UNIVERSITY OF TECHNOLOGY EDUCATION WINNEBA -- KUMASI

AN ASSESSMENT ON THE EFFECT OF WELDING AND HEAT TREATMENT ON MEDIUM CARBON STEEL

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DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this project work is the result of my own original research and that no part of it has been presented for another degree of this university or elsewhere.

Signature ……………………………………………….. Date…………………………………

JOSEPH ZOYAH

SUPERVISOR'S DECLARATION

I hereby declare that the supervision of the project was supervised in accordance with the guidelines of supervision of project work laid down by the University of Education Winneba

Signature……………………………………………… Date………………………………

DR. ENOCK A. DUODU

DEDICATION

I dedicated this project to my Congregation, Brothers of the Immaculate Conception (FIC), Ghana Province.

ACKNOWLEDGEMENT

I am very grateful to God the Almighty for His love, protection, guidance and the good health granted me for the period of my academic work of study. I would like to express my heartfelt gratitude to some distinguished personalities who have advised, guided and contributed significantly to the success of this right up from the onset till the end.

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Also, I would like to thank the Provincial Superior and his Councilors in the Congregation of the Brothers of the Immaculate Conception (FIC) Ghana Province and all the brothers for their support spiritually, financially and physically towards the success of my research. May the good Lord who called us together, continue to unit and give us his abundant blessings.

ABSTRACT

The main aim of this project is to investigate the hardness and impact properties of medium carbon steel treated at different heat treatment processes. Three types of heat treatment were performed including annealing, quenching and tempering. During annealing process, the specimens were heated at 900°C and soaked for 1 hour in the furnace. The specimens were then quenched in a medium of water and open air, respectively. The treatment was followed by tempering processes which were done at 300, 450°C, and 600°C with a soaking time of 2 hours for each temperature. After the heat treatment process completed, Rockwell hardness test and Charpy impact test were performed. The fractured surfaces of the samples were also examined by using Scanning Electron Microscope. It was observed that different heat treatment processes gave different hardness value and impact property to the steel. The specimen with the highest hardness was found in samples quenched in water. Besides, the microstructure obtained after tempering provided a good combination of mechanical properties due to the process reduce brittleness by increasing ductility and toughness.

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CHAPTER ONE

INRODUCTION

1.1 Background to the Study

The process of joining metals together with the help of, heat arc or pressure is called welding. Similar or non-similar metals could be done by welding. Especially the arc welding process, the parent metals and the electrodes are melted and after cooling it becomes solidified to form a bond of joint which is strong and solid. This is done in a very high melting point. It is in contrast with soldering and brazing which is done in a lower melting point of materials. In brazing and soldering, the parent metals do not melt as in arc welding. It is only the filler metal that is melted over the joint to form the bond between them. All these have an effect on the strength of a material.

A cool dry air is good electric insulator. However, when it is heated it becomes ionized and is capable of conducting electricity. This is the main reason why lightening invariably strike the chimney of a building. In the electric arc, heavy electric current flows through a path of heated arc which reduces or increases the tensile strength and the temperature of metals.

Garg (2015), there are many different sources that can be used for welding, including a gas flame and electric energy arc, ultrasound and the forge welding. While often an industrial process welding can be done in many different environments including open air, under water and open space, regardless of the location. However, welding and heat treatment remain dangerous to the material when precautions are not taken to regulate the heat during and after welding, there would be a lot of hazard.

Other types of gas sources apart from oxygen and acetylene that can be used for welding and heat treatment are tungsten inert gas and metal inert gas welding.

Somsky (2019), until the end of 19^{th} century, which the only welding process used, was forge welding. This is what blacksmiths used to join metals by heating them into crystallization temperature and hammering them together. Other welding processes that are among the first to develop were, arc welding and oxy-fuel welding.

Knowing the effects of heat treatment and welding on the materials is vitally important factor in the welding industry. Therefore care must be taken before, during and after welding. Also there are new developments of welding technology and because of this, those who do not have much knowledge about them end up in causing accidents, Which many a time leads to death and destruction of properties. Some of the accidents could have been prevented if welders were to take safety precautions into consideration.

Another area that needs a critical observation is the collapsing of bridges and buildings. Research has revealed that bridges and buildings have collapsed due to lack of knowledge of the tensile strength, heat treatment and the effect of welding on the materials been used. So many people have died and properties destroyed just the fact that somebody has neglected the responsibilities instructed into him or her. This could be intentionally or unintentionally.

It is not just doing a work as an engineer or a contractor, but coming to understand the hazards, challenges and the safety measures that involved before one can then undertake any construction or project. Most of the accidents that occurred are due to lack of knowledge on safety, on the strength, the heat treatment and the effects of welding have on the materials on the part of the consultant, project manager or the contractor.

1.2 Statement of the Problem

Many of the welders, contractors, builders and project managers do not have much practical knowledge on the strength, the property and the effects of welding on the material to be welded or heat treated. The few who have a bit of knowledge do not take serious notice of them. A good number of them do not have the basic skills of testing the tensile strength, the temperature to be heat treated of material before, after and during welding or heat treatment.

1.3 The Purpose of the Study

The purpose of this study is to investigate the microstructure, testing of the tensile strength, the effect of welding and heat treatment on metals, especially medium carbon steel. it is to bring forth the awareness and recognition of the importance and the values of knowing the tensile strength, the effects of welding on medium carbon steel that will prevent unnecessary collapsing of bridges and building which sometimes lead to death and lose of properties as well as financial loses.

The study will contribute significantly to the development in material safety in the welding and fabrication industry, which plays a major developmental role of the Ghana's economy.

The finding of the study would also help people in authorities, especial TEVET and those at the Technical Universities to formulate policies that would help reduce loses, accidence, and collapsing of building and bridges while promoting safety in the welding and fabrication industries. This finding could also be serving as a contribution of reminder to the welding and fabrication industries that are of existence as a wide range of building up an academic and practical knowledge.

All the things mentioned above and many other things that are not mention, prompted the writer to undertake this research.

1.8 Significance of the Research

I believe a lot of people might have done research on the effect of welding current, type and sizes of electrodes and heart treatment on materials in the welding and fabrication industries, especially the manufacturing of metals. However, there is still a lot to be done where metal rods and plates are used for building and welding. It is on this note the researcher is mandated to champion and venture into this topic to help the scientific data, thereby developing the policy makers interest, governmental bodies, NGOs, building, welding and mechanical engineers, contractors and consultants, and all those who matter to ensure they formulate the right policies. Policies that will ensure that right material must be used for the right job to prevent accidents, collapsing of bridges and buildings. Furthermore, it will draw the attention of those stakeholders in Ghana to see the need to show concern and interest on the issue of educating individual as well as the country to know the importance of having fore knowledge of the effects of welding and heat treatment on medium carbon steel.

1.5 Organization of the study

The organization of the study is done in done in five chapters. Chapter one is the introduction to the research which includes the background t0 the study, the statement of the problem, the purpose of the study, and the organization of the study.

Chapter two deals with literature review that include the properties of steel, the tensile strength of some steels, type of heat treatment and their effects on the structure of steels, the relationship between welding and the property of steel and the effect of welding on steels. Chapter three deals with the materials and methods used for the study. Chapter four presents the results and discussion of the findings. Chapter five deals with the summary, conclusion and recommendation of the study.

Chapter four have to deal with the following sub headings; the introduction, the statistic of respondents, the percentages of respondents, research questions and the views of respondents to the questions.

Chapter five summed up all with the summary, conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The researcher had recognized the importance and the need to read through a lot of written documents and number of some articles in existence in continuance of the research work. This reading is to broaden and to enlighten the horizon of the researcher based on the problem at hand. The following headings will be considered on the literature review.

- Wearing of protective clothes
- Properties of metals (steel)
- Tensile strength of some metal steels and their uses
- Types of heat treatment and their effects on the structure of a steel
- The relationship between welding and the properties of steels (metals)
- The effect of welding on the parent metals

Safety is a critical consideration for any person doing welding and heat treatment. The worker can be safe when proper precautions are taken. These safety precautions must be strictly observed by workers. Welding and heart treatment is also associated with hazards and the welders need to adhere to informed safety rules and regulations governing their work.

Ghana National Fire Service (2013}, reports that accidental fire outbreak and electrocution claim more lives in Ghana every year. The report say more injuries are from electric shock and fire, which occurs through improper handling of gas cylinders, and accidental contact with an exposed wire or other parts of live wire, electrical circuit such as electrical wiring or part of an electrical appliances or gargets. When heat treatment is done, the fire must be properly quenched to prevent fire outbreak. The proper tools and safety clothes needed for the worker must be available to prevent any accident.

According to Garg (2016), effort for the prevention of accident has begun in the 19th century with the adoption of factory inspection laws. This first started in Britain and then in the United States and other countries (Factory System). Great effort has been made by other agencies to enforce safety rules, regulations as well as giving information to the public to educate them. At the beginning of the 20th century a new branch of engineering was developed due to the campaign carried out against unsafe working condition and action by the insurance companies. They devoted to fining out and eliminating such hazard (industrial safety), State Insurance Company (SIC) Ghana.

There was a report by a Taipei times that Greek registered tanker went up in flame in Ghana in Tema on the 25th of March 2015. According to the paper, sparks from welding ignited a fuel leak on the Greek MV Polaris at the port which is about twenty kilometers from the heart of Accra. The vessel was completely burn to ashes including all those who were on board. The then minister who was in charge of energy (Mr. Kofi Adah) told the reporters on the 25th of March 2015, that the people who were on board were 12 Ghanaians, Guineans, Greek and a Russian who were carrying welding repairs work to the MV Polaris at the port of Tema.

If the safety of occupational in the welding industries and countries that are developed continue to be as bad as the stated above, then it shows very clearly that the state of safety and related situations and cases in welding in the developing countries would be most serious one. It means that this is an important matter that needs to be talked and addressed in a holistic way. We can say that the working condition in the developed countries is far, far better than we the developing countries and this is what happened to them. Imagine what will happen to the very poor working conditions of developing countries such as Ghana and other African countries.

2.2 Wearing of protective clothing

As a welding engineer you are often expected to work on site. This involves working partly-completed building or equipment being erected out of door which introduces additional hazard. Attentiveness and additional precaution must be key when working under such condition.

Very tremendous advances have been made in the design of protective clothing in recent years. Protective clothing are manufactured now into the highest standard with regard to material, construction, resistance to heat, and wear or to damage. These protective clothing are hand shields or helmet, wellington boots or safety shoes, overalls and cloves. The protective clothing worn will depend upon the nature of the work.

Goggles or welding shields must be worn to protect the eyes from heat and glare and from particles of hot metal and scale. It is very important to protect the eye and face from exposing them to the infra-red rays which would cause the face to become uncomfortable, hot and may induce serious eye troubles. Too much ULTRA- VIOLET radiation received by the worker or anybody in that vicinity can cause an effect to the eye which is similar to sunburn in the eye and the skin refers to as ARC EYE. The working area must therefore be protected with a welding screen. This should be made of heavy fire-resistant canvas, and painted with black or grey or to have a welding booth in case of school situation. "Arc eye" the painful exposure will not be felt until between four and twelve hours later, and it is very likely that the affected worker wakes up at night with the characteristic pains of arc eye. The persons affected usually complain of feeling of sand in the eye, which become sore, burn and water.

