS G 3141 SPCC, SPHC
Yield point	: min 20.0 kgf/mm^2 max. 38.5 kgf/mm^2
Tensile stress strength	: min. 28.0 kgf/mm2 max. 55.0 kgf/mm2
Thickness	: 0.18 – 1.2 mm
Width	: 615 – 1219 mm
Thickness of welded zone	: two times
Value of lapping	: approximately 22mm
Cycle time	: 40 seconds

2.3.3 Utilities

Welding power supply	: single phase AC 380V±5% 50Hz
Motor power supply	: three phase AC 380V±5% 50Hz
Control power supply	: three phase AC 380V±5% 50Hz
Compressed air supply	: 0.69 – 0.49Mpa
Cooling water supply	: 0.29 – 0.15Mpa 13liter/min lower than 30'C
Hydraulic supply	: 11 – 14Mpa 60liter/min. from line

2.3.4 Main Unit

1. Main Frame

   The main frame is fabricated by welded construction, and on this frame main carriage unit, back-bar, two sided guide units, punch unit and others are assembled

2. Carriage unit

   On this unit, welding head assemblies and welding transformer are mounted, this unit is driven by motor on V-guide rails

3. Welding unit

Welding transformer	: model RS-T
Rated capacity	: 120kVA
Rated primarily voltage	: 380V
Rated frequency	: 50Hz
Max. Welding Capacity	: 300kVA
Max. Welding current	: 26000A
Rated duty cycle	: 8%
Max Welding pressure	: 8800N
Welding electrode size	*: Ø300mm x 12t*
Contact electrode size	*: Ø220mm x 12t*
Space between electrodes	: 118mm
Direction of welding	: from operator side to drive side
Start and finishing of welding	: by photo sensor

4. Clamp unit

Entry clamp pressure	: 500 kgf x 2
Exit clamp pressure	: 500 kgf x 2

5. Side guide unit

Side guide unit are attached at entry and exit side of the welding machine. Leading and trailing strip are centered by these units manually

6. Punch unit

Punch unit is mounted on the exit side of the welding machine. Two Ø15mm holes are punched on the trailing strip by hydraulic cylinder.

The illustration of welding machine component and process shown in figure 2.5 and 2.6 below:

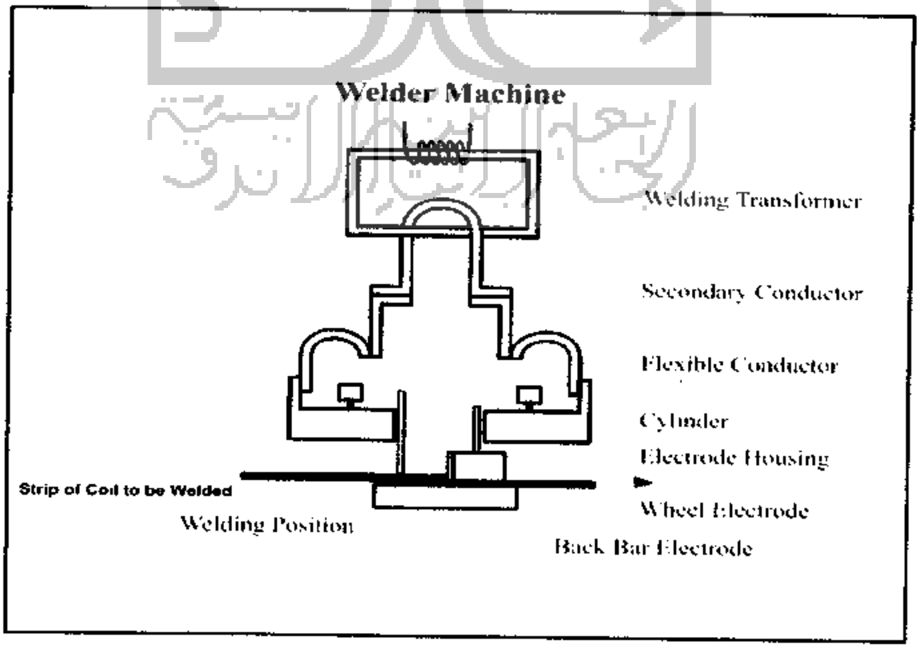

Figure 2.5 Welding Machine Component

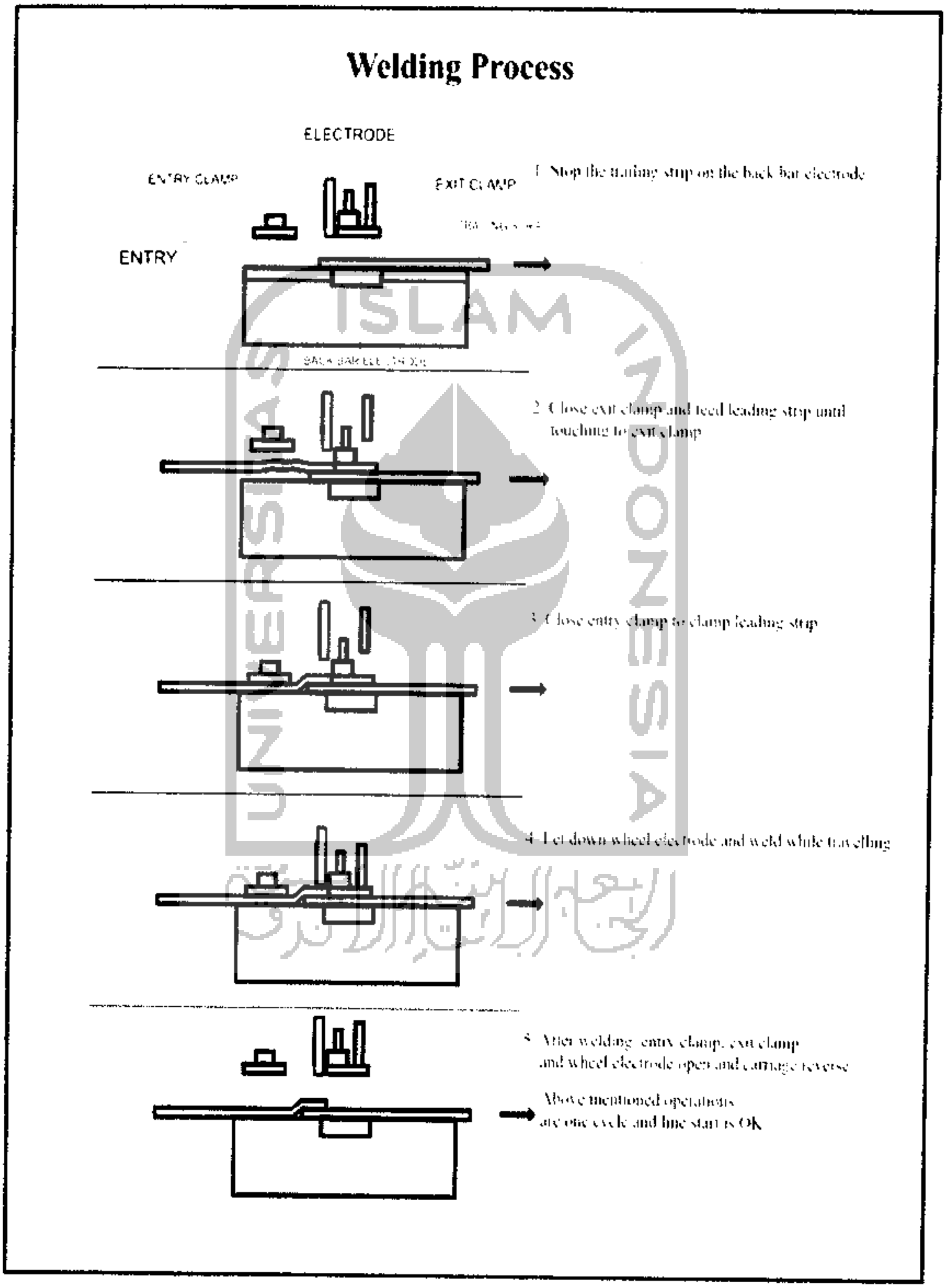

Figure 2.6 Welding Process

2.4 Welding

Welding is a metal joining process in which coalescence is obtained by heat and pressure. In welding, the metallurgical bond is accomplished by the attracting forces between atoms, but before these atom can bond, absorbed vapors and oxides must be eliminates from contacting surfaces (Oswald & Munoz, 1996). Some factors influencing welding result are the proportions of the work pieces, the electrode materials, electrode geometry, electrode pressing force, weld current, weld time and the base metal itself. It necessary to control or adjust welding current, welding time and electrode pressure according to the material, thickness and others to be welded. Welding process involving thermal energy to melt the base metal, this phenomenon expressed in this equation $E = I^2 R t$ where E is energy (joule), I is current (ampere), R is resistance (ohm) and t is time (second).

Seam welding is a resistance welding method used to join two to four overlapping metal sheets which are up to 3 mm thick each. Two copper electrodes are simultaneously used to clamp the metal sheets together and to pass current through the strip of coil, it relies on two electrodes to apply pressure and current to join metal sheets. Resistance Seam Welding/Roll Welding is a resistance welding process that produces a weld at the surfaces of overlapped parts along a length of a joint. Instead of using two cylindrical electrodes as in case of spot welding, here two circular disks are used as electrodes. The work piece, in this case is strip of coils is passed through the space between the two discs, and under pressure applied by the discs and current flowing through them, a continuous weld is formed. With seam welding the material passes between two rotating wheels or welding rollers.

Generally a welding activity will form 3 different zones, which are:

- Base metal : metals that not affected by the welding activity
- Heat Affected Zone (HAZ) : zone within the base metal that experience structural changes but does not melt during the welding.
- Fusion Zone : the welded area of the metals

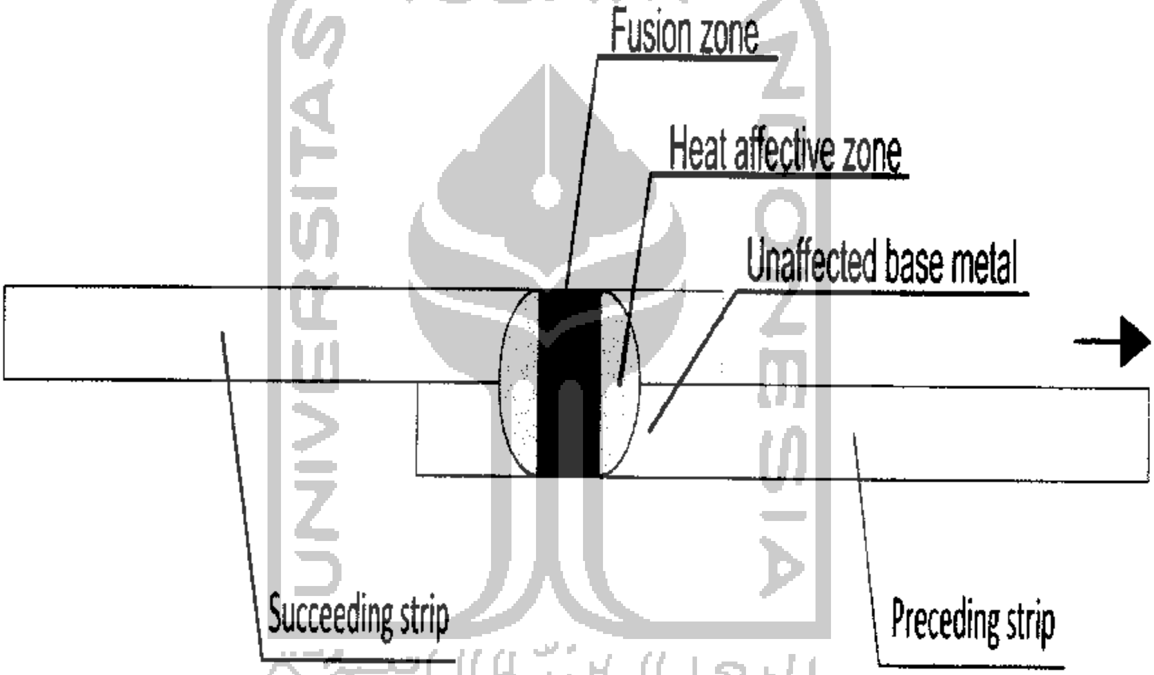

Figure 2.7 Welded Area In Strip Of Coil

Based on David, Babu, & Vitek (2003) explanation that during welding, where the molten pool is moved through the material (FZ), the growth rate and temperature gradient vary considerably across the weld pool. Geometrical analyses have been developed that relate welding speed to the actual growth rates of the solid at various locations in the weld pool. An important aspect of weld solidification is the dynamics of weld pool development and its steady state geometry. Weld pool shape is important in the development of grain structure and dendrite growth selection process. Thermal conditions in and near the weld pool and the nature of the fluid flow have been found to influence the size and shape of the weld pool. Where in steels sheet joint the shape and size of the weld pool arranged so that the overlapping strip of coil joint are stronger than the strip of coil itself.

