DESIGN AND CONSTRUCTION OF AN ELECTRIC ARC WELDING MACHINE

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DECLARATION

I, Tionsha Godwin Aondongo, declare that this work was done by me and has never been presented elsewhere for the award of degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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External Examiner's Signature

DEDICATION

This project report is dedicated to my parents` Mr. and Mrs. Tionsha and to my siblings; Emmanuel, Elizabeth, Simon, Blessing and Mercy; I love you all. Above all I dedicate this project report to God Almighty with whom all things are possible.

ACKNOWLEDGMENT

This report shall be incomplete without the due recognition of my parents Mr. And Mrs. Tionsha for their financial and moral support throughout the duration of my educational pursuits. My supervisor Dr. J Tsado will never be forgotten for his selfless supervision, moral and technical advice throughout the course of implementing this project work. My project colleague and also a friend Saliu Mohammed aka Shaba is highly appreciated. I also wish to say thank you to my room mate and also a friend Michael Olah and to all those who contributed to the success of this project I say thank you.

ABSTRACT

The aim of this project is to design and construct an electric arc welding machine with an automatic over temperature shut down

This was achieved through the design and construction of a step down transformer with high current capacity at the output, which supplies the welding current. An automatic over temperature shut down was incorporated to protect the welding transformer from being damaged due to over heating; a lamp was included to aid welding in the dark.

The welding machine proved to be very effective in carrying out its function. The voltage and current produced was sufficient to join the metal works upon which test were carried out.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

An electric arc welding machine is simply an electrical device that is used to join two or more metals together. A welding machine in our contemporary day society is so important that it can not be over emphasized. This is owing to the fact that hardly any metal work can be carried out without the need arising of a welding machine. This can be seen in the fabrication and construction of metallic doors, windows, gates, tanks, bridges, kiosks, chairs, tables, bicycles, vehicles, engines etc.The process is most widely used for ferrous alloys in the structural steel work, ship building and general fabrication industries [12]. In fact the name "metal work" is synonymous to "welding machine". It is because of its great importance that has led to the design and construction of an electric arc welding machine in this project report.

The welding machine is basically a step down transformer with a very high current at its secondary which is capable of generating heat sufficient enough to melt an electrode used to join two or more metals together. The secondary winding is tapped strategically to obtain different voltage drops suitable for various welding applications. In this design, the welding machine features a lamp to aid welding in the dark. It has a push handle which makes it easy to carry about, it features an automatic high temperature shut down to protect the welding transformer from damage caused by over heating and oil as coolant for the welding transformer. The transformer iron core is sourced from flat steel sheets by cutting them into desired size with the help of shearing machine and hack saw.

The casing is also sourced in a similar way by cutting, bending, welding and filing the flat metal sheets. The transformer primary windings consist of standard wire gauge 14(SWG14) and the secondary consist of SWG 9.The transformer is immersed in transformer oil contained in the casing .An auxiliary casing is formed to house the rest of the machines control circuit to isolate them from the transformer oil. The control circuit consists of electronic components such as 240V/12V transformer, rectifier diode, 9 volts regulator, relay, capacitor, transistor, resistor, light emitting diode (LED), thermistor, resistor, lamp holder and bulb, on/off switch and jumper wires as connection links. All the above components are sourced from electrical, electronics and metal work shops.

All welding processes are categorized either as:

1. **Fusion Welding**: This involves melting of the parent metal. Examples are;

a) Carbon arc welding, metal arc welding, electron beam welding, electro slag welding and electro gas welding which utilize electric energy [1].

b) Gas welding and Thermit welding which utilize chemical energy for melting purpose.

2. **Non-fusion welding:** This does not involve melting of parent metal. Examples are; energy for melting purpose.

a) Forge welding and gas non-fusion welding which use chemical energy.

b) Explosive welding, friction welding and ultrasonic welding etc which use mechanical energy.

c) Resistance welding which uses electrical energy.