The precaution is to prevent the harmful radiation form the welding arc and pool from the eye and the face. It is also to prevent excessive heat to the eye and face during heat treatment. This is achieved be the use of special glass filters which are of suitable color and density as well as to reduce the intensity of the visible eye rays. Too much visible light will dazzle the worker while little light will cause eyestrain and headaches. The removal of slag by chipping can create an accident hazard to the face and eyes. Although welders are often tempted to chip away without protection, the use of a shield or goggles having clear glass windows is importantly essential in all such operations.

Sackey (2019), states that the ultra-violet rays during electric arc welding can injury the eyes of other people who may be near the welding area. The welding area may therefore be protected with a welding screen. This should be made of fire resistance canvas and painted with black or grey ultra violet protective paint if available. However, blue or green are equally efficient. The screening should be done in such a way that stray radiation is kept to a minimum. The welder wears the welding helmet to protect the throat, face and forehead from the infrared and ultra violet radiation produced by the arc. A cap should be worn under the helmet to protect the scalp. The helmet is fitted with two lenses. These are the inner lens and the outer lens. The inner lens is specially tinted to protect the eyes from the intense light and the invisible rays produced by the arc. The outer lens is replaceable. This is clear and it protects the inner lens from being damaged by the metal particles. Most helmets should have an adjustable headband, so that it can be raised and lowered when necessary. They are held by one hand and have to place on the table when work is being position for striking the arc. The hand shield is less convenience than the helmet, but it is appropriate when students are watching a demonstration in the workshop.

If a person is exposed to a flash, the effect of "Arc Eye" can be minimized by the immediate use of a special eye lotion which should be available in the first aid box. One experience of the distressing results which follow exposure to stray radiation is usually enough to make the victim very vigilant in the future.

Leather aprons and gloves: welder's body and clothing should be protected from heat of the metals, radiation and burns cause by flying globules of molten metals spark. They should be flame retardant outfit. The apron should be long enough and the glove should be well fettered.

It is very necessary to protect the feet and legs in the same way as the hands and the forearms. Do not wear shoe or boot that offers no protection from underneath.

In safety footwear, protection is provided by a steel toe-cap inside the boot or shoe, which conforms to a specification in accordance with BS (British Standard) 1870. This standard required that steel toe-cap must be capable of withstanding a blow of either 134 joules or 200 joules. Footwear in the former category has to be marked GRADE 2and in the latter GRADE 1. In order to avoid the hazard of slipping, simple wear industrial boot or shoe which have reliable non-slip soles?

2.3 Mechanical Properties of Steel

The properties possessed by steels will not only influence their suitability for a particular component or structure and its performance under service condition, but also to the great extent, the choice of manufacturing or fabrication process required to produce it. E.g.

a. Tensile strength: this is the ability of a material to withstand a stretching load without fracturing. Tensile strength of a material is a maximum stress that can be applied to it before it breaks.

   Tensile strength is applied in the construction industry include; bond strength testing of adhesives, mastics, sealants, and bonds between bricks and foam layers.

b. Compressive strength: this is the ability of a material to withstand a squeezing load without crushing and fracturing.

   In mechanic, compressive strength is the capacity of a material or structure to withstand load tending to reduce size.

c. Shear strength: the ability of a material to withstand offset load, or cutting actions without fracturing

d. Impact strength: the ability of a material to withstand an impact of a hammering, or striking load

2.3.1 Tensile strength and heat treatment of steels and their uses

Dead Mild Steel; the carbon content of dead mild steel is very low, it possesses high ductility and malleability that enable it to be deep drawn and pressed into complicated shapes by cold working. The tensile strength of dead mild steel is 330MN/m2.

It is used for chains for lifting tackle, crane hooks and ornamental architectural iron work.

Mild Steel; this is a low carbon steel contains more iron carbide than dead mild steel, making it much harder but less ductile and malleable. It is probably the most widely used fabrication materials, being easily cold worked or hot worked. The tensile strength for mild steel is 460 to 500MN/m^2.

Medium Carbon Steel; these steels are less malleable than the low carbon steels and cannot be cold worked to any great extent without the risk of fracture. The tensile strength for this steel is 700 to 800 MN/m^2. It is used for high tensile tubing, crankshafts, forgings and axels, hammer heads, screw drivers, and leaf springs.

High carbon steel: these steels combine hardness with high strength. They are less ductile and less tough than medium carbon steels. These steels are not recommended for cold forming, but can be hot forged within a carefully controlled temperature range. Also, they may be machined satisfactorily when heat treated. The tensile strength for high carbon steel is 900MN/m^2. It is used for shear blades, coil springs, high tensile wire, files, drills, taps and dies. It is also used for metal turning tools, knives, fine-edged tools and ball bearings.

2.3 The Effect of Heat Treatment on Medium Carbon Steel

Heat treatment is a process that involves a combination of time-controlled heating and cooling operations of metal without changing the product shape that will produce desire mechanical properties and to observe the microstructure after heat treatment (D.D. Fadare2011). Heat treatment is used to improve the mechanical properties of the metal alloys. Basically, the product performance will improve when the strength of material increased (Ashih Bhateja, 2012). It can be divided into three main processes namely annealing, quenching and tempering. In general, the procedure of heat treatment process consists of three stages. The first stage is heating the material, the second stage is to hold the temperature and the third stage is to cool down the metal to room temperature.

The treatment of medium carbon steel with can significantly change the mechanical properties, such as ductility, hardness and strength. Heat treatment of slightly affects other properties such as its ability to conduct heat and electricity. The carbon and manganese content in medium carbon steel make quenching and tempering the most common method of heat treatment for this type of steel. The process involves repeatedly heating the steel to about 723℃ and cooling it rapidly by quenching it in a liquid such as oil or water. The temperature and time of this process allows manufacturer to precisely control the final properties of the steel.

The definition of medium carbon steel based on Serope Kalpakjan book Kalpakjan,(2010) and Rajan et al. (2011) refer to iron alloy with more than 0.25% to 0.6% of carbon. This type of steel provides a good balance between strength and ductility and it is common in many types of steel parts. Iron consists of a crystal lattice of iron atoms that allows tendency, making medium carbon steel harder than iron. Additionally elements such as chromium, manganese, tungsten and vanadium can also act as hardening agents in steel. Carbon makes the steel harder but also brittle, so manufacturing carbon steel requires a balance between hardness and ductility.

The most common uses of medium carbon steel are in heavy machinery such as axles, crankshafts, couplings and gears. Steel with carbon content between 0.4 to 06 percent is commonly used in railroad to make axles, rail and wheels.

The importance of various form of heat treatment operations on medium carbon steel is in order to foster the problems that may arise in making a wrong choice of these steel materials or faulty heat treatment operations which may give rise to serious disruption in terms of human safety, high cost and untimely failure of the machine components is of great concern. The mechanical properties such as ductility, strength, hardness and tensile strength can easily be modified by heat treating the medium carbon steel to suit a particular design purpose. Tensile specimens were produced from medium carbon steel and were subjected to various forms of heat treatment processes like annealing, normalizing, hardening and tempering. The stiffness, ductility, ultimate tensile strength, yield strength and hardness of the heat treated samples were observe from their stress strain curve. The value of the yield strength was observed to be higher for the tempered specimen possibly as due to the re-organization of the grain, followed by the hardened, normalized and annealed specimens.

Heat treatment is the process of heating metals without or letting it reach it molten or melting stage and then cooling the metal in a control way to select the desire mechanical properties. It is used to make metal stronger or more malleable, more resistance to abrasion or more ductile. Medium carbon steel can be heat treated by austenizing, quenching and then tempering to improve their mechanical properties. On cost basis, the heat treatment of medium carbon steels provides tremendous load ability.

The heat treatment process that is used for medium carbon steel is normalizing. This process is used to produce stronger and harder steel compared to the full annealing steel, so the application normalizing process is used as a final treatment.

Medium carbon steels can be brazed by using preheat of 200 to 400 **F** (93 to 204°C), with a good bronze rod and a brazing flux. However, these steels are better welded by the metal-arc process with mild steel shielded electrodes.

Medium carbon steel is typically the most readily welded steel in a room temperature to avoid weld cracking.

Heart treatment of steel alters the rate of temperature above the upper critical point, which is possible to produce a wide variety of different structures in steel even though the carbon contents remain the same.

In the case of solid phases associated with steel the rate of diffusion of the different constituents is inevitably slow, and it is quite possible to speed up the rate of cooling so that by the time the metal is quite cold, diffusion has to come to a halt.

2.4.1 Annealing

Annealing is the process whereby steel or other metals are heated to a comparatively low temperature after cold –working in order to cause recrystallization temperature. The steel is heated to a point just above the upper critical point, 830°C to 860°C. The gamma-iron become unstable and starts to change into the alpha form. Annealing process improves bending consistency and reduces the chances of cracking. This process is a softening process of heat treatment. The purpose of it is to relieve internal stress, reduce brittleness, improve ductility and machinability and refine the material crystal structure.

For example in the semiconductors industry, silicon wafer are anneal so that dopant atoms, usually boron, phosphorus or arsenic can defuse into substitution position in the crystal lattice resulting in drastically changes in the electrical properties of the semiconductor materials.

There are three stages of annealing with each stage producing different result.

1. Recover stage – this result in softening the material through removal of primarily linear defect called dislocations and the internal stress they cause. Recovery occurs at the lowest temperature of all annealing process and before the appearance of new strain free – grains without changing the grain size and shape.
2. Recrystallization stage – New strain- free grains nucleate and grow to replace those deformed by internal stresses.
3. Grain growth – the microstructure starts to coarsen and may cause the metal to loss substantial part of it original strength. All of the cold working are eliminated at this point. Grain growth can be detrimental to the properties of the materials and can typically produce a rough surface appearance on component formed from steel metal.

The temperature variation has a much stronger influence of the annealing of metals than time variations.

The ferrite starts to precipitate out as the temperature drops below the upper critical point and new crystal of carbon-free metal begin to appear around the original crystal boundaries. As more carbon comes out, it begins to form a series of large new crystals. When the temperature passes through the lower critical point, then the remaining austenite changes completely into pearlite.

In annealed steel the ferrite and pearlite are divided up into separate areas which results into a comparatively coarse crystal structure and this affects the tensile strength of the steel.

2.4.2 Normalizing

Normalizing is a heat treatment process in which the steel is heated to above the upper critical point to ensure an austenite structure and then allowed to cool in a draught-free atmosphere. The carbon has no sufficient time to diffuse completely from the ferrite areas into the austenite. This is commonly employed to relieve the strains produced by forging operations and to refine the coarse grain structure produced by hot-rolling.

2.4.3 Hardening

Hardening is a heat treatment process which involves the rapid cooling of a steel by dipping it in a liquid substance. It is also known as quenching. The liquid into which the steel is dipped to promote the rapid cooling is term the quenching bath, which could be either water or special quenching oil.

This heat treatment process consists of plunging the steel, at a temperature just above the upper critical point causes a great and quick drop in temperature. When quenching steel from an austenitic condition, the rate of cooling is very fast in a way that not merely does the carbon fail to diffuse throughout the mass and form large concentration of ferrite, but its whole precipitation is suppressed altogether. Most of the carbon content is frozen in the super-saturated within the body central cubic iron itself. This prevails throughout the whole structure of the steel. Hardness refers to the ability of metal to resist permanent indentation, usually by indentation or known as penetration when in contact with an indenter under load. (ASM Handbook, 2000). In addition the hardness is the resistance to scratching, cutting or abrasion. Hardness is one of the mechanical properties of metal which is when a load is applied it will gives the ability to resist being permanently, and deform. The higher the metal hardness will cause the higher resistance need to deform.