2.5 Electrode

Electrode is a terminal through which electric current passes between metallic and nonmetallic parts of an electric circuit (Columbia Electronic Encyclopedia, 6th Edition, 2009). Generally, circuit's current is carried by metallic conductors, but in some circuits the current passes for some distance through a nonmetallic conductor. An electrode is usually in the form of a wire, rod, or plate. It may be made of a metal, e.g., copper, lead, platinum, silver, or zinc, or of a nonmetal, e.g., electrolyte, gas, or carbon. The electrode through which current passes from the metallic to the nonmetallic conductor is called anode and that through which current passes from the nonmetallic to the metallic conductor, the cathode. (Electron flow is in a direction opposite that of conventionally defined current.) In most familiar electric devices, current flows from the terminal at higher electric potential (the positive electrode) to the terminal at lower electric potential (the negative electrode); therefore, the anode is usually the positive electrode and the cathode the negative electrode. In some electric devices, e.g., an electric battery, nonelectric energy is converted to electric energy, causing current to flow within the device from the negative electrode to the positive electrode, so that the anode is the negative electrode and the cathode is the positive electrode.

Welding electrode is an electrode that used to conduct current through a work piece to join two pieces together. Depending upon the process, the electrode is either consumable, in the case of gas metal arc welding or shielded metal arc welding, or non-consumable, such as in gas tungsten arc welding. The electrodes used for welding have many shape, depend on how they will be used and their specification such as stick and circle.

2.6 Metallurgy Aspects

Metallurgy is a part of materials science that studies the physical and chemical behavior of alloying elements, their compounds, and their mixtures, which called alloys (Wikipedia, 2010). Metallurgy studies the microscopic and macroscopic properties using metallography, study of the physical structure and components of metals. In metallography, a sample that being analyze flattened and polished, the sample then etched to reveal the microstructure and macrostructure of the metal, after that the sample examined in an optical or electron microscope, and the image contrast provides details about the composition, mechanical properties, and processing history. Using only metallographic techniques, a skilled technician can identify alloys and predict material properties.

Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25× magnification (ASM Metals Handbook vol. 9, 1985). The microstructure of a material can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, wear resistance, and so on, that will determine the application of these materials. The microstructure is very critical because the microstructure reveals the grains of an alloy, which then from the grain the properties and characteristic of an alloy could be determined.

The grain size of an alloy highly affects the strength of an alloy, the fine grain size is often desired for high strength, large additions of solute atoms are added to increase strength and bring out new phase of relationships, fine particles may be added to increase strength and phase transformations may be utilized to increase strength. The boundary between grains is regions of disturbed lattice only a few atomic diameters wide, the crystallographic orientation changes abruptly in passing from one grain to the next across the grain boundary. The ordinary high angle grain boundary represents a region of random misfit between the adjoining grains. As the difference in orientation between the grains decreases, the state of order in the boundary increases (Dieter, 1976).

Mechanical strengthening of grain boundaries is provided by experiments on bicrystals in which the orientation difference between longitudinal grain boundaries varied in a systematic manner. The yield stress of the bicrystals increased linearly with increasing misorientation across the grain boundary. These results imply that a simple grain boundary has little inherent strength and that the strengthening due to grain boundaries results from mutual interference to slip within the grains. The role of grain boundaries in causing non homogeneous deformation and in introducing multiple slip empirically established by Hall and Petch that the tensile yield strength was related to grain size by $\sigma_y = \sigma_o + kd^{-\frac{1}{2}}$

Where: σ_y = the yield strength

σ_o = friction stress opposing motion of dislocations

k = 'unpinning constant' measuring the extent to which dislocations are piled up at barriers

d = the grain diameter

The Hall-Petch equation has been found to express the grain size dependence of the flow stress at any plastic strain out to ductile fracture. Also to express the variation of brittle fractures stress with grain size and the dependence of fatigue strength on grain size.

2.7 Copper Based Alloy

Copper and copper alloys (Cu and Cu alloy) are among the most commercially important metals because of their excellent properties, ease of manufacture and numerous applications. They are widely used because of their excellent electrical and thermal conductivity, resistance to corrosion and ease of fabrication. Low alloyed Cu are used extensively for cables and wires, electrode, reactor wall, electrical contacts and a wide variety of other parts that are required to pass electrical current. The development of electronics industry has led to a number of new applications for Cu alloys including lead frames, connectors and other electronic components. These applications require alloys with unique combinations of strength, conductivity and thermal stability.

Many types of high electrical conductivity alloys have been developed by researchers around the world. A number of commercial alloys have been developed and these are used for a variety of applications requiring combinations of high-strength, high-conductivity and resistance to softening. A small amount of certain element additions are required to achieve optimum properties in these alloys. The electrical-resistance welding process reached full development in the production of strip of coil, aviation assemblies, car chassis and bodies, metallic furniture, and other applications. This welding process uses copper and Cu based alloys as the electrode material. Electrical resistance welding involves passing a high current at a low voltage through a circuit closed by the pieces that to be welded, these pieces are maintained in close contact with the two electrodes with an applied pressure. The heat generated by the electrode is enough to produce local fusion of the pieces under pressure, leading to a forged union to join the steels. Therefore electrode materials must exhibit high electrical and thermal conductivities, combined with high strength, at elevated temperatures.

CHAPTER III

RESEARCH METHODOLOGY

This chapter explains the research methodology and the steps in conducting this research. This chapter consists of some sub chapters which are explain about object of research, problem formulation, research framework, data collection, product development, and product application. All sub chapters will be explained details as follows:

3.1 Research Object

This research conducted in PT. XYZ in Jakarta. The object of this research is a welding electrode for welding machine which is a part of Continuous Galvanizing Line Machine as explained above. The data and information conducted in PT XYZ during the research are:

1. The general information of PT XYZ
2. Continuous Galvanizing Line machine flow process
3. Limited Over-Lap Seam Welding machine flow process
4. Parameter and standard in Limited Over-Lap Seam Welding Machine
5. Welding electrode properties.

3.2 Identification and Problem Statement

This process is being done to formulate the problem which is to develop a domestic welding electrode to replace import welding electrode that has some inefficiency which already being explained and stated in background of the problem.

3.3 Data Collection

The data to support this research gathered in 5 ways:

1. Consultation with supervisor about research focus.
2. Field study by doing direct observation in Continuous Galvanizing Line machine and welding activity in Seam Welding machine.
3. Get statistical and primary data in the company by doing some testing and analysis in the company facility.
4. Interviews with the employees in the company about process and activity related to this research.
5. Data from Metal Industries Development Centre (MIDC) in Bandung about electrode properties and micro structure photograph.

3.4 Data Processing

All data and information gathered in the research will be processed and analyzed in order to develop the domestic welding electrode to replace the import welding electrode in Seam Welding machine.

3.5 Research Result Analysis

The result from data processing will be discussed and analyzed in order to achieve the research objective.

3.6 Research Framework

The steps to conduct this research are as follow:

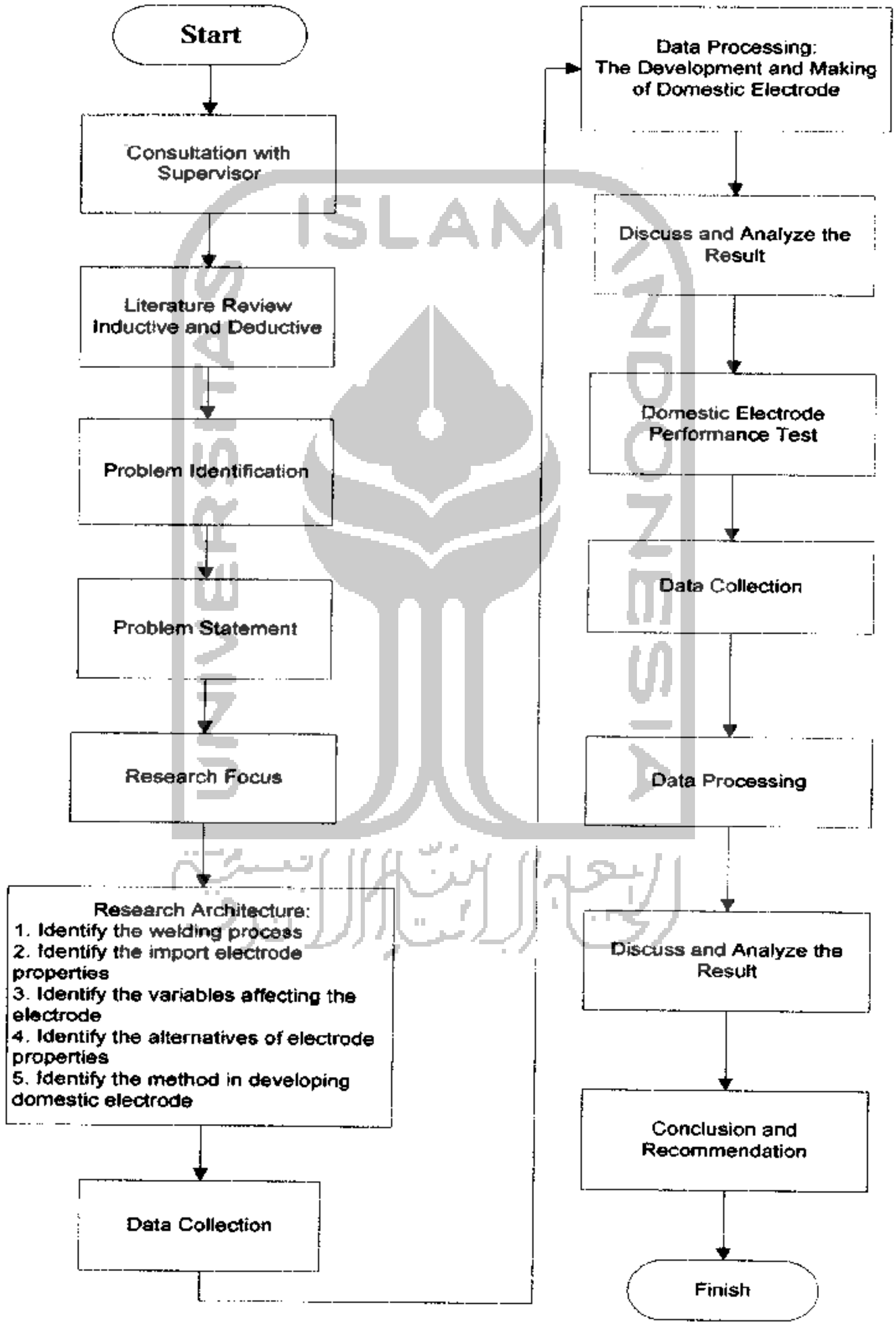

Figure 3.1 Research Framework

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 PT. XYZ

4.1.1 PT. XYZ in Brief

Because the data that used in this research is confidential, the company name and profile will not be published in this research, for easiness of identification the company name will be assumed as PT. XYZ.