2.4.4 Tempering

Tempering is a process of re-heating of a quench-hardened steel to below it lower critical and quench it again in oil or water. The effect of this heat treatment process is, it increase greatly the toughness of the steel. Tempering temperature below 200℃ relieve the hardening strength, but when the temperature is above 200℃ the hard and brittle structure can be modified. This low temperature is enough to loosen the severely distorted body central cubic lattice structure of the quench-hardened steel and cause the carbon to be precipitated into a more stable condition. Some of the carbon enable to come out of solution, not in the normal form of laminated of pearlite but in harder and finely divided forms of pearlite known as troosite sorbite. Sometimes the two operations of quenching and tempering are combined in one by rapidly cooling the steel to it tempering temperature and then holding at that temperature for some time to allow the precipitation of the carbon content and lessen the danger of cracking. Tempering is necessary to increase ductility and toughness of martensite. Some hardness and strength is lost after tempering treatment. The microstructure of medium carbon steel become tempered martensite matrix. That's means the tempered marten site consists of carbide precipitated which can increase hardness during high tempering temperature.

2.5 The Relationship between Welding and the Properties of Metals

When two or more pieces of metal are joined by fusion welding the weld pool and the edges of the parent metal are molten. The molten metal solidifies and becomes small casting as the joint cools down. The welded joint is usually weaker than the surrounding metals. However, the chilling effect of the parent metal refines the crystal size of the joint and prevents excessive weakness.

All the common physical properties for in their turn affect the ease with which welding can be performed, and the type of process which can be used.

The first property of interest when welding is the melting point, which is also known as the melting range. The melting point or melting range has very great importance.

The temperature at which the material melts has a considerable influence in determining methods by which it can be welded. Arc welding methods are more suitable to the higher melting point materials and gas welding to those of lower melting points. Aluminum is mostly welded by oxy-coal gas or oxy-hydrogen flames, whilst nickel with its higher melting point required the hotter oxy-acetylene flame or arc welding methods.

The need to maintain a correct relationship between the temperature of melting and that of the arc or flame is associated with the heat required to melt the metal. The theoretical amount of heat required to melt the higher melting point alloy is small in relation to the heat extracted from the weld these temperatures by conduction, radiation and convection. Therefore, differences in latent heats seem to play minute part in determining differences in welding behavior.

Copper is outstanding among the more common non- ferrous metals in requiring a great deal of heat in welding. This high rate of heat input and high rate of heat loss by conduction from the welding zone makes it more difficult than usual in maintaining the delicate thermal equilibrium necessary just to melt the welding edges and not burn through. The operator sees this as a difficult in controlling penetration. The molting metal drops right through the joint and leaves a hole or fail to fuse the edge. This applies to metal-arc welding than gas welding, since in the former the heat input cannot be controlled independently of the addition of the filler. In general, the lower the conductivity the less the practical difficulty in welding.

2.5.1 Electricals Conductivity

This appears to be of little importance in fusion welding process but seems to be a great consideration to resistance welding. Where nickel alloy may be satisfactorily welded, using a low- power machine similar to that used for mild steel, aluminum requires a machine capable of delivering a very high current over a very short time, and pure copper is not suitable to this process.

The high thermal expansion of copper is a considerable annoyance in all welding process. It can cause movement of the joint edges which interferes with the proper execution of the weld and gives rise to distortion which must be subsequently removed. Contraction stress may also be possible for producing cracked weld in those alloys. In those cases where thermal expansion and contraction do not seems to be an immediate worry they may indirectly lead to problems giving rise to residual stress.

Where the components being joined operate at normal atmospheric temperature they can benefited by being bonded by modern adhesives .the bonding process are carried out beyond the temperature at which changes in the grain structure occur and therefore, preventing weakness of the parent metal. Adhesive bonding is used on motor-car body panels and highly stresses components such as wheel studs.

A heat treatment can effectively make a metal have a certain level of electrical resistance. The reason that this happen is that when metals are heated, their electrons can absorb additional energy and makes them faster than normal.

2.6 The effect of welding on the parent metals

The study of this is to focus on exploring the influence of welding process parameter on the microstructure and mechanical properties of medium carbon steel weldment preparation through arc welding process.

Fusion welding operations cause temperature gradients in the plate to be joined. The limits of the gradients are the melting point of the parent metal and room temperature. In the case of steel, a portion of the parent metal will be within the upper and lower critical temperature ranges.

The effects of the welding on the parent metal occur on the fusion zone, overheated zone, annealed zone and on the transformation zone.

Fusion zone; when the temperature reaches the melting point, the cooling rate is the order of 350°C-400°C/min, which is the maximum quenching range. The weld is less hard than the adjacent area of the parent metals because of loss of useful elements such as carbon silicon and manganese.

Overheated zone; on the overheated zone the temperature reaches 1100°C—1500°C. The cooling is extremely faster in the order of 200°C—300/min, which resulted to some grain coarsening.

Annealed zone; the temperature here reaches a bit higher than 900c. The parent metal has a refined normalized grain structure. The change is not complete due to the high cooling rate in the order of 170°C-200°C/min.

Transformation zone; the temperature for the transformation zone is between 720°C and 910°C. These are the upper and lower critical temperatures between which the iron in steel transforms from a body- centred cubic to a face- centred cubic structure. On this zone the parent metal tends to re-crystallize.

When a welding flame is applied to the plate its temperature is raised so as to prevent chill casting of the weld deposit occurring. There will be pronouncement of grain growth because of the heat from the welding flame is applied for a longer period than the heat from the arc.

When a weld is made of low carbon steel with the addition of filler materials, there will be results structures such as;

- Metal which has been molten will be made up of the deposited metal mixed with the parent metal.
- There will be a fusion line at the junction between the metal which has been melted and the un-melted parent metal.
- A heat- affect zone which extends from the fusion line to the parent metal which has not been heated hot enough to change the original structure.

- Adjacent to the fusion line is a zone of coarse grains. This metal has been heated nearly to its melting point and grain growth has resulted.
- Progressing away from the weld through the coarse grains. The grains become smaller and the zone where they are very fine is called the green zone. This metal has been heated to crystalize and then cools before the grains have time to grow.
- Progressing away from the refine zone. In this zone some of the grains were re-crystalized and others were not, resulting into a mixed structure.

In the shielded metal arc welding process, the following parameters are paramount and important. These are; welding current, voltage and speed, time temperature, and pulse frequency. These parameters and the electrode composition enhance the properties of the weldment. In order to obtain weldment with enhance properties and excellent bead geometry, a good combination of welding parameters is very essential. Hence the recent use of arc welding controls system, for enhancing the proper selection of welding process parameters. The joint design and configurations and the welding process are very important for obtaining an appropriate joint of different properties.

Numerous researchers have carried out studies under the effect of welding parameters on the properties of weld joint. Agarwal and Manghnami in their study revealed that the arc column measure about 600**C** across it length and diameter. It is particularly suitable source of heat energy for welding since its heat is effectively concentrated. This effective concentration of heat energy is due to current density factor. Kim et al, revealed in their study the need to properly select optimal welding parameter to provide good work quality which is identified by its microstructure and mechanical properties.

Medium carbon steel has found wide applications in the building industry. One of the applications of medium carbon steel is the constructions of bridge beams. The safety factor is a major factor to be considered in the constructions of bridges because it involves the lives of the bridge users. The factor of safety depends on the type and quality of medium carbon used in building a strong bridge frame. Therefore, there is need for high quality materials that have good mechanical properties and can withstand high loading forces in building of bridge frame to sure it does not collapse easily during and after fabrication. Study by Adzor et al established that with increasing welding current, the hardness, yield strength and tensile steel of micro- alloy steel joint decrease while both impact strength and percent elongation showed increase trends. The study also revealed that E7016 electrode as the best for excellent hardness. Boumerzoug et al also revealed that grain characteristics of weld regions significantly improve the hardness of a weld joint.

Welding current is something that has to be taken into serious consideration. When the current is higher than a particular diameter of electrode, there would be heat concentrations on the base metal that would definitely have a negative effect on the medium carbon steel. The higher the current the higher the effect of heat on the yield strength, and other mechanical properties of the metal. Therefore, care must be taken when selecting the welding current for a particular size of electrode diameter.

The appropriate welding current must be used for welding different diameters of electrodes. Figure 2.1, 2.2, and 2.3 shown the effect of welding current and electrode size, the effect of welding current on the yield strength and the effect of welding current and electrode size on the elongation percentage of arc-welding medium carbon steel respectively.

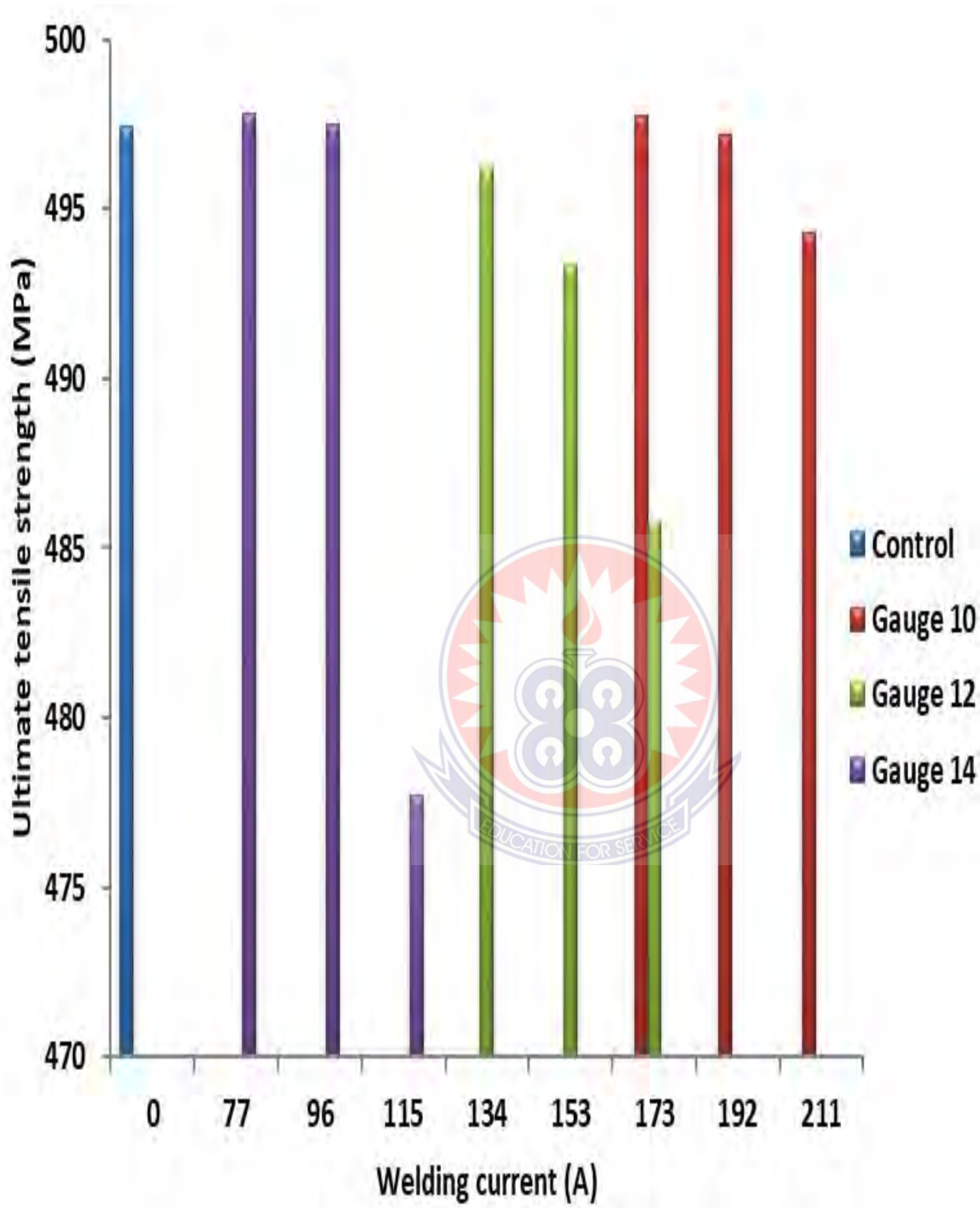


Figure 2.1 the effect of welding current and electrode size on the ultimate tensile strength of arc-welded medium carbon steel (1035).

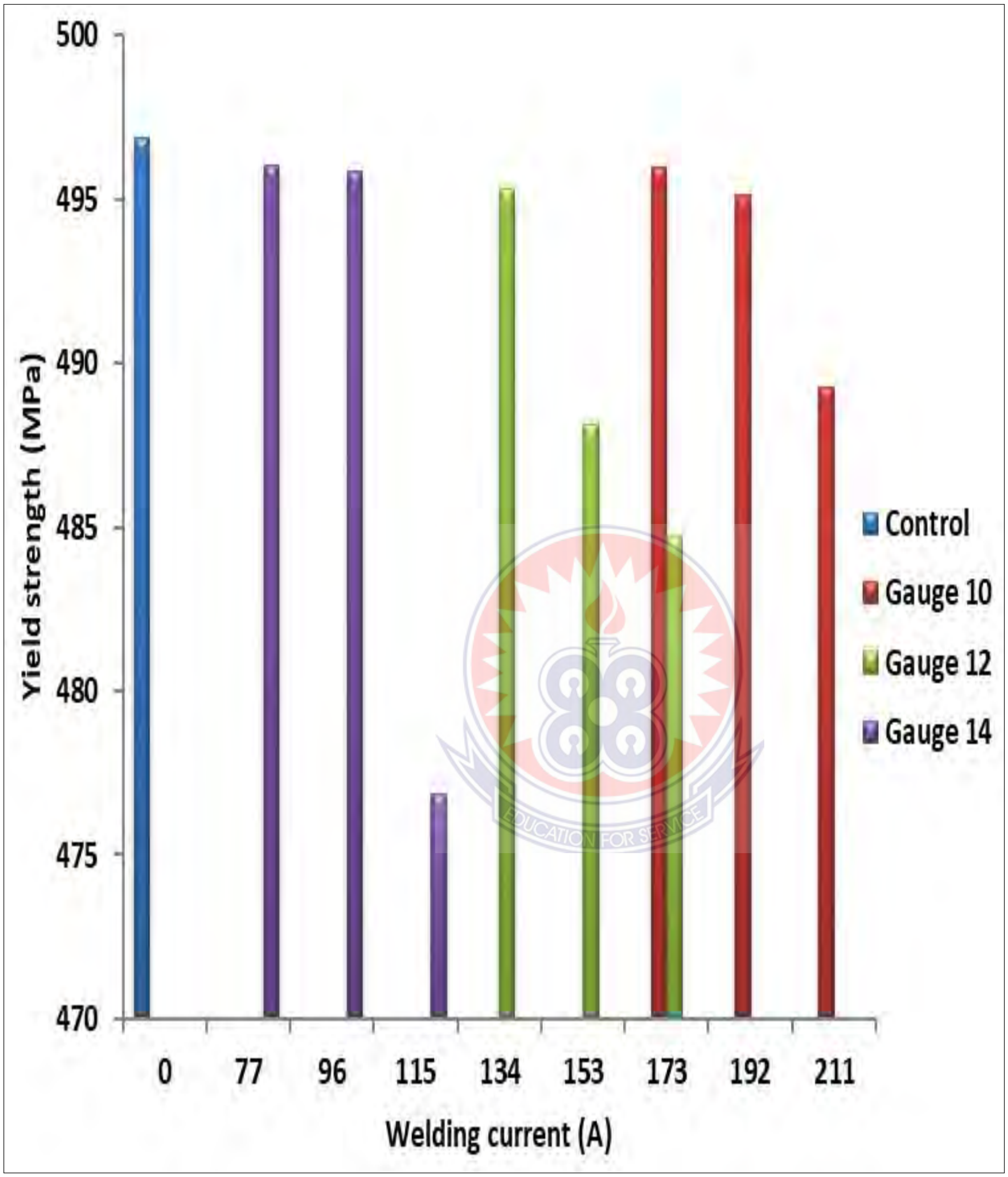

500
495
490
485
480
475
470
Yield strength (MPa)
0
77
96
115
134
153
173
192
211
Welding current (A)
Control
Gauge 10
Gauge 12
Gauge 14

Figure 2.2 Effect of welding current on the yield strength of arc-welded medium carbon steel (C1035).

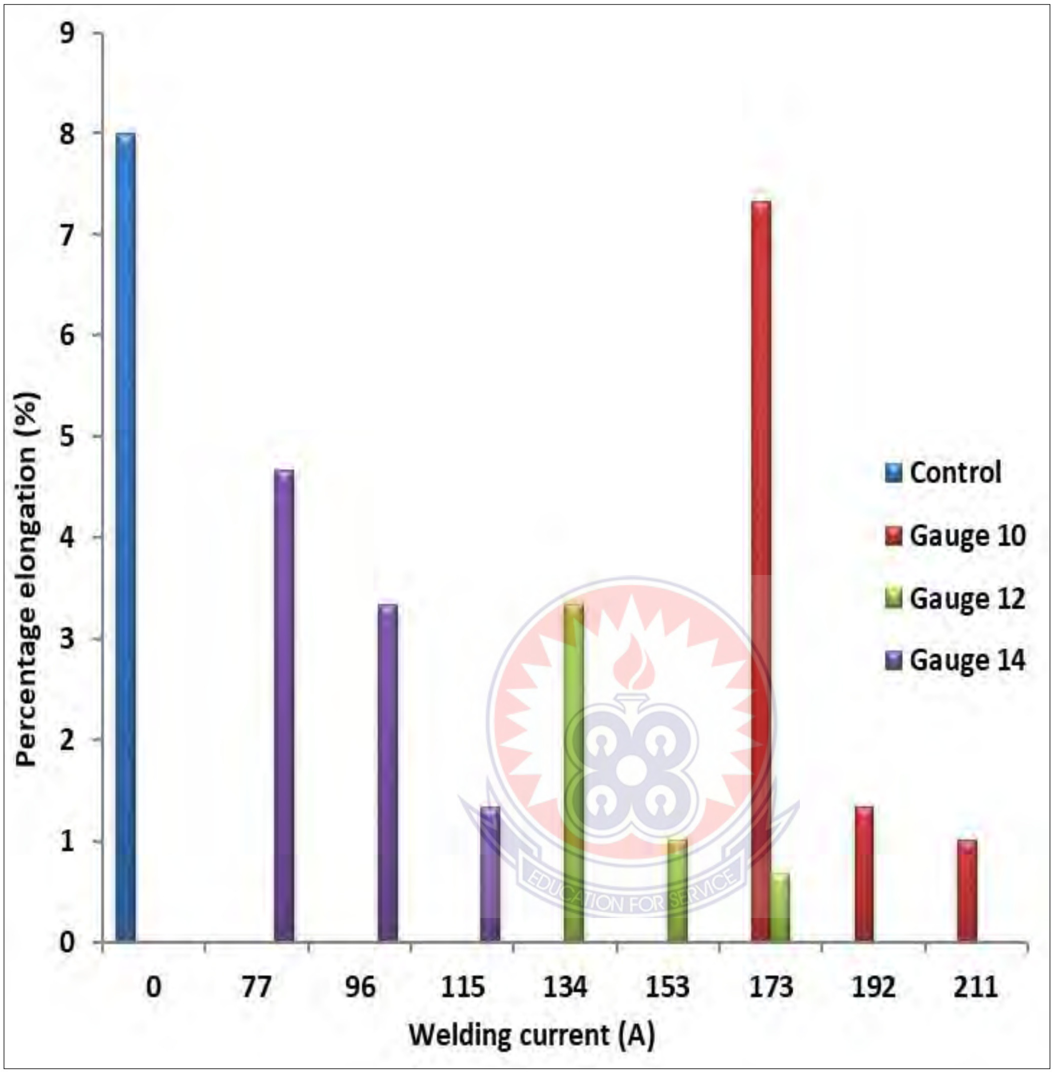


Figure 2.3 Effect of welding current and electrode size on the percentage elongation of arc-welding medium carbon steel (1035).

2.6.1 Distortion

Distortion affects some of the properties of steels and this can be controlled. The problem of distortion can be controlled by the use of correct welding procedure sheets and ensure a correct edge preparation and fit-up. Use the reasonable root gap to ensure penetration. Ensure that there is proper alignment of the plates and the right welding process which produces the less distortion.

Make shrinkage forces work to achieve correct alignment by the use of pre-setting. Pre-setting locates parts in such a position that they pull into line due to the contracting weld metal. To minimize stress, the direction of welding should be away from the point of restrain to the point of freedom. A correct tacking should be used for the particular metal being welded if tacks are used.

Back-to-back assemblies are used to restrain and balance the weld shrinkage of each other, when fastened back to back.

Restraining methods: jigs and ta fixtures may also be used to restrain or control movements of the components during welding. If close control over accuracy is required, then restrain of the, weld deposit should be balanced and distributed by techniques called step-back techniques.

Work piece may be achieved by using wedges, strong backs, chains, clamps and stays which remain in position during cooling. Even though these methods prevent most of the movement, however, there is stress in the fabrication which is progressive build-up. Tack weld should be made at intervals of half the pitch employed for mild steel in order to minimize distortion.

2.6.2 Weld decay

When some steels are heated through a temperature range of 500℃—800℃ and allowed to cool slowly, they undergo a structural change that is detrimental to their inherent corrosion resistance. Such problem can occur in the heat-affected zone of a weld and a band is formed in the adjacent parent metal parallel to the weld deposit where resistance of corrosion is reduced greatly.

This condition is due to chromium in the grain boundary areas combining with carbon to form chromium carbides which subsequently precipitate out leaving a chromium depleted layer within the grain boundaries. The depletion of the chromium is directly responsible for the drastic reduction in the metal ability to resist corrosion. Consequently when subjected to a corrosive medium under service conditions, the depleted areas are eaten out and the grains of metal simply fall apart thus the name ‘weld decay.

2.6.3 Causes of weld cracks

Generally speaking cracks in medium or high carbon steel can occur when some when some time has elapsed after finishing the welding. These cracks are called cold cracks or delayed cracks.

Solidification cracks can also occur immediately after welding finished but these are not rare, either, the delayed cracks that occur more frequently are explained below.

The main causes of delayed cracks are considered to be associated with the following.

- Harding of HAZ
- Existence of much diffusible hydrogen in the weld metal
- Big constraint
- Prevention of Delayed Cracks

- Prevent HAZ from hardening

In the welding procedures, the most effective means to prevent delayed cracks is preheating. By preheating the base metal, the cooling rate at the time of welding becomes smaller and the rise of hardness of HAZ is suppressed.

The appropriate preheating temperature depends on the steel grade and plate thickness.