4.1.2 Limited Over-Lap Seam Welding Machine

This welding machine is designed and manufactured to join the leading and travelling strip of coil by seam welding in Continuous Galvanizing Line machine. The operations are to overlap two strips, clamp together and seam-weld them by a pair of *wheel electrodes*.

4.1.3 Welding Wheel Electrode

Welding electrode is an electrode that used to conduct current through a work piece to join two metal pieces together, in this case is strips of coil that processed in Continuous Galvanizing Line Machine. The welding electrode used is welding wheel electrode.

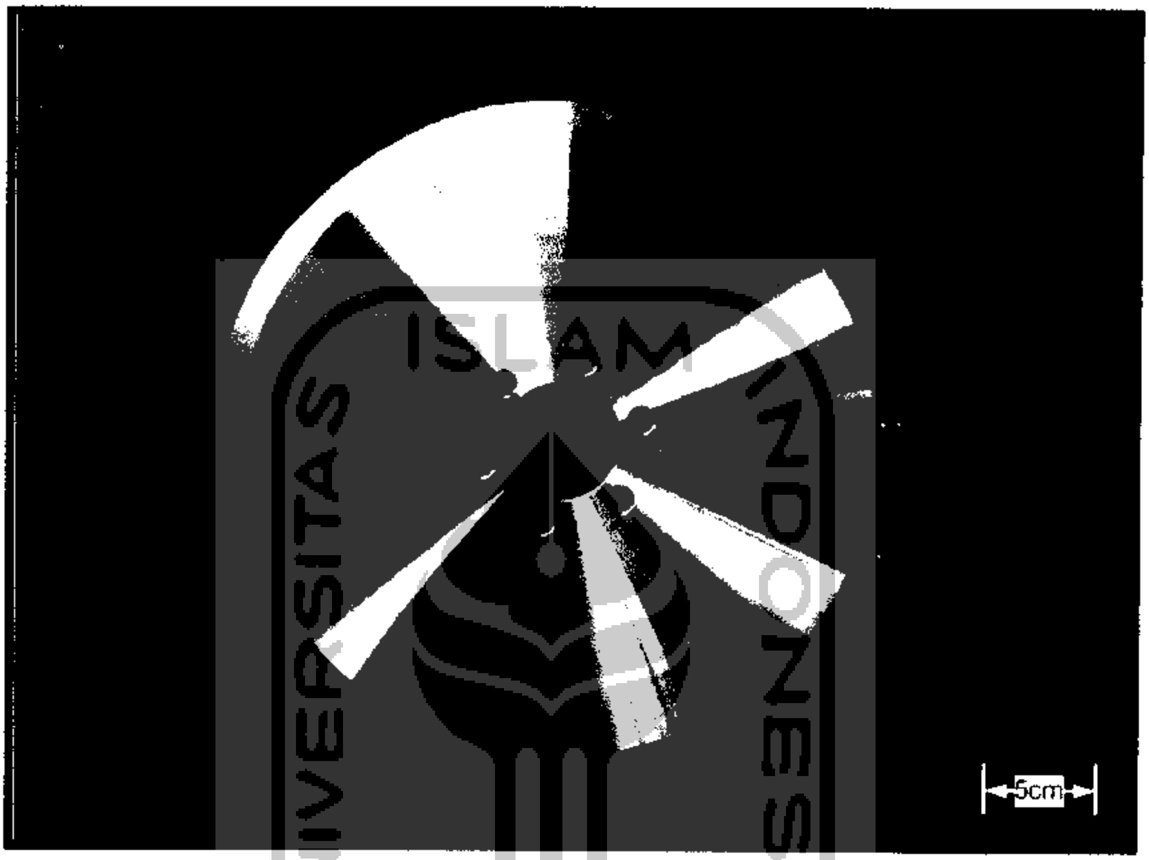

Figure 4.1 Import Welding Electrode

This chapter will explain about the method and analysis to develop a domestic welding wheel electrode to replace the original Japan made welding. After the domestic welding electrode being made, the domestic welding electrode will be perform some performance test to challenge the imported one to determine whether domestic welding electrode could be used to weld the strip of coil in Continuous Galvanizing Line Machine safely and fulfill the welding quality assessment.

4.2 Domestic Welding Electrode Development

4.2.1 Data Collecting

4.2.1.1 Properties of Import Welding Electrode

Researcher use metallographic techniques, study of the physical structure and components of metals to determine the properties of import welding electrode. The metallographic result shows that the import welding electrode metal properties consist of Cu (copper): 98.37%, Cr (chromium): 1.17% and the remaining substances are unknown and will be defined by researcher.

4.2.1.2 Microstructure Test of Import Electrode

Studying the microstructure of a material provides information about its composition, processing technique, properties and performance of the material. These microstructural features affect the properties of a material, and certain microstructural features are associated with superior properties. Through microstructural examination we can determine if a component made from specific material and whether the material receives certain processing treatments or not. Microstructural analysis used in research studies to determine microstructural characteristic of a material, the characteristic of a material resulted from some parameters such as composition and processing technique. Through this microstructural analysis, the structure, properties and elements relationships of the material are developed. Figure 4.2, 4.3, 4.4 and 4.5 shows the microstructures photos of import welding electrode in different magnification.

Figure 4.2 Import Welding Electrode Microstructure Photo with 50x Magnification

Figure 4.3 Import Welding Electrode Microstructure Photo with 100x Magnification

Figure 4.4 Import Welding Electrode Microstructure Photo with 200x Magnification

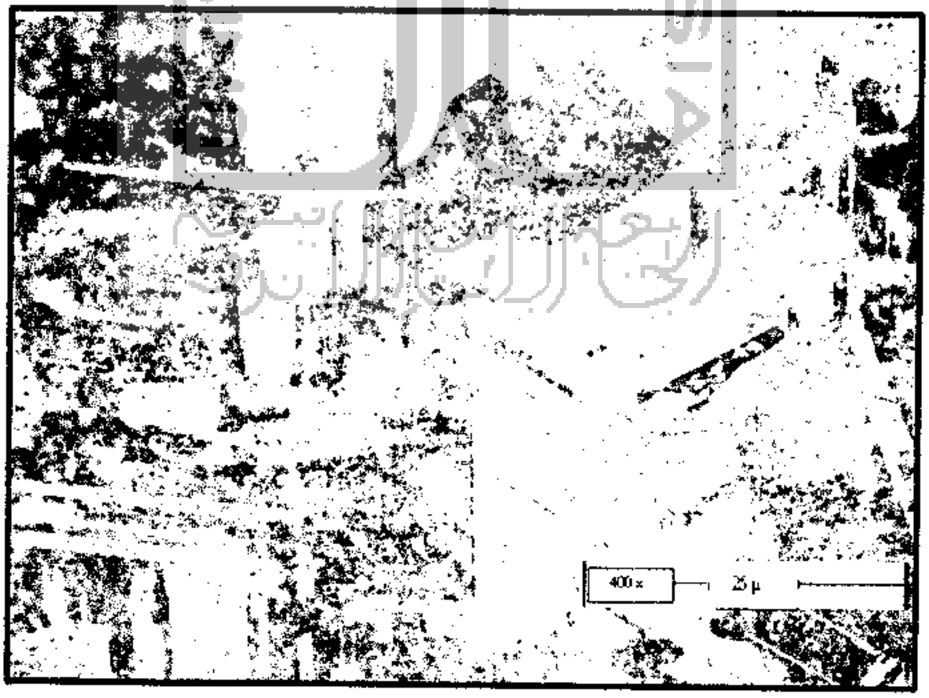

Figure 4.5 Import Welding Electrode Microstructure Photo with 400x Magnification

4.2.2 Data Processing

4.2.2.1 Developing Domestic Welding Electrode

Based on ASM Metals handbook of nonferrous alloys and pure metals, one of the best compositions to build seam welding wheels is 99% of Cu and 1% of Cr (ASM International , 1985). Because not all the composition of import welding electrode revealed in the metallography process, which 0.47% of its substances remaining unknown, based on the literature review and consultations with supervisor, the researcher decide to add Zirconium (Zr) to build domestic welding electrode. Zirconium chosen because it will complement the alloy with its own characteristic to increase the quality of domestic welding electrode that being made. The characteristic and analysis of Cu, Cr and Zr chemical element, also after it combined as alloy will be explained below.

Copper is a chemical element with the symbol **Cu** with atomic number 29 in periodic table. Copper considered as malleable ductile metal with very high thermal and electrical conductivity. Copper melting point is at 1084.62 °C and its electrical resistivity at 20 °C is 16.78 nΩ·m. Copper has the second highest electrical conductivity of any element, the number one is silver. Pure copper characteristic are rather soft, malleable and the surface color seems rather pinkish, reddish, orange, or even brownish. Copper has good corrosion resistance and usually used as thermal conductor, electrical conductor, a building material, and usually combine with other materials to produce various metal alloys. Copper usually used as alloy for industrial needs to get really good machinability characteristics because of its character. Copper is often too soft for its applications, so it is incorporated in numerous alloys.

Chromium is a chemical element which has the symbol **Cr** with atomic number 24 in periodic table. It is a steely-gray, lustrous, hard metal and has a high melting point at 1907 °C and its electrical resistivity at 20 °C is 125 nΩ·m. It is also odorless, tasteless, and malleable. Chromium known of its high corrosion resistance and hardness, the used of chromium in steel and alloy resulting in highly resistant to corrosion and discoloration of the steel and increase its hardness. The strengthening effect of forming stable metal and the strong increase in corrosion resistance made chromium an important alloying material for steel.

Zirconium is a chemical element which has the symbol **Zr** with atomic number 40 in periodic table. It is a lustrous, grey-white, soft, ductile, and malleable metal which is solid at room temperature, though it becomes hard and brittle at lower purities. Zirconium is used as an alloying agent for its strong resistance to corrosion and heat resistance. Zirconium's melting point is at 1855°C and its electrical resistivity at 20 °C is 421 nΩ·m.

The first step in the development of a new alloy was to first determine its basic elements. Consideration of the trade-off between high strength and high electrical conductivity was important at this stage. Yamamoto, Sasaki, Yamakawa, & Ota (2000) states that generally, strength and electrical conductivity act against each other, which means materials with high strength tend to have low electrical conductivity. Observation to a favorable combination of mechanical properties and electrical conductivity, alloys belonging to the Cu element are commonly applied for fabrication of electrodes for resistance spot and seam welding of low carbon steels. Copper and Cu-based alloys are certain candidates to build this welding electrode since copper has excellent thermal and electrical conductivities. But pure copper is too soft for many technical applications and different approaches to harden copper were done as there are adding other elements, work hardening, grain refinement, solid solution hardening and precipitation hardening.