- **Lessen diffusible hydrogen in the weld metal**

Diffusible hydrogen comes into the metal during welding from the moisture in the welding consumable, on the growth face and in the atmosphere. Hydrogen that entered the weld metal can defuse with time and part of it reaches HAZ to cause crack occurrence by its pressure. To lessen diffusible hydrogen in the metal one have to;

- Use low hydrogen type electrodes in shielded arc welding
- Use solid wires in gas metal arc welding to reduce hydrogen to a lower level
- Apply immediate post heating to the weld joint to remove hydrogen.

- **Minimize constraint**

When the straining force that is created by welding cannot be released from the weld joint, it can generally be said that the joint is under strong constraint. Normally, the created stress can be released from the weld joint if the joint can deform. However, when the plate thickness is big or the structure is complicated, the stress cannot be released by the weld joint deformation and thus the stress tends to be released by cracking. This is the reason why cracks tend to be generated when the constraint of the weld joint is strong

To reduce constraint, it is necessary to design a structure with thinner plate and simpler configuration. It is more practical to avoid welding of stress-concentrated areas and to weld in an appropriate welding sequence to minimize stress concentration.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter presents the materials and method used for welding and heat treatment of medium carbon steel. For a welding to be carried out, there are other machines and tools to enable a successful work done. However, safety precaution has to be taken into consideration. Safety of the welder, tools and equipment. The welders have to make sure that the eyes, foot, and the entire body is protected from injury.

3.2 Materials

Medium carbon steel (1035) was used as the base material for the experimental study. Electrode used was gauge 10 (E6013) 3,35mm, gauge 12 (E6013) 2.5mm, and gauge 14 (e6013) 2.0mm. The equipment used were universal testing (model M500 – 25CT), bend testing process, optical microscope, shielded metal arc-welding machine and measuring tools such as rule, tape measure try square and scriber.

3.3 Materials for the heat treatment

The materials need for heat treating are medium carbon steel, steel rule, leather apron, goggles, tongue, forge, charcoal, hammer, oil and water, hand cloves chalk or crayon. The chemical composition of medium carbon steel samples used for this investigation is given in table.

Table 3.1 Chemical Composition of Base Metal

Element	Composition (Wt. %)	Element	Composition (Wt. %)
C	0.348	Nb	0.005
Fe	98.52	Ti	0.0010
Si	0.112	V	0.0085
Mn	0.692	W	0.016
P	0.033	Pb	0.0050
S	0.042	Sn	0.0050
Cr	0.054	Zn	0.011
Mo	0.0050	Co	0.044
Ni	0.064	Cu	0.33

The project was started with the preparation of the specimen of medium carbon steel about 14 samples. The sample was cut with dimension 55mm x10mm x 10mmthat follow standard dimension chirpy impact test. Then it will divide into two parts of heat treatments and non-heat treatment. For non-heat treatment only two sample of medium carbon steel is used to observe the microstructure, perform the hardness test and impact test.

3.3 Method

A cylindrical shape of medium carbon steel with dimension of 200mm x 10mm was gotten from the St, Basilide's Vocational and Technical workshop and machined into the desired dimension 8mm x 150mm. To ensure adequate removal of inclusions, the sample of the steel was properly cleaned and degreased. Double V-groove of 3.2mm with depth of 4mm was made on the sample to be welded. The welding process was carried out using the Shielded Metal Arc-Welding machine. One run in a rotary flat welding position was utilized in producing the butt joint. The welding current, electrode sizes, heat input were varied while the welding speed (2mm/s) were kept was kept constant throughout the entire processes. 230 volts of an arc voltage and 65volts of an open circuit were maintained throughout the welding process.

The well-meant was prepared for tensile and microstructural investigations. For each test, three samples were measured and the average results taken. The tensile properties of the weldment were measured using universal testing machine with the ultimate tensile strength and percentage elongation calculated using equations.

The micro analysis of the well-meant was done using light optical microscope. The specimen underwent the following preparation prior to the microstructural analysis: grinding using 220, 320, 400, 600, and900 grit sizes of emery paper, polishing using alumina powder and etching. After the grinding, the operation was subjected to thorough polishing to obtain even and smooth surface. The polished specimens were etched in a cid solution water for about 20 – 30seconds, wash with distil water, dried and view using an optical microscopic x400 magnification.

The method will continue for heat treated experiment. The specimen is prepared for about 12 samples for heat treatment. The sample will then undergo heat treatment process which are annealing, quenching and tempering. After this process, the samples were undergoing sample testing process. The samples will undergo microstructure analysis by using the metallurgical microscope (ASTM E18) standard. The samples also undergo Charpy impact test (ASTM E23) and the fracture surface is observe using camera. After getting the results, the project comes to a conclusion and the data and the result was then compared and analyzed.

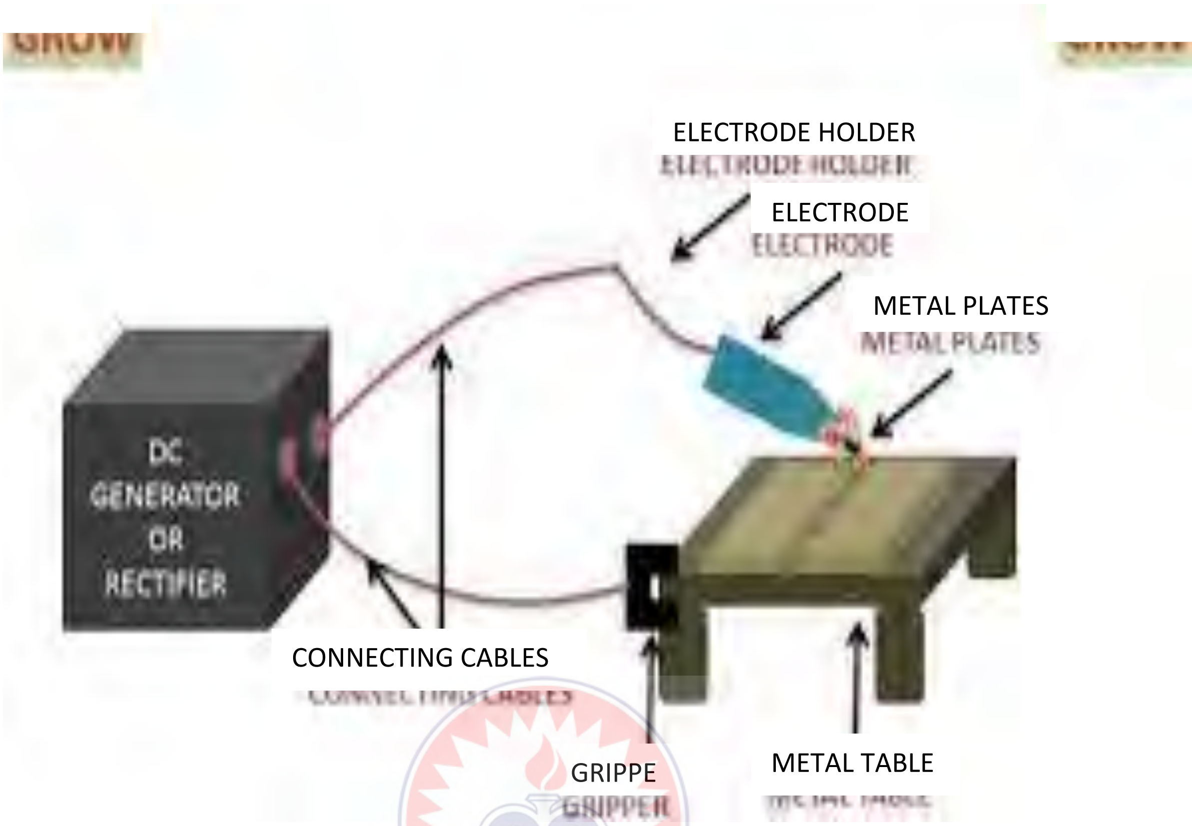


Figure 3.1: Work bench, welding machine and pieces prepared for welding

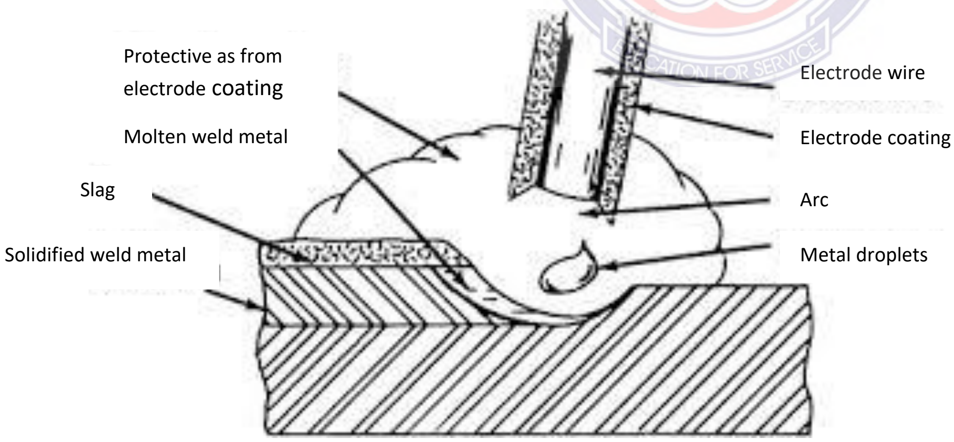


Figure 3.2: Right hand shielded metal arc-welding process

Bench vice – it is a mechanical apparatus to secure an object that is to be worked on the work bench. It is a holding device as an important instrument in trade and shaping application. The bench vice has two parallel jaws as part of the design. Bench vice of various sort will be connected to a work bench to carry the work piece throughout specific activities such as sawing, cutting, drilling, grinding chiseling and many

3.3.2 The base or parent metal

This is the main material used for welding and heat treatment. There are different types, kinds, shapes and forms of metals. To work on any material it is vitally important to know its mechanical properties, physical properties and electrical conductivities. The materials can be in a sheet, pipe, angular or in the form of rod. But here we are dealing with only medium carbon steel.

3.3.3 Hacksaw – the hacksaw is a type of hand tool designed purposely for pies, rod s and brackets through materials such as plastic, steel and other metals. It is a tool for cutting hard substances mostly metal. It has a wide and straight blade under tension. It has a frame which is adjustable for tightening to cut according to need of operation. It also has a blade of different sizes. The blade can have different teeth set like 14, 18, 24 and 32 teeth per inch. There is another hacksaw which is the small version with a blade having half size. This small hacksaw is called junior hacksaw. The quality of the junior hacksaw blade is restricted and it is made of simple low alloy steel.

We also have power hacksaw wick uses electricity for operations such as cutting dicker diameters of iron rods metal pipes and plates where the hacksaw cannot be used, see fig. 3.3

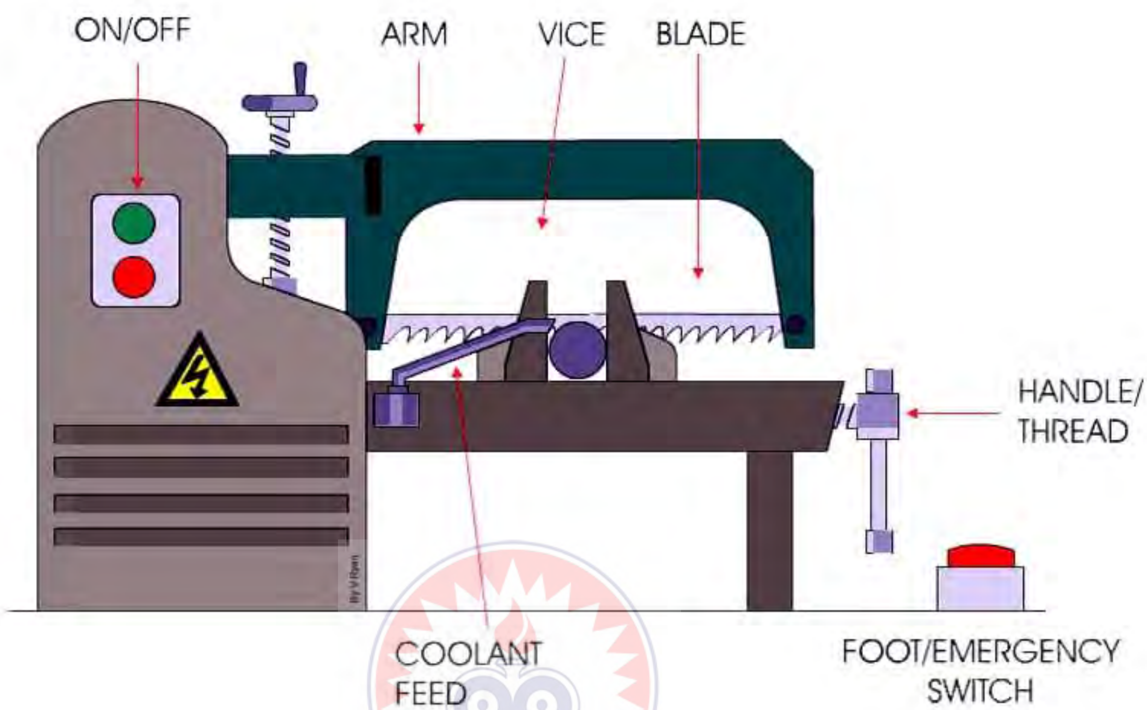


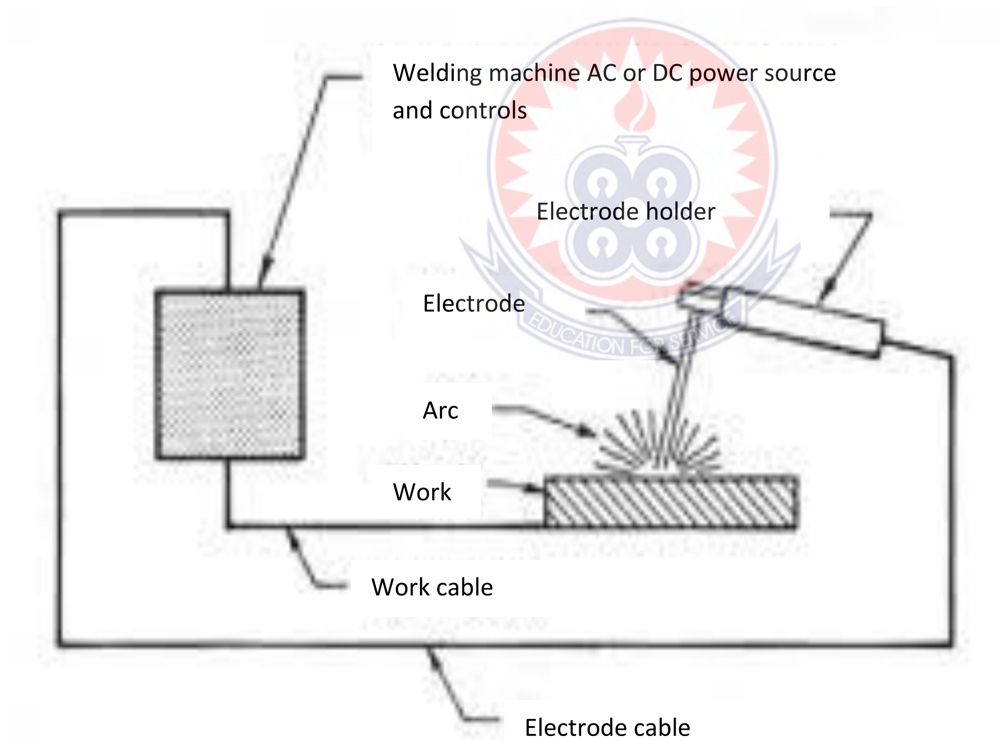
Figure 3.3 Electric power Hacksaw

3.3.4 Files – the file are tools are used for filing metals to their required measurement for specific use. They are of different sizes, grades and shapes. Files set for metal work are needle file, flat file round file half- round file and file rasps.

3.3.5 The welding plans – the welding machine could be direct current (DC), alternating current (AC) or a transformer.

In other to weld a metal you must to select the appropriate machine suitable to it. Is that direct current or alternating welding machine that is to be used for the job? If the wrong welding plan is selected, there would be challenges in getting the desire result.

Figure 3.3: Types of welding plans with different cables and electrode holders



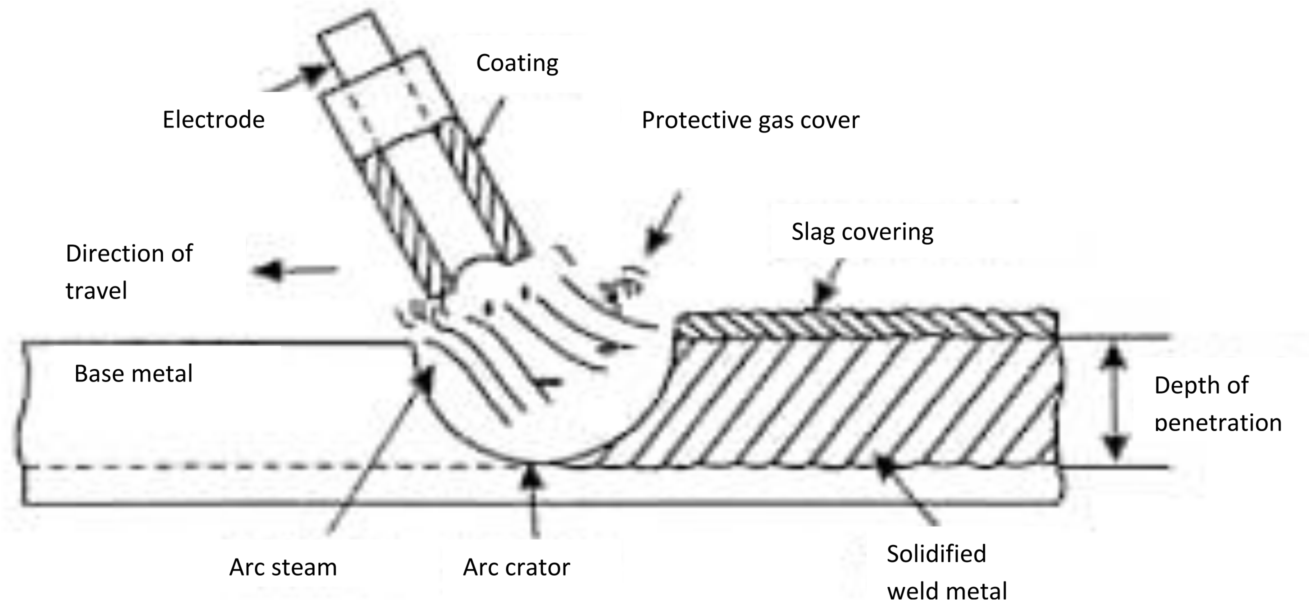


Fig. 7.14 Cut away view of the arc welding with a coated electrode

Figure 3.4: left hand welding process

3.3.6 Electrodes -- are welding rods that are codes with some element to provide protective agents from oxidation to the weldment from the atmosphere, the electrode also melts to join the base metals together and also form part of the base metal. When the oxidation comes in contact with the molten metal, the can lead to cracks after the solidification of the weld pool.

The welding current must be selected accordingly to match with the diameter, the type of electrode and the thickeners of the base metal to be welded. The wrong choice of current can have a great effect on the w

3.3.7 The chipping hammer – it is of robust construction and well balance, and it is used for the removal of the welding slag from the surface of the weldment after solidification. It is also used for cleaning the impurities that are still left on the surface of the weldment after chipping.

3.3.8 Wire brush – the brush is made of wood and stainless bristles, and it is used for cleaning the welding surface, removal of slag and rust.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion of the study.

4.2 Mechanical properties of based metal and mild steel weldments

This chapter is to seek and discuss the outcome of the results for the research.

The results presented depict the chemical constituent of the base metal and welding electrodes respectively. It also reveals that various properties of metals experience change when they go through a heat treatment. Some changes make the metals more resilient and or resistance while others allow them to be reshaped. Even though modern technology has created new methods for this type of treatment, blacksmiths many years ago used to accomplish similar goals by heating and cooling metal for horseshoes, wagon parts and more.

The results shows that as metals are heated their volume, surface and length will expand. Thee term for these action is called thermal expansion. Each metal will have a different rate of expansion when exposed to the heat.

Another effect the heat treatments have on metals is that the structure of them will go through a transformation .this is due to the fact that heat displaces the allotrope atom in metals and causes them to reform in a different configuration. It not only can change the structural shape of the metal, but it also can alter its strength, ductility and hardness of it.

A heat treatment can effectively make a metal have a certain level of electrical resistance. The reason that this happen is that when metals are heated, their electrons can absorb additional energy and makes them faster than normal.

Magnetic metals such as nickel, cobalt and ion can lose some of their magnetism by undergoing a heat treatment. In some cases, they are no longer magnetic at all.

Figure 2.1 demonstrates the effect of welding currents (77, 99, 115,134, 153, 173, 192, and 211 A) on the UTS welded join using welding electrodes of gauges 10, 12, and 14. Figure 2.2 shows that at welding current of 77, 96 and 115 A, only gauge 14 electrode produced weldment. Figure 2.3 shows that at different electrode gauges, the ultimate tensile strength of the weldment decreased with increasing welding current. Electrode of gauge 14 produced weldment of the ultimate tensile strength (497.801MPa) at welding current of 77 A, compared with the parent metal and weldment produced with gauge 10 and 12. Appling welding current of 173 A, electrode of gauge 10 produced no weldment unlike gauge 14 electrodes. With gauge 12 electrodes weldments showed lower ultimate tensile strength as compared with the base metal. Figure 1 showed that gauge 10 and 12 electrodes produced weldment of maximum ultimate tensile strength using welding current of 173 A and 134 A respectively. It was observed that the gauge 10 (3.25mm) electrode produced weldment of better UTS compared with the weldments produced using gauge 12 (2.5mm) electrode. Figure 2 shows the effect of welding current (77, 96, 115, 134, 153, 173, 192 and 211) on the yield strength of the weldments using welding electrodes of gauges 10, 12, and 14. Figure 2 showed that with the welding current of 77,96 and 115 A, no weldment was produced using electrode of gauge 12 (2.5mm) and gauge 10 (3.25). The yield strength values for the three weldment produced were lower compared with the parent C1035 metal. Figure 2 showed the yield strength of the weld joints produced with different electrode gauges decreased with increasing welding current. Gauge 12 electrode produced weldment with maximum yield strength at a welding current of 134 while gauge 10 and gauge 14 electrodes produced weldments of maximum yield strength at welding current of 173 and 77 A respectively the weldment showed better yield strength at different welding current using gauge14 electrode. Figure 3 showed the effect of welding current (77, 96, 115, 134, 153, 173, 192, and 211 A) on the percentage elongation of the welded joints using welding electrode of gauge 10, 12 and 14. At welding current of 77, 96 and 115 A, weldment were only obtained using gauge 14 (2.0mm) electrode. Also, the percentage elongation decreased with increasing welding current using different electrode gauges. Figure 3 showed that gauge 14 electrodes produced weldments of higher percentage elongation at a welding current of 77 A.