According to Nikolaev, Borodai, & Pleshakov (2008), to increase the wear resistance and strength of metals and alloys, additions of niobium, vanadium, zirconium, and rare-earth elements, as well as of certain nonferrous metals, strontium, boron, and other elements or their compounds, are used. The positive effect of additions is seen upon their introduction into coatings and performance of welding electrodes in amounts of 0.1% or even 0.01%. The low application other elements in metallurgy in the production of welding materials will affect the structure and properties of the steel and metal of the seam welding electrode. A quantitative estimate of how much the additions of alloying components will affect the welding characteristics of seam metal will depend on the nature and concentration of the addition elements characteristic.

The most important factor determining weld metal properties is chemical composition (Gharavol, Sabzevar, & Haerian, 2009). Based on Batra (2007), Bockus (2006), Gharavol, Sabzevar, & Haerian (2009), Ma, Wang, Li, Gai, & Zhu (2009), Liu, Su, Dong, & Li (2005) and Wang, Dong, Zhang, & Xu (2009) study about chemical elements and their influence on metal alloys, the researcher decided to add Chromium (Cr) and Zirconium (Zr) substances to the Copper (Cu) electrode. The addition 1% of Cu and 0.1% of Zr will increase the metal properties and characteristic of domestic welding electrode that being made.

The study of Ghosh, Haldar, & Chattopadhyay (2009) revealed that pure Cu is too soft to be used as an electrode, it will need some addition of other element that will increase its hardness. Addition of Cr elements has obtained significant changes in morphology and microstructure of Cu, Cr elements also refines the columnar structure and decreases the surface roughness of Cu in electrode that already analyzed by Wang, Dong, Zhang, & Xu (2009). This statement also in line with Gharavol, Sabzevar, & Haerian (2009) analysis which explain that Cr addition to low alloy steel in the range of 0.05% - 0.91% will increase the hardness and tensile properties and also refinement of the microstructure of the alloy.

Besides Cr, Zr element also has a significant role in enhancing the properties of an alloy. According to Jovanović & Rajković (2009), a very small addition of Zr (less than 0.1%) improve hardness and electrical conductivity of alloy due to very low solubility of Zr in Cu matrix. The addition of Zr has significant influence on the morphology and mechanical property of composites too, the refinement mechanism of Zr was attributed to the combined effects of increase in nucleation rate at the constitutionally super cooled zone ahead of the solidification front and reduction in growth rate (Ma, Wang, Li, Gai, & Zhu, 2009). Batra (2007) revealed that the addition of Zr to the alloy strongly influenced the sequence of precipitation. Because of this, an improvement in the fatigue resistance of the alloy results due to a change in the nature of pure Cu to the alloy. If Zr is added, the Zr in the copper matrix could act to retard the softening of the alloy at high temperatures (Ellis, 2006). Because of the reason that explained above, Cr and Zr elements were added to form an alloy of CuCrZr welding electrode.

For the optimal application of these materials it is necessary to know changes in microstructure due to treatment via different external factors such as heat treatment, ageing, water quenching, etc. Slugen, Ballo, & Domonkos (2000) explained that precipitation hardened alloys reach an optimum strength after the thermo mechanical treatment involving a solution annealing at high temperature to dissolve the alloying elements, then a water quench to keep the alloying elements in supersaturated solid solution at room temperature and finally an ageing treatment at intermediate temperatures to decompose the supersaturated solid solution.

The strengthening effect in conventional solid solution aging is limited due to low solubility of Cr in Cu at the solid solution temperature, and grain structure. Rapid solidification can lead to an obvious extension of the solid solubility of Cr and Zr in Cu matrix and remarkable refinement of grain size. Upon aging, very fine dispersions of Cr and Zr are precipitated in the matrix. As a result the dispersion hardening effect is greatly intensified without degrading the electrical conductivity. Aging is a common heat treatment for many copper alloys, with the aim of raising their strength and hardness. The high hardness of Cu-Cr-Zr alloys is attributed to the precipitation and dispersion strengthening, and the excellent electrical conductivity to the very low solubility of Cr and Zr in Cu (Jovanović & Rajković, 2009). The strength and hardness increase with decreasing grain size, with a reduction in grain size, the barrier for dislocation increases and this account for the increase in strength and hardness (Liu, Su, Dong, & Li, 2005), this statement also in line with Hall Petch equation $\sigma_y = \sigma_o + kd^{-\frac{1}{2}}$ about grain size in alloy microstructures.

So the hardness of the alloy is obviously influenced by aging treatment meanwhile the hardness generally correlates with yield and ultimate strengths. The correlation of hardness and strength represent in figure 4.6.

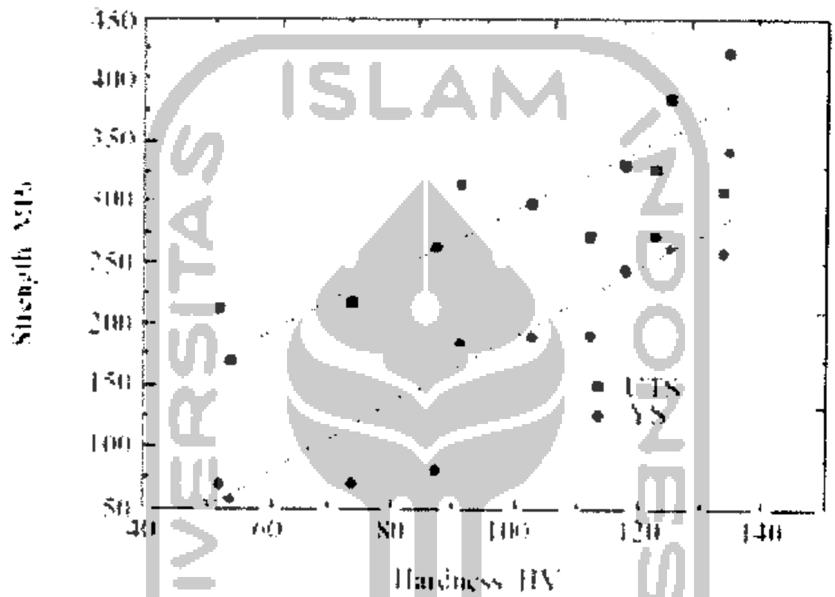

Figure 4.6 Correlation of Hardness with Strength of CuCrZr Alloy. Adapted From Danhua, Jihong, Pengfei, Desheng, & Jiming (2007)

It is known that the high hardness of CuCrZr alloy is due to the low solubility of Cr elements in Cu, Yamamoto, Sasaki, Yamakawa, & Ota (2000) studied this matter and conclude that the maximum Cr solubility in Cu is approximately 0.89% at 1077°C, whereas the solubility of Cu in Cr is negligible, the material that investigated is Cu alloy with 1% of Cr and 0.1% of Zr (CuCr1). The equilibrium phase diagram of Cu – Cr shown in figure 4.7.

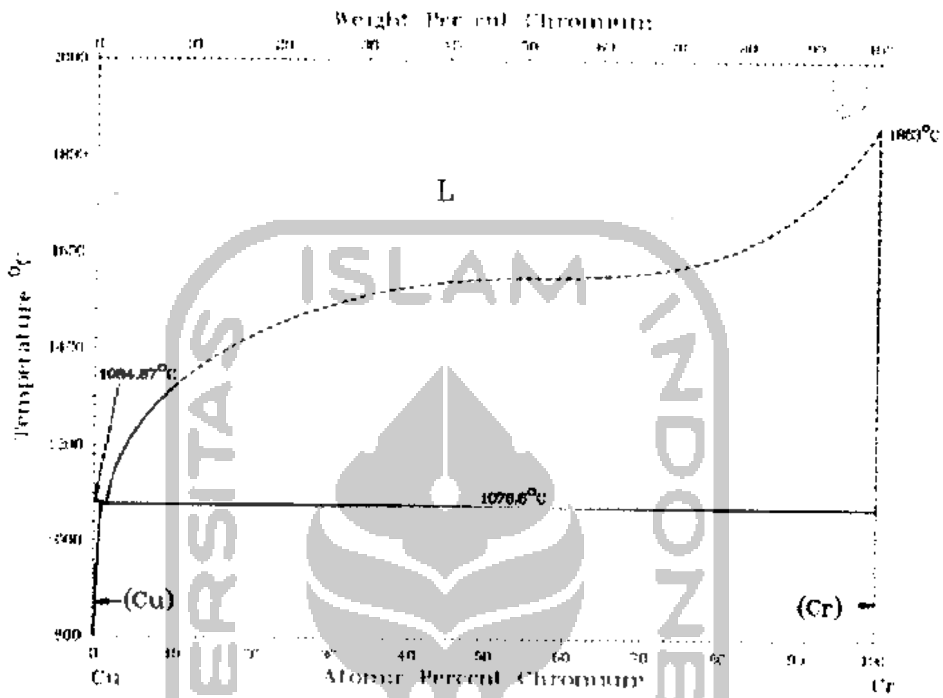

Figure 4.7 The Equilibrium Phase Diagram Of Cu – Cr. Adapted From Yamamoto, Sasaki, Yamakawa, & Ota (2000)

To increase the hardness, different thermal treatments with varying aging times and temperatures were conducted and the hardness of each condition was measured. This was done to find the best conditions to increase the hardness.

Table 4.1 Overview of Different Aging Parameters. Adapted From Jessner (2006)

Aging Temperature (°C)	Aging Time (min)	Micro Hardness (HV)
450	30	71 ± 1.3
	60	103 ± 2.2
	120	104 ± 2.7
	360	140 ± 3.0
475	30	112 ± 2.7
	120	136 ± 2.1
	240	134 ± 3.8
	360	135 ± 4.0
500	60	134 ± 4.2

As can be seen, the highest hardness was reached at a temperature of 450°C and an aging time of 6 hours with 140 ± 3 HV. At this temperature, the solubility of Cr in Cu is very low and the driving force to build precipitations is rather high. But the mobility of Cr is low; this is why it takes 6 hours to reach the maximum hardness. With increasing aging temperature the mobility increases but the driving force to precipitate Cr decreases because more Cr can be dissolved in the matrix (475°, 6 hours: 135 HV). At an aging temperature of 500 °C the solubility is even bigger and fewer precipitations can be build. The highest hardness reached at the lowest aging temperature can be explained by a higher driving force for precipitations, since the solubility of Cr in Cu is lower. At higher temperature more Cr can be dissolve and the driving force to build precipitations is lower.

4.2.2.2 Microstructure Analysis

From the microstructure photo at 200um, 100um, 50um and 25um it can be seen that the elements are dispersed in all the alloy structure. The microstructure and grain size of the elements are very uniform which account for the dispersed Cr and the unknown elements in Cu alloys. The dispersed Cr and unknown elements, also the heat treatment that applied counts for the high hardness and high electrical conductivity of import welding electrode.

For domestic welding electrode that contains 1% Cu and 0.1% Zr elements in Cu alloy, the effect would be different. Based on Ellis (2006) study about a cast of CuCrZr alloy with similar amount of elements percentage, it is assumed that the dark spot in the microstructure photo will be subjected to Cr elements that strengthen the alloy, the orange-brown color which is the major color in the alloy representing Cu elements, and the bright orange color representing Cu-Zr elements that counts for the high hardness of the alloy. To strengthen the analysis, Ellis (2006) observation of a cast Cu-6%Cr-5.4%Zr alloy will be presented. The samples of Cu-6%Cr-5.4%Zr were polished and examined in the scanning electron microscope (SEM). Back scattered electron (BSE) imaging was used to qualitatively determine the location of the elements and phases present in the casting. It was also possible to use the images to quantitatively determine the volume fraction of each phase. Energy dispersion spectroscopy (EDS) was used to semi quantitatively determine the composition of each phase observed. The image is shown in figure 4.8.

Figure 4.8 Detail of General Microstructure (BSE Image) with EDS Spectra. Adapted From Ellis (2006)

Using EDS and the information from the x-ray diffraction results, the observed regions were identified as elemental Cr dendrites, elemental Cu dendrites, and Cu-CuZr in the interdendritic spaces. The Cr and Cu have a larger, dendritic structure. Based upon this structure and the various melting points, it is surmised that the Cr solidified first followed by the Cu. The remaining Cu-Zr liquid solidified last. This study and image are in line with the import electrode microstructure photo.

4.3 Domestic Electrode Performance Test

4.3.1 Data Collecting

4.3.1.1 Visual and Physical Examination

Visual and physical examination conducted to identify and analyze the difference between import and domestic electrode. The image is in figure 4.9 below.

Figure 4.9 Import and Domestic Welding Electrode

4.3.1.2 Hardness Test

Hardness test conducted to compare the endurance and strength between import and domestic electrode. The data are in table 4.2 and 4.3.

Figure 4.10 Electrode Radius Information

Table 4.2 Hardness of Import Electrode

No	Outer (HV)	Middle (HV)	Inner (HV)
1	124	128	122
2	128	122	126
3	116	110	112
average	122.7	120	120

Table 4.3 Hardness of Domestic Electrode

No	Outer (HV)	Middle (HV)	Inner (HV)
1	118	124	116
2	120	118	121
3	114	112	113
average	117.3	118	116.7

4.3.1.3 Welding Test

Welding test conducted to see the difference between import and domestic electrode when used to weld the strip of coil. The data are in table 4.4 and 4.5.

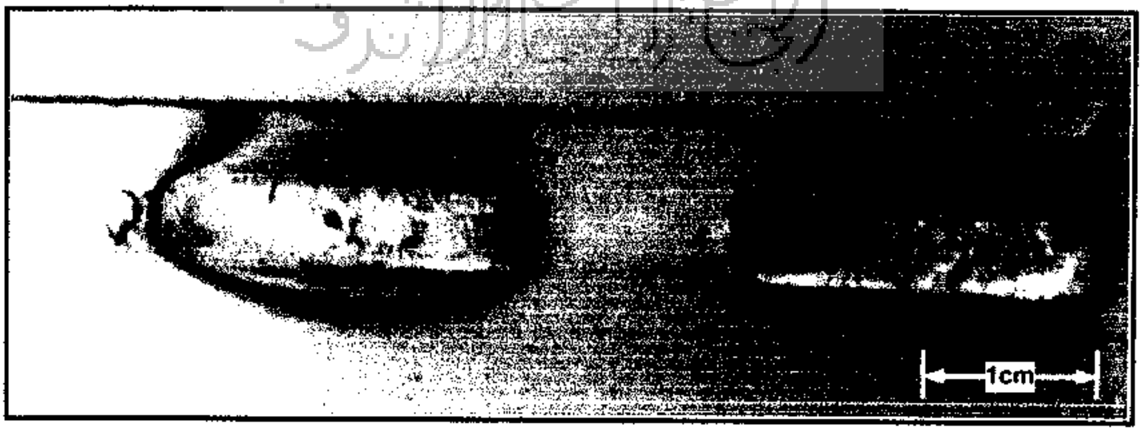

Figure 4.11 Weld Result

Table 4.4 Welding Test of Import Electrode

Thickness x width (mm)	weld thickness (mm)	weld width (cm)	HAZ width (cm)	weld length (cm)	HAZ length (cm)	weld interval (cm)	HAZ interval (cm)	spot
0.2 x 914	0.44	0.4	0.6	2	2.2	1.75	1.55	25
0.25 x 882	0.6	0.4	0.65	2	2.2	1.7	1.6	24
0.30 x 882	0.8	0.4	0.8	1.9	2.1	1.75	1.6	24
0.50 x 914	1.1	0.4	0.8	2	2.1	1.8	1.7	25
0.6 x 1219	1.38	0.45	0.9	2.1	2.25	1.8	1.6	33
0.7 x 1219	1.6	0.475	1	2.1	2.2	1.6	1.5	33
0.8 x 914	1.82	0.5	1.15	2.2	2.3	1.5	1.4	25
1.0 x 914	2.4	0.5	1.3	2.3	2.5	1.4	1.3	25
1.2 x 1219	2.6	0.5	1.3	2.3	2.4	1.4	1.3	33

Table 4.5 Welding Test of Domestic Electrode

Thickness x width (mm)	weld thickness (mm)	weld width (cm)	HAZ width (cm)	weld length (cm)	HAZ length (cm)	weld interval (cm)	HAZ interval (cm)	spot
0.2 x 914	0.45	0.4	0.5	1.5	1.6	2.2	2.1	25
0.25 x 882	0.6	0.4	0.6	1.6	1.75	2.1	2	24
0.30 x 882	0.73	0.45	0.6	1.8	1.9	2	1.8	24
0.50 x 914	1.1	0.45	0.8	1.9	2	1.8	1.7	25
0.6 x 1219	1.3	0.5	0.9	2	2.1	1.7	1.6	33
0.7 x 1219	1.52	0.5	1	2.1	2.2	1.6	1.5	33
0.8 x 914	1.8	0.5	1.1	2.2	2.3	1.5	1.4	25
1.0 x 914	2.2	0.52	1.1	2.3	2.4	1.4	1.3	25
1.2 x 1219	2.6	0.52	1.2	2.3	2.4	1.4	1.3	33

4.3.1.4 Weld Strength Test

The weld strength test conducted to identify whether the result of domestic electrode weld in the strip of coil is strong, save and fulfill the quality requirement to be processed in CGL machine. The test conducted by punching the strip of coil weld using a hammer and chisel. If the weld is broken, it means that the weld is not good, but if the strip of coil that broke rather than the weld means that the weld is good and fulfills the quality requirement. The images of weld strength test are shown in figure 4.12 until 4.20.