According to research study of the microstructure of medium carbon steel by using metallurgical microscope, the result shows that the annealed specimen with mainly ferrite structure gave the lowest hardness value but highest ductility and toughness value. However, after quenching the microstructure shows the formation of martensite. This martensite shows that the hardness increase and specimen is too brittle and not suitable for any application. Then, tempering is necessary to increase ductility and toughness of martensite. After tempering at high temperature 600oC the microstructure changed from martensite to tempered martensite and also found the formation of recrystallized ferrite grains. Then, according to the result, the hardness value after quenching in water which is 11.85 HRC shows the higher hardness than cooling by open air which is 8.95 HRC. This is due to the water is the best media for quenching treatment because it is cooled rapidly. However, the hardness is changed when specimen undergoes tempering process at different temperature. The hardness after tempering is decreased when tempering temperature increased. Through this tempering the hardness of medium carbon steel begins to drop then the toughness of a material increase as the absorbed energy increase. Lastly the objective to investigate the impact toughness of medium carbon steel also achieved. Based on the result obtained, the toughness of steel increase as the absorbed energy increases when tempering temperature increase. This result shows that the microstructure obtained after tempering provides a good combination of mechanical properties because this process reduce brittleness by increase ductility and toughness and at the same time reduces.

4.3 Micro Structure of non-heated medium carbon steel

The results has proved the heart treatment always develops hardness softness, and improves the mechanical properties of such as yield strength, tensile, ductility, corrosion resistance and creep rapture. These processes also help to improve machining effect and make them versatile.

The microstructure provided by the manufacture is in the soft annealed condition. This material is easy to machine with cutting tools and the microstructure suitable for hardening. The soft annealed microstructure contain of soft matrix in which carbon are embedded. In medium carbon steel this carbide are iron carbides. Higher carbide content means higher carbon compound and therefore higher resistance to wear. This investigate medium carbon steel were ground, polished and etching metal etching solution to observe the microstructure for non-heat treated. The specimen was observed and the microstructure for non-heat-treated showed a combination of ferrite and pearlite as shown in Figure 4.1

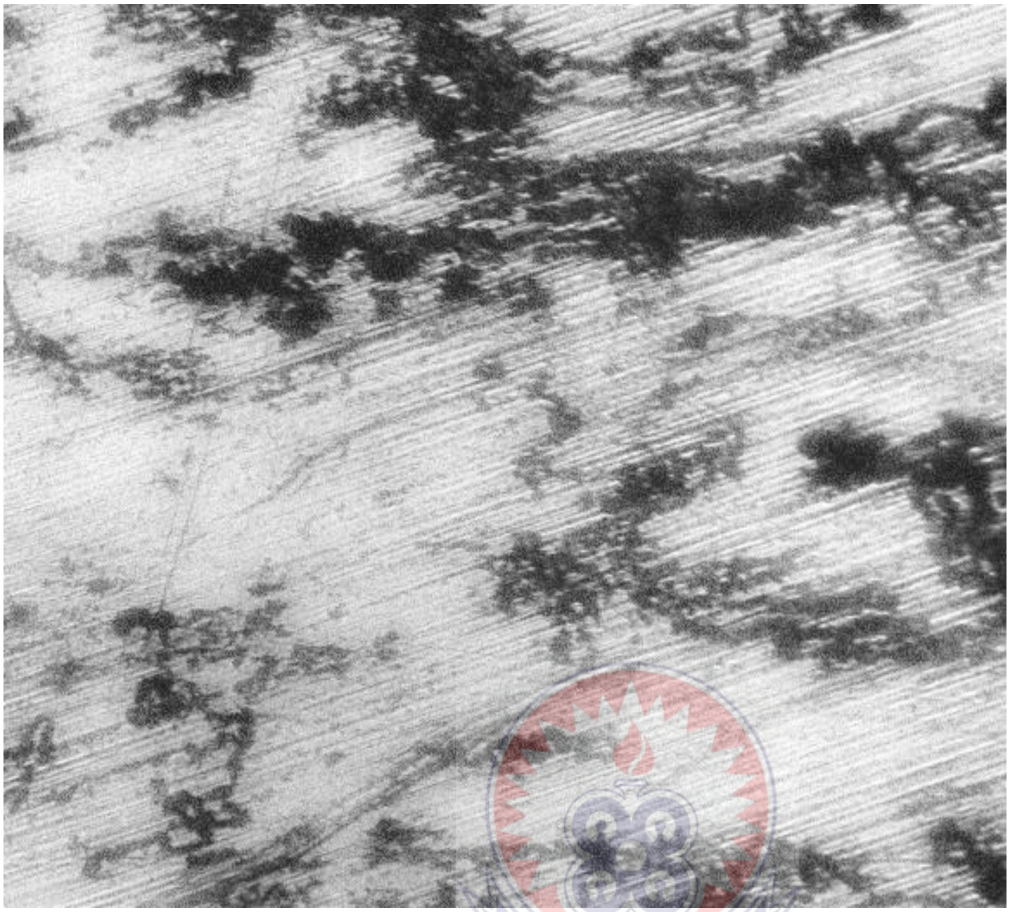


Figure 4.1: Microstructure of non-heat treated steel (10X)

Pearlite is usually a lamellar combination of ferrite and cementite. It is formed by eutectoid decomposition of austenite upon cooling by diffusion of C atom, when ferrite and cementite grow contiguously.

Ferrite form by the slow cooling of austenite, with the associated rejection of carbon by diffusion ferrite has a good strength and moderate ductility. These ferrites are ferromagnetic. They are not heat treatable and have excellent corrosion resistance, moderate formability, and relatively inexpensive.

Before quench in water the specimen were anneal with 900℃ for one hour and at that time microstructure become austenite. Annealing means changes of crystal structure from ferrite to austenite. From that figure it shows the formation of martensite. When the specimen of the medium carbon steel are rapidly quenched from austenite temperature to room temperature in room of water, the austenite will decompose into a mixture of some medium carbon martensite and fewer pearlite but if the specimen is not quenched sufficiently rapidly, the carbon atom will allow the reforming of ferrite, pearlite or bainite from austenite. At this stage, the microstructure is hard; hence increase in hardness and tensile strength but reduction in ductility of the material.

Besides that, martensite hardness depends on the carbon content of the steel. This is because the higher carbon content, the higher the hardness.

The microstructure of medium carbon steel after quench in water is shown in figure 4.2

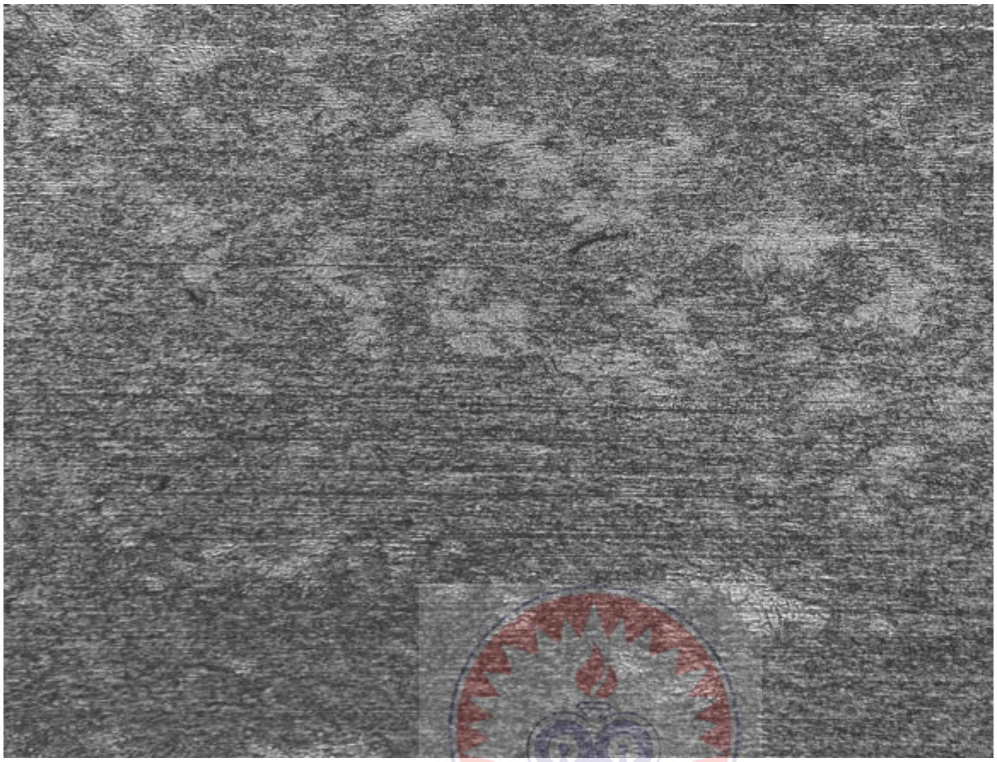


Figure4.2: Microstructure of hardened Medium Carbon Steel (10X)

However, martensite is too brittle and cannot be used after quench for any application. Martensite brittleness can be reduced by applying a post heat treatment known as tempering. Tempering is necessary to increase ductility and toughness of martensite. Some hardness and strength are lost after tempering temperature. The microstructure of medium carbon steel become tempered martensite. The microstructure of tempered at 600℃ is shown in figure 3. The microstructure shows the formation of crystalized ferrite grains with graphite fakes site in martensite matrix. That’s mean the martensite consist of carbide precipitated. This particle can increase hardness during high tempering temperature.

Figure 4.3 Microstructure of tempered medium carbon steel

Therefore, by increase in tempering temperature, the hard constituent of martensite is being transformed to comparatively soft troos tite and also called as tempered martensite that have better combination of mechanical properties.