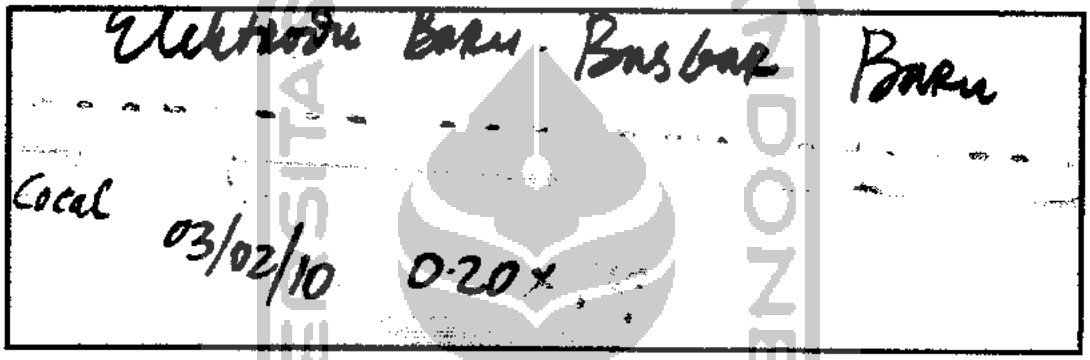

Figure 4.12 0.20mm x 914mm Strip of Coil Weld

Figure 4.13 0.25mm x 882mm Strip of Coil Weld

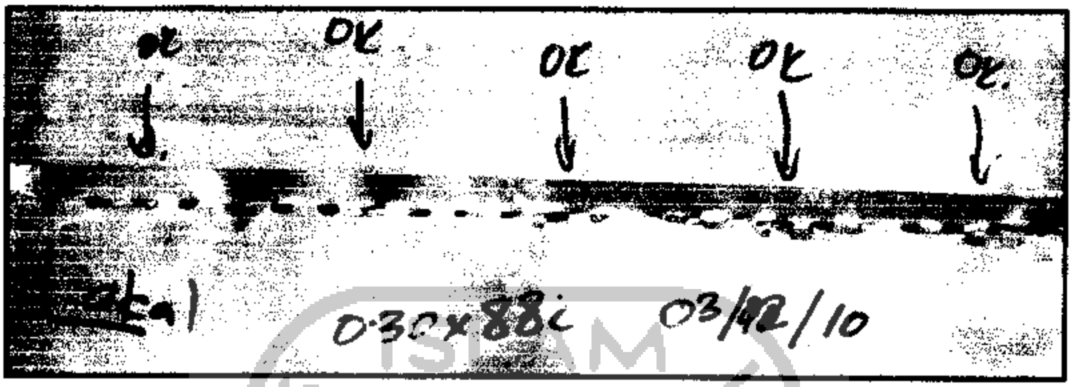

Figure 4.14 0.30mm x 882mm Strip of Coil Weld

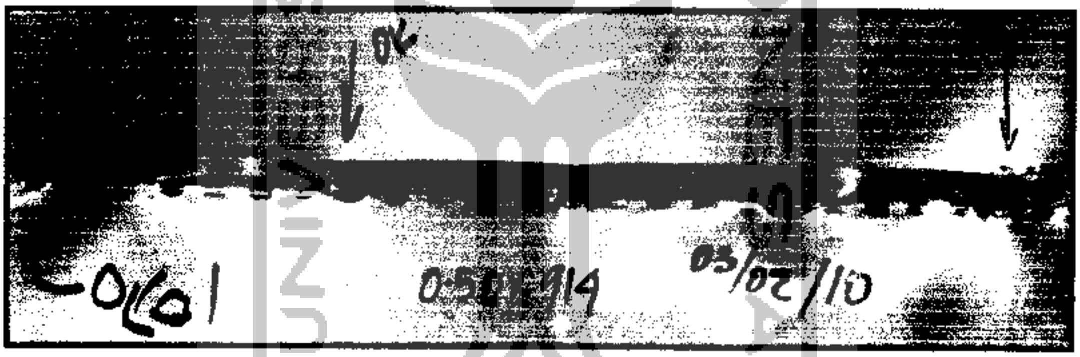

Figure 4.15 0.50mm x 914mm Strip of Coil Weld

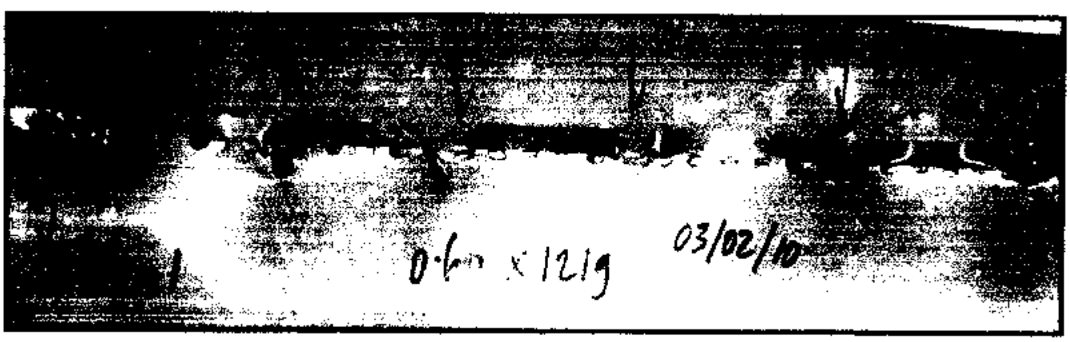

Figure 4.16 0.60mm x 1219mm Strip of Coil Weld

Figure 4.17 0.70mm x 1219mm Strip of Coil Weld

Figure 4.18 0.80mm x 914mm Strip of Coil Weld

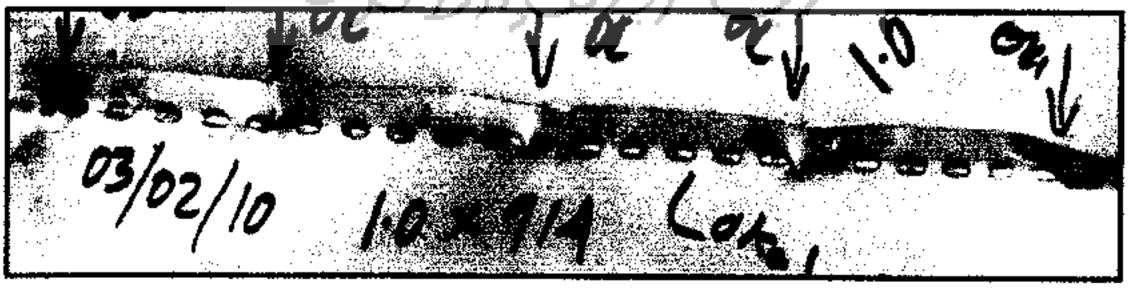

Figure 4.19 1.0mm x 914mm Strip of Coil Weld

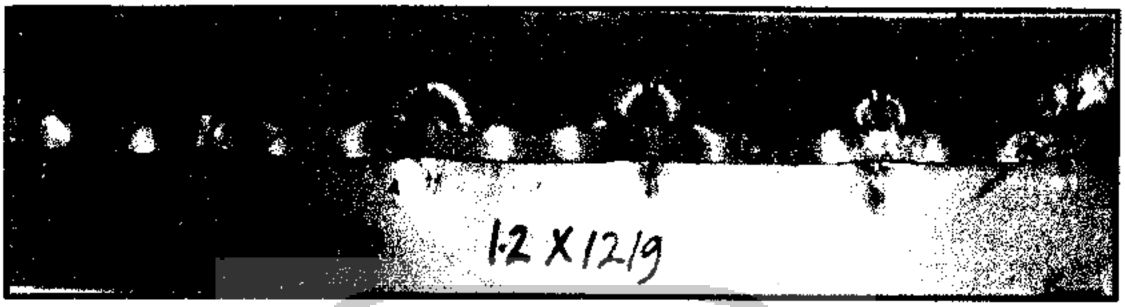

Figure 4.20 1.2mm x 1219mm Strip of Coil Weld

4.3.2 Data Processing

4.3.2.1 Visual and Physical Analysis

The visual observation of import and domestic electrode is very identical, but there is color difference between them. Import electrode color is very homogeneous orange compare to domestic electrode which is darker and the color is not homogeneous. This difference is caused by different technique in the making of the electrode, import electrode use die casting and heat treatment in the process whether domestic electrode use sand casting because its economical attributes that stated by Lost & Foundry TM (2010) with natural air in the solidification process and made without heat treatment. But the color difference is not a problem because the quality measure is according to the welding test itself.

4.3.2.2 Hardness Test Analysis

The comparison of hardness between import and domestic electrode will be shown in 4.21, 4.22 and 4.23.

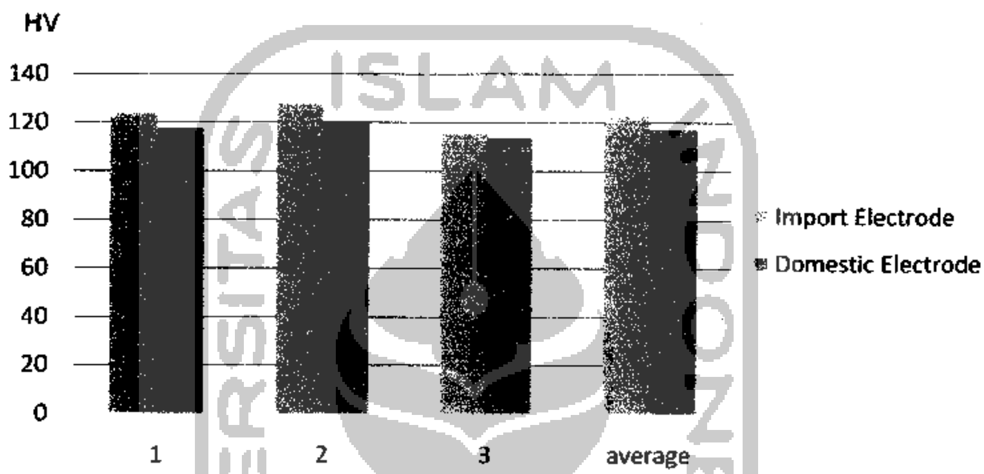

Figure 4.21 Hardness in Electrode Outer Radius

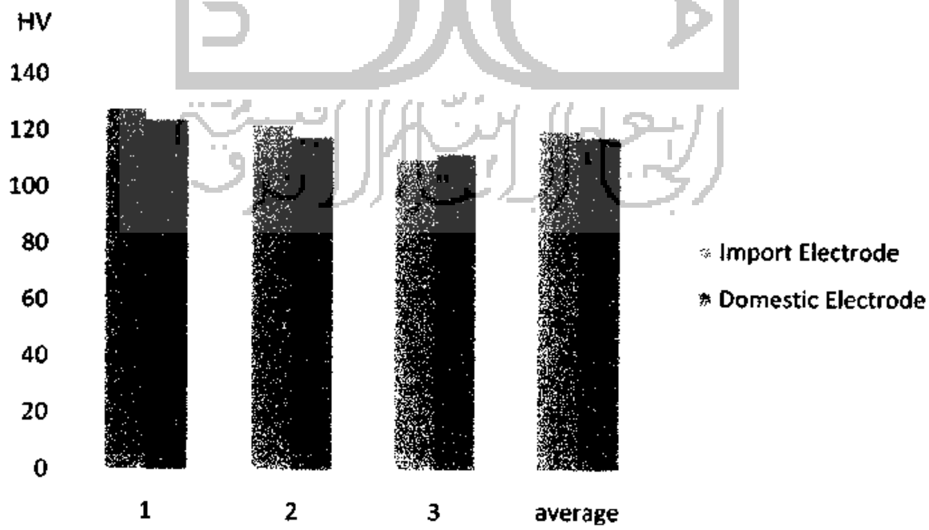

Figure 4.22 Hardness in Electrode Middle Radius

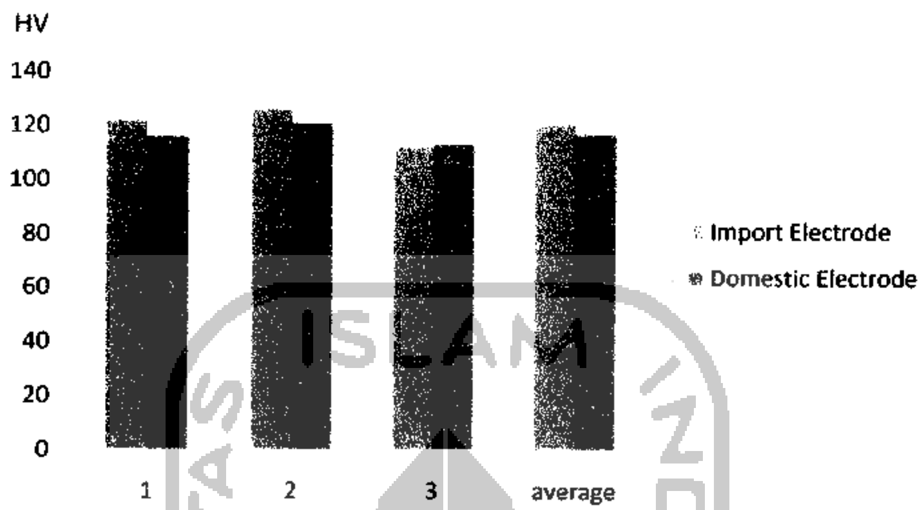

Figure 4.23 Hardness in Electrode Inner Radius

From the diagram above it can be seen that the hardness of domestic electrode is slightly lower than import electrode, but the difference is not high so the domestic electrode is appropriate to be used. It also can be seen that the hardness does not differ significantly over the radius, this indicates a homogenous microstructure over the whole specimen.

By statistical process using Independent Samples T Test where

Ho : The population of import and domestic electrode is same ($\mu 1 - \mu 2 = 0$)

H1 : The population of import and domestic electrode is not same ($\mu 1 - \mu 2 \neq 0$)

Since the hypothesis showing that the difference between domestic electrode and import electrode does not have to be equal to zero, hence it use 2-tailed probability where $\alpha = 0.01/2 = 0.005$, hence

If probability > 0.005 then do not reject Ho

If probability < 0.005 then reject Ho

Based on Independent Samples T Test result, the P-value of each variable in hardness are:

1. Variable : Outer

   P-value : 0.283

2. Variable : Middle

   P-value : 0.442

3. Variable : Inner

   P-value : 0. 308

From all the variable, the P-value is > 0.005, hence do not reject Ho, it is concluded that the population of domestic electrode and import electrode is not different significantly. This shows that the hardness between import electrode and domestic electrode did not differ significantly.

4.3.2.3 Welding Test Analysis

The comparison of welding result between import and domestic electrode will be shown in figure 4.24 until 4.31.

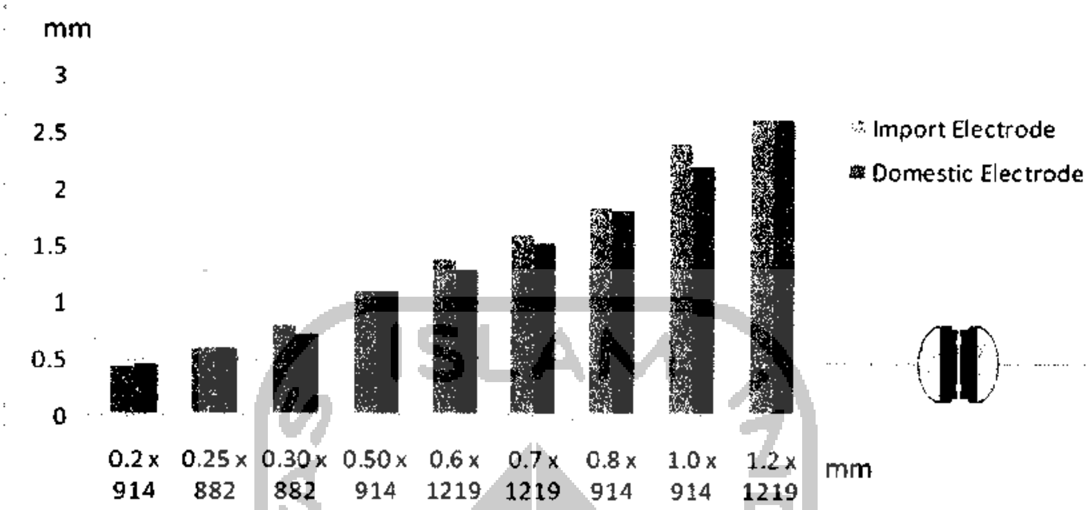

Figure 4.24 Weld Thickness Comparison

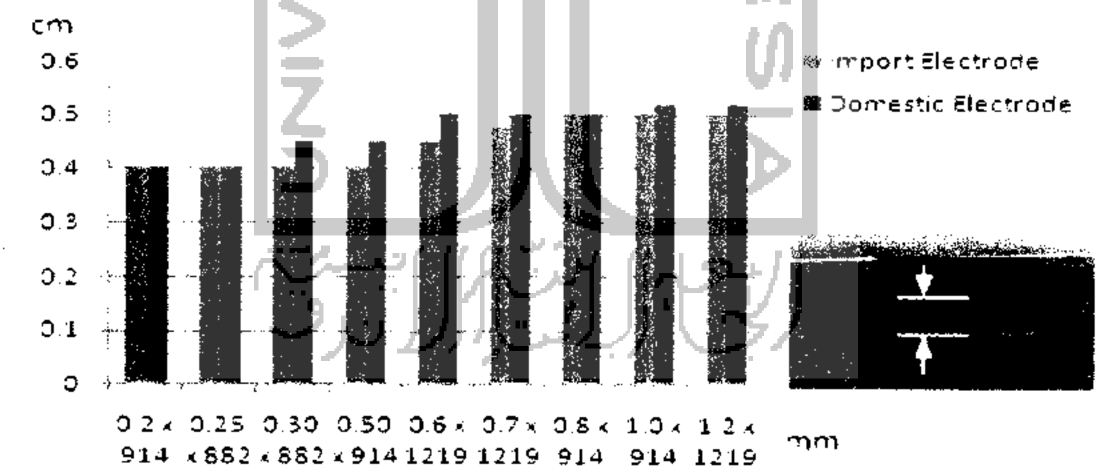

Figure 4.25 Weld Width Comparison

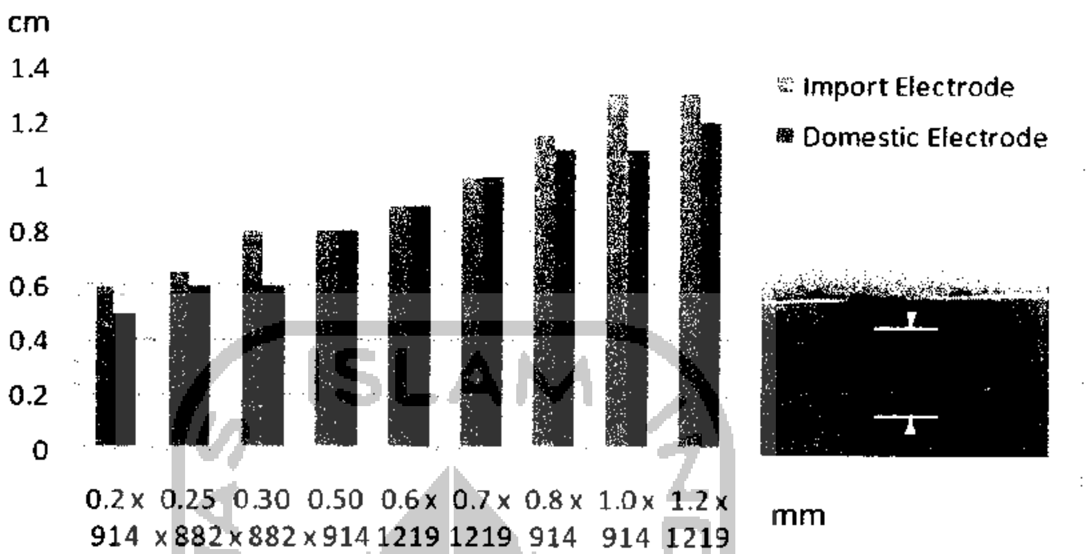

Figure 4.26 HAZ Width Comparison

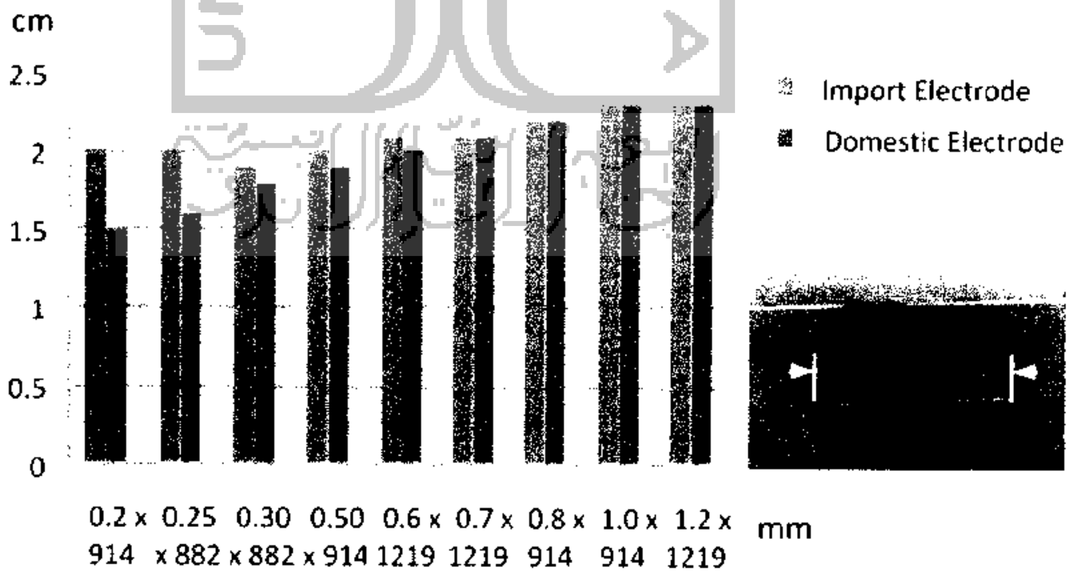

Figure 4.27 Weld Length Comparison

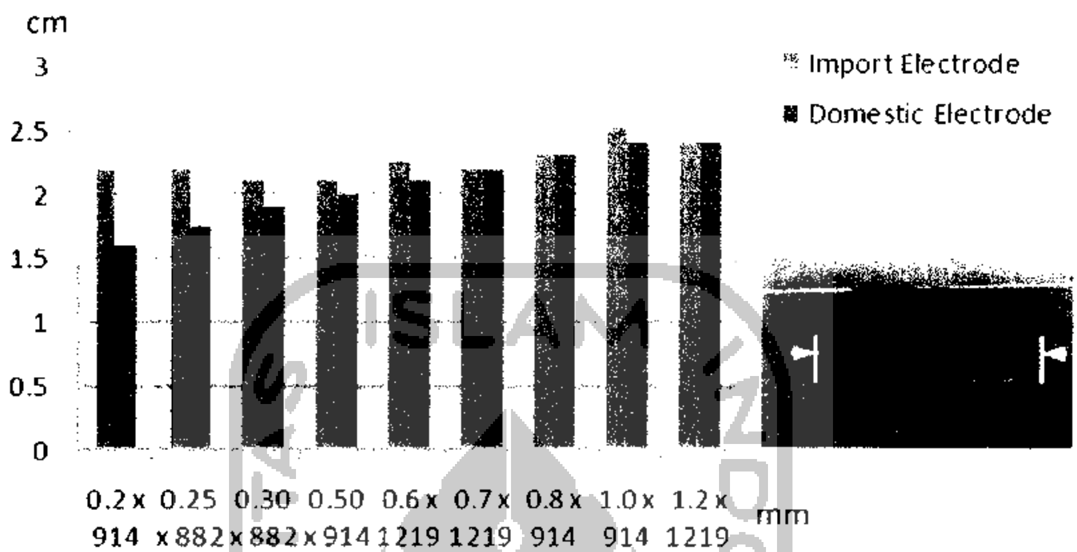

Figure 4.28 HAZ Length Comparison

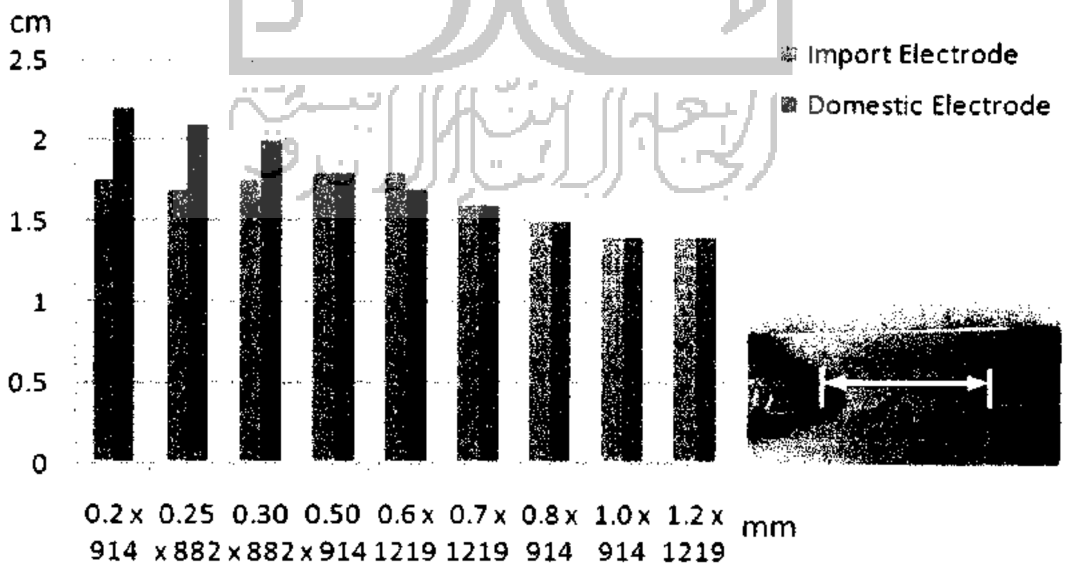

Figure 4.29 Weld Interval Comparison

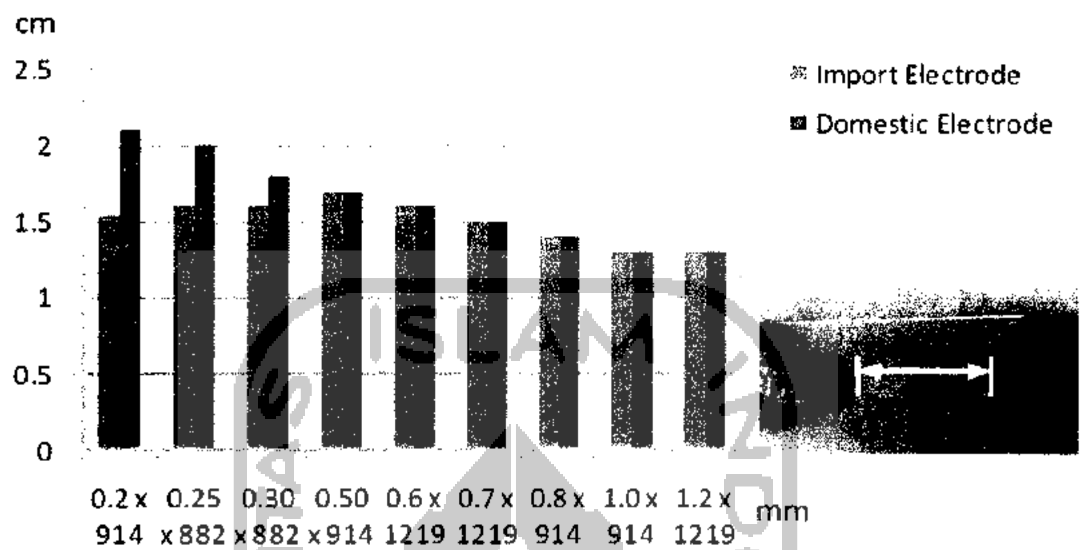

Figure 4.30 HAZ Interval Comparison

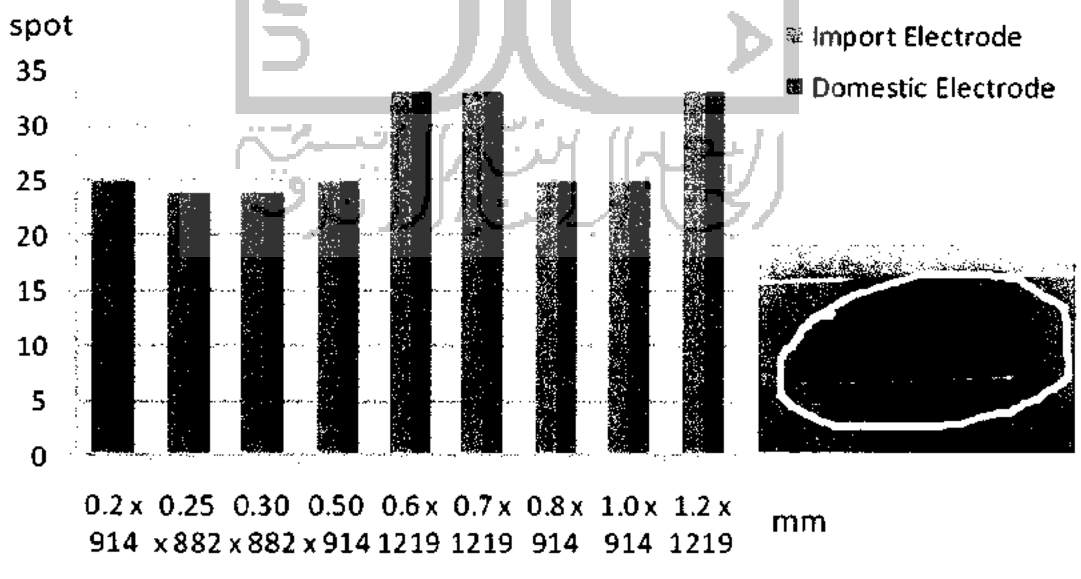

Figure 4.31 Weld Spot Comparison

Based on the diagrams above, it can be shown from the parameters of welding test comparison that domestic electrode welding quality is slightly lower than the import electrode one. Although domestic electrode welding quality is lower, the difference is very little compared to import electrode, so the domestic electrode welding quality considered good.

By statistical process using Independent Samples T Test where

Ho : The population of import and domestic electrode is same ($\mu1 - \mu2 = 0$)

H1 : The population of import and domestic electrode is not same ($\mu1 - \mu2 \neq 0$)

Since the hypothesis showing that the difference between domestic electrode and import electrode does not have to be equal to zero, hence it use 2-tailed probability where $\alpha = 0.01/2 = 0.005$, hence

If probability > 0.005 then do not reject Ho

If probability < 0.005 then reject Ho

Based on Independent Samples T Test result, the P-value of each variable in welding are:

1. Variable : weld thickness
   P-value : 0 .902
2. Variable : weld width
   P-value : 0.910
3. Variable : HAZ width
   P-value : 0.983
4. Variable : weld length
   P-value : 0.038

5. Variable : HAZ length

   P-value : 0.030

6. Variable : weld interval

   P-value : 0.055

7. Variable : HAZ_interval

   P-value : 0.042

8. Variable : spot

   P-value : 1.000

From all the variable, the P-value is > 0.005, hence do not reject Ho, it is concluded that the population of domestic electrode and import electrode is not different significantly. This shows that the welding test between import electrode and domestic electrode did not differ significantly.

4.3.1.4 Weld Strength Analysis

From all the punch test that conducted in many different thickness of strip of coil, none of them fails the punch test, which means that the weld are stronger than the strip of coil. Based on this test, it is concluded that the welding quality already fulfills the quality requirement, and the strip of coils are safe to be processed in CGL machine. Therefore the domestic electrode is safe to be use and can substitute the import electrode. More obvious image of the success in the punch tests are shown figure 4.32 and 4.33.

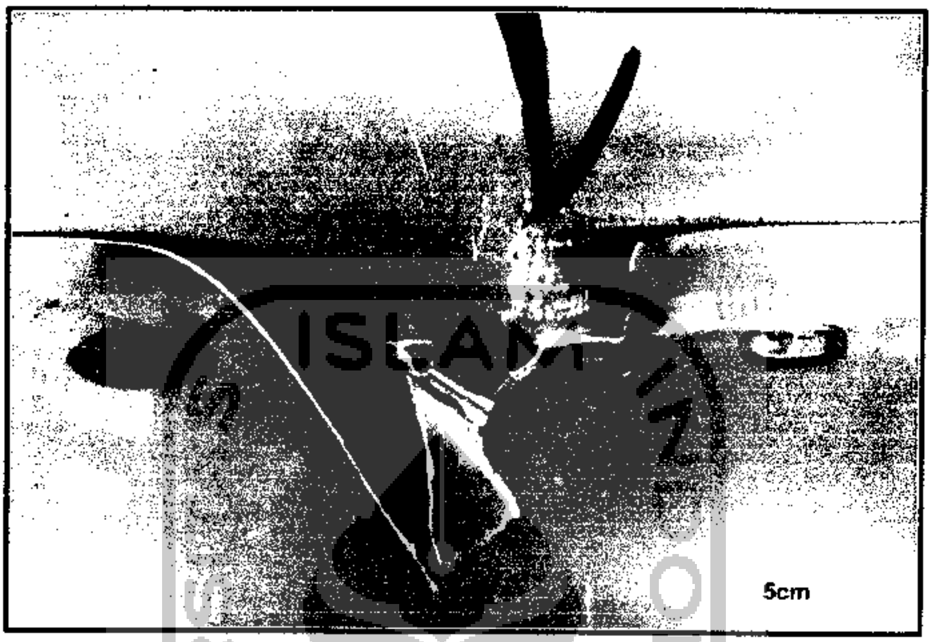

Figure 4.32 Strip of Coil Punch Test

Figure 4.33 Strip of Coil Punch Test

CHAPTER V

DISCUSSION

5.1 Domestic Welding Electrode Development

The first step to make domestic welding electrode is conduct a spectrometer analysis to identify the chemical material in Japan made welding electrode. The result of spectrometer test is 98.37% Cu and 1.17% Cr. After literature study and consultation with supervisor, domestic welding electrode will be made of 98.9% of Cu, 1% of Cr and 0.1% of Zr. The process in alloying the electrode started by melting Cu rod at 1200°C. When all Cu rods melted completely, add Cr powder and mix the powder in the Cu alloy until all Cr powder dissolve in Cu liquid. After the Cu-Cr alloy reach homogeneous state, insert Zr powder and mix the alloy until all Zr powder dissolve in the Cu-Cr liquid and reach their homogeneous state. The homogeneous state of the alloy will depend on temperature, mixing time and the grains size of the elements. When Cu-Cr-Zr alloy liquid reach its homogeneous state, pour the liquid alloy into sand cast and wait until the alloy fully solidified. Next, take the alloy from sand cast, cut, machining, grinding and shape the Cu-Cr-Zr alloy like Japan made welding electrode and the domestic welding electrode is ready to be use.

5.2 Domestic Welding Electrode Analysis