4.4 Hardness after Quenching with Hardness after Tempering

CONDITION	HARDNEE (HRC	
After Quenching	11.85	8.95
After Tempering	9.01	8.77

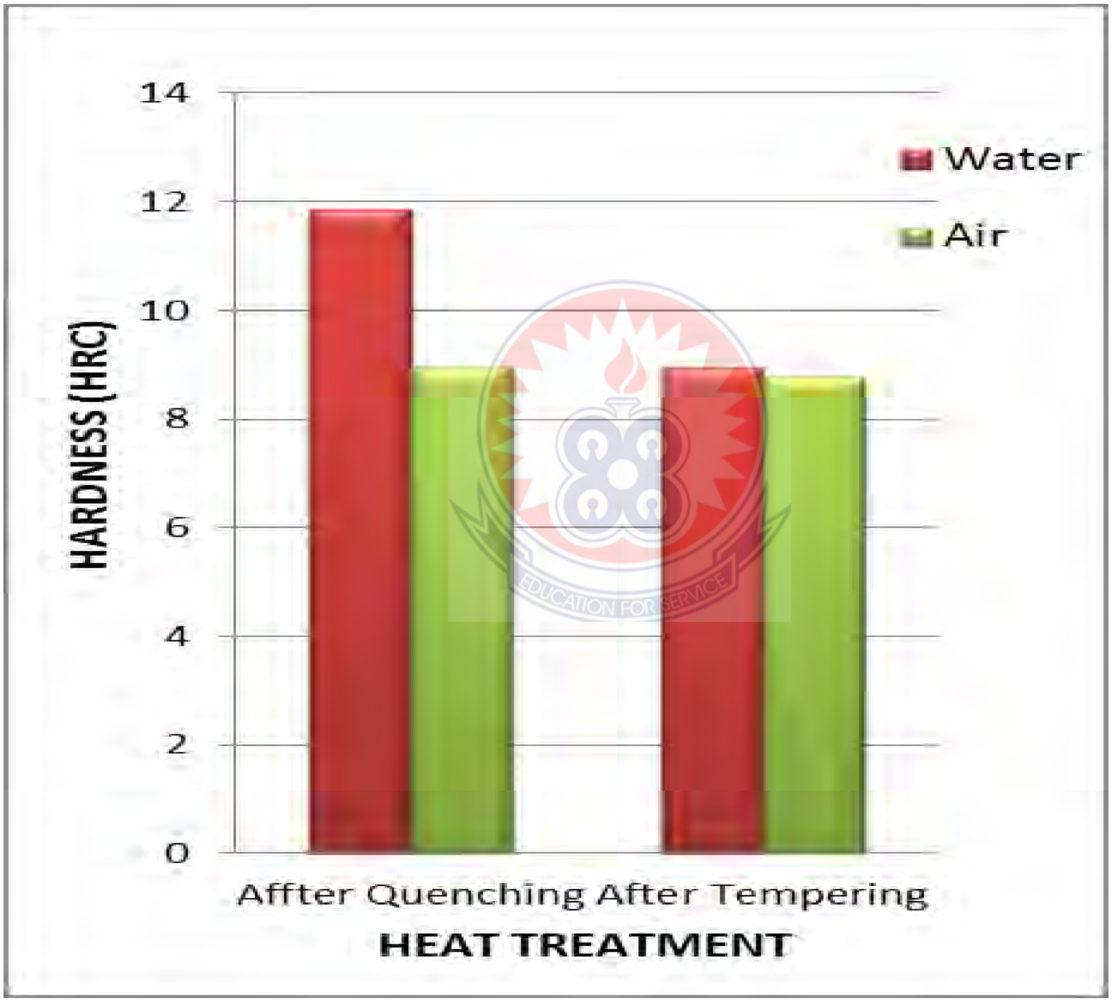


Figure 4.5 Graph of Comparison Result for Hardness Value vs. Different Heat Treatment

The graph in Figure 4 plotted the hardness (HRC) against heat treatment process. This bar graph shows the result from Table 2. As can be seen from the graph, the hardness of medium carbon steel after quenching is higher than the hardness of sample after tempering. This happen because quench hardening is a mechanical process in which steel are strengthened and hardened. That's mean the quenching is the process to improve the hardness while tempering is the treatment to improve the

Toughness and ductility. Therefore during tempering the hardness will decrease and that the hardness of medium carbon steel after quench in water is higher than quench by open air. This is because water is fast quenching rate and the best quenching media than air and oil to produce the excellent tool performance. Water is one of the most efficient quenching media where maximum hardness is acquired. However, there is a small chance that it may cause distortion and tiny cracking. The variation of hardness of medium carbon steel at various tempering temperatures in the range of 300℃ - 600℃.

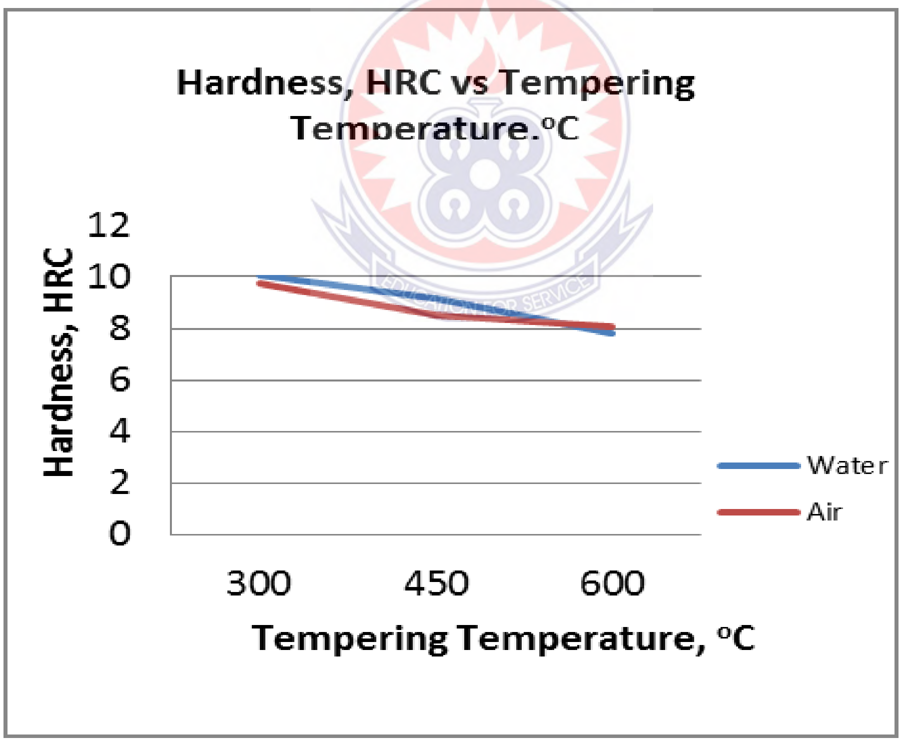


Figure 5: f Hardness, HRC vs Tempering Temperature, (℃)

The graph from Figure 4.5.1 shows that hardness decrease as tempering temperature increase for both different quenching media. This is because by tempering the process of quenched medium carbon steel could be modified to decrease hardness and increase ductility and impact strength gradually. Besides that, this happen also due to transformation of martensite to tempered martensite.

3.3 Impact Test After heat treatment with different tempering temperature this 14 specimen consist of heat treated and non-heat-treated will undergoes Charpy impact test. The fracture surface obtain is shown as in Figure 7 using camera.

Figure 5.5.2 Specimen after Impact Test

Figure 5.5.3 Fracture Surface after Impact

Table 4.2 Impact test Results

Tempering Temperature (^{0}c)	Absorbed Energy (J)	
300	10.8	11.9
450	12.2	13.5
600	13.3	19.5

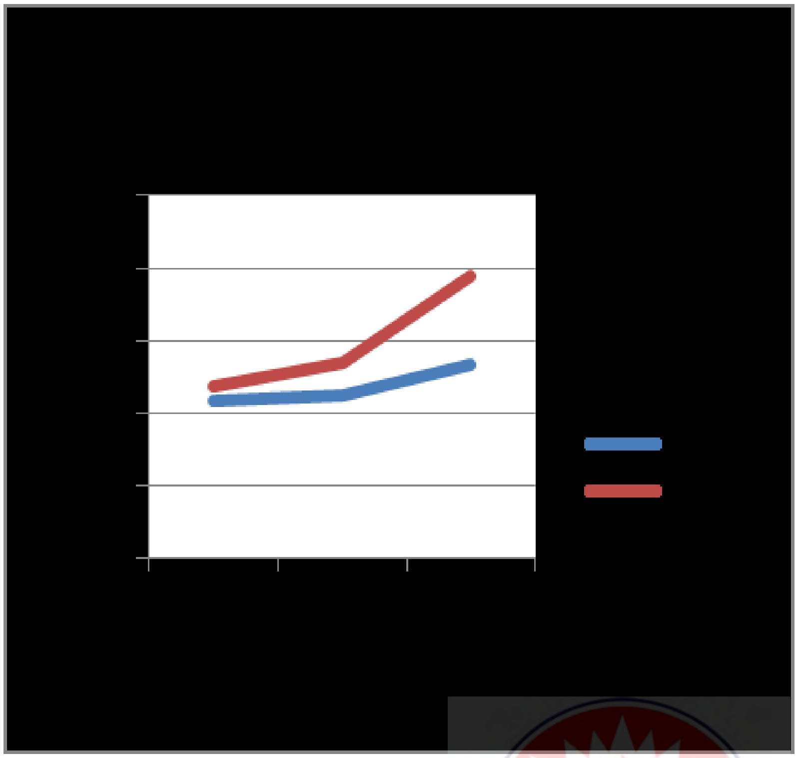


Figure 8: Graph of Absorbed Energy, J vs. Tempering Temperature ℃

The mechanical properties of tempering samples showed that the toughness in J is increased as tempering temperature increase. When tempering temperature increase, the absorbed energy also increases. Therefore the specimen after tempering provides a good combination of mechanical properties because these processes reduce brittleness by increase ductility and toughness. At the same time reduce hardness when tempering temperature increase.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the finding, conclusion based on the analysis made of the research and the recommendations.

5.1. Summary of the Finding

The cardinal reason and main purpose of this study was to assess the effect of welding parameters on the mechanical properties of arc-welded C1035 medium carbon steel and the effect of heat treatment on the hardness and impact properties of medium carbon steel.

The study sought to examine the effects of different types of electrodes with different welding currents. The study also sought to experiment and to come out with the results of the microstructure of harden medium carbon steel, the microstructure of tempered medium carbon steel through heat treatment and testing after heat treatment. The research was to get the best materials and methodology when welding or heat treating medium carbon steel.

It is clear that the ultimate tensile strength (UT), yield strength and ductility of medium carbon steel of the welding joint with increasing welding current using electrodes of different gauges affect the weldment. Therefore, when welding consideration has to be taken in the following things such as welding current, the diameter of the electrode, the diameter of the steel to be welded as well as the type of coding.

Different electrode gauges and diameter of the steel with the wrong welding current will produce different well-meant that would give different effects on the steel. The right current has to be selected according to the electrode gauge and the diameter of the material to be welded.

On the part of heat treatment of the medium carbon steel, it was observe that the different heat treatment processes produces different hardness value and impact property to the steel. It has also been noticed that the heat treatment of medium carbon steel can significantly change the mechanical properties such as ductility, hardness and strength. It can also affect other properties like its ability to conduct heat and electricity as well. for that matter, when heat treating medium carbon steel, the right procedures and temperatures have to be observed critically in order to obtain the intended desire results.

5.2 Conclusions

This study explored the influence of process parameters on the microstructure and mechanical properties of C1035 medium carbon steel elements prepared using shielded metal arc-welding process. The UTS, yield strength, and ductility of the welded joints decreased with increasing welding currents using electrodes with different gauges. This was probably induced by the martensitic phase. At higher welding current, the heat input and cooling rate increased correspondingly which induce the formation of martensitic structure. The electrode of gauge 14 produced weldments of higher ultimate tensile strength of 497.801 MPa and yield strength of 496.04 MPa at welding currents of 77 A respectively, compared to other electrodes gauges. This was guaranteed by the absence of phosphorus and sulfur in the electrode composition. The weldments produced using different electrodes gauges showed lower percentage elongation compared with the base metal. Among the weldments produced using different electrode gauges, weldment produced with electrode gauge 10 gave higher percentage elongation (7.33%) indicating presence of more pearlite zones in the weldment structure.

5.3 Recommendations

Based on the finding of the study, here are some recommendations made by the researcher:

- Head of departments and lecturers should devote enough time in teaching and learning of the effects of welding on medium carbon steel.
- There should insure that lecturers and instructors are well endowed with the requisite knowledge and skills by authorities to improve the teaching and learning of the effects of welding and heat treatment on medium carbon steel.
- Student should engage in experimental activities to Aquent themselves with the welding and heat treatment programme.

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