Domestic welding electrode that made in this research is a Cu (copper) based alloy with addition of 1% of Cr (chromium) and 0.1% of Zr (zirconium) elements. The characteristic that needed for this welding electrode is a high strength and high electrical conductivity of the electrode. Cu has excellent thermal and electrical conductivities, but pure Cu is too soft to be use as an electrode, that is why the addition of Cr and Zr elements is needed. Cr elements will increase the hardness of the electrode and Zr elements will refine the grain structures, this statement also in line with Hall-Petch equation $\sigma_y = \sigma_o + kd^{-\frac{1}{2}}$ about grain size in an alloy. The alloying disperse Cr and Zr element in Cu matrix and refine the grain size and precipitation of the electrode to increase its properties and support its performance as a welding electrode. Finally the domestic electrode is made with a high strength and high electrical conductivity to be used in the welding machine at CGL machine, and could challenge the performance of import welding electrode.

5.3 Domestic Welding Electrode Performance Analysis

Based on the performance test that conducted, the performance of domestic welding electrode to weld the strip of coil in CGL machine is slightly lower than import welding electrode, because the technique in the making of domestic electrode is not as advance as the original welding electrode from Japan that use die casting and heat treatment process. However, the quality of the weld performed by domestic welding electrode still safe and fulfils the quality requirement in CGL machine that have high tension strip of coil. Therefore, the domestic welding electrode is safe to be used and can substitute the import welding electrode.

5.4 Cost Analysis

On the cost side, domestic welding electrode is very cheap compare to original Japan made welding electrode. The total cost to purchase the original welding electrode from Japan is Rp. 110.000.000 whether the cost to produce domestic welding electrode is only Rp. 7.000.000. Domestic welding electrode is very cheap because it does not use heat treatment, die casting and delivery cost from Japan that is very expensive. Although the endurance time to use domestic welding electrode is lower than the original Japan made electrode because the domestic electrode erode faster than the Japan made electrode, but the difference is not high. Based on the explanation above, domestic electrode is very beneficial for PT. XYZ compared with original Japan made welding electrode.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The conclusions obtained from this research study are as follows:

1. The first step to make domestic welding electrode is conduct a spectrometer analysis to identify the chemical material in Japan made welding electrode. The result of spectrometer test is 98.37% Cu and 1.17% Cr. After literature study and consultation with supervisor, domestic welding electrode will be made of 98.9% of Cu, 1% of Cr and 0.1% of Zr. The process in alloying the electrode started by melting Cu rod at 1200°C. When all Cu rods melted completely, add Cr powder and mix the powder in the Cu alloy until all Cr powder dissolve in Cu liquid. After the Cu-Cr alloy reach homogeneous state, insert Zr powder and mix the alloy until all Zr powder dissolve in the Cu-Cr liquid and reach their homogeneous state. The homogeneous state of the alloy will depend on temperature, mixing time and the grains size of the elements. When Cu-Cr-Zr alloy liquid reach its homogeneous state, pour the liquid alloy into sand cast and wait until the alloy fully solidified. Next, take the alloy from sand cast, cut, machining, grinding and shape the Cu-Cr-Zr alloy like Japan made welding electrode and the domestic welding electrode is ready to be use.

2. The quality and performance of domestic welding electrode are lower than the Japan made electrode, but the difference is not high. The welding quality that performed by domestic welding electrode is still safe and fulfills the quality requirement to be processed in CGL machine. Therefore, domestic welding electrode is safe to be use and can substitute Japan made welding electrode.
3. The total cost to purchase the original welding electrode from Japan is Rp. 110.000.000 whether the cost to produce domestic welding electrode is only Rp. 7.000.000. Therefore, domestic welding electrode is very beneficial to PT XYZ because of its lower price and good quality performance.

6.2 Recommendation

The recommendations from this research study are as follow:

1. For company, it is better to find a way to substitute fast moving import product that have a high cost with a domestic product that cost less. This approach will benefit the company rather that depending on import products.
2. For further research study, it is better to find other chemical elements that will increase the alloy properties and quality.