The selection of a welding process depends on the

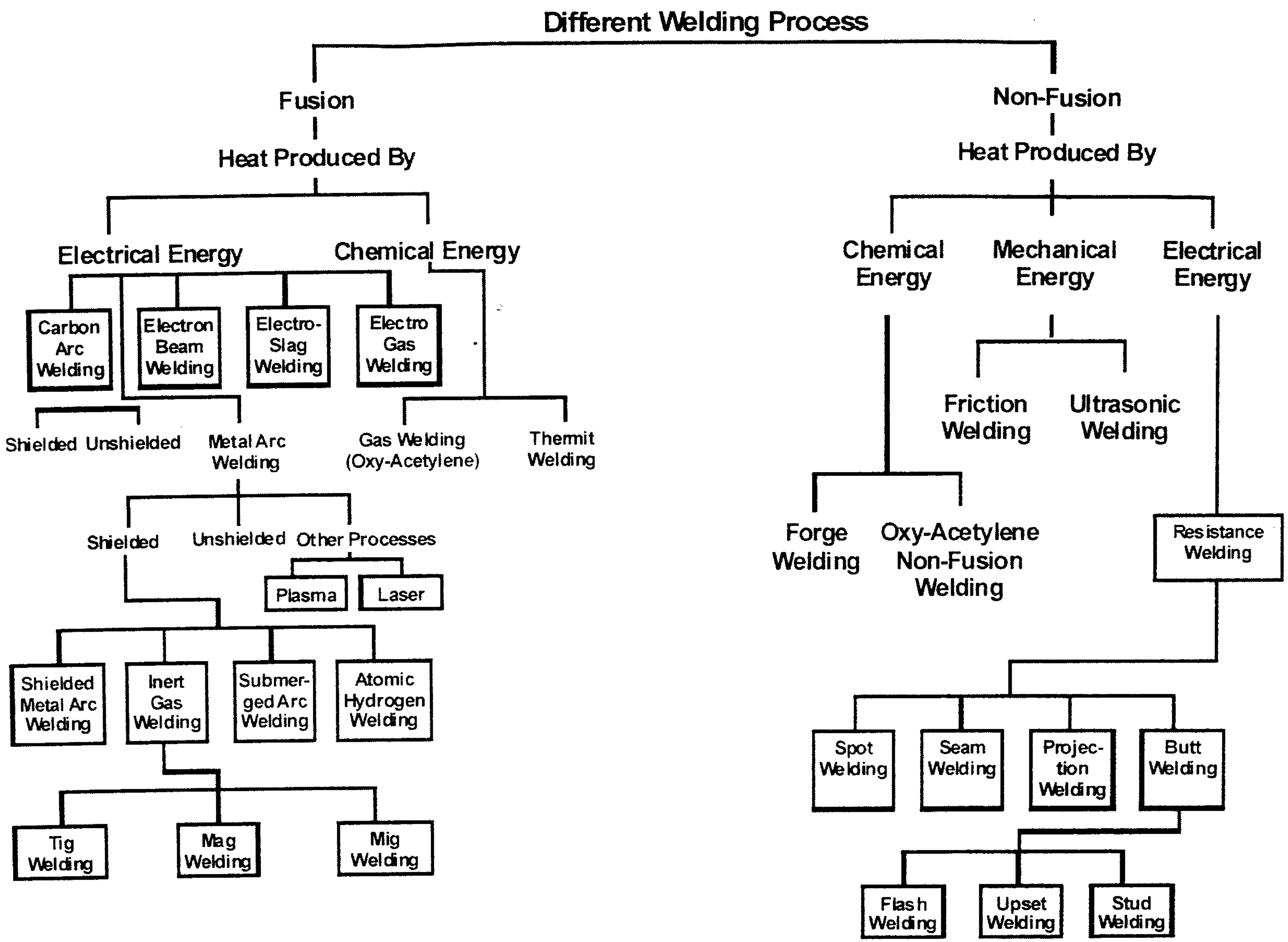
i. Kind of metals to be joined

ii. Cost involved

iii. Nature of products to be fabricated

iv. production techniques adopted [1]

Table1.1 Showing The Different Welding Techniques



1.1 Aims and Objectives

The main objective of this project is to design and construct an electric arc welding machine with an automatic over temperature protection.

1.2 Methodology

In any electric arc welding machine there is usually a welding transformer, welding electrode and a means of cooling. The most modern ones also feature control circuitry such as over temperature protection, welding current and voltage displays, over temperature shut down, an illumination lamp and mobility on wheels.

In this project the method of implementation was that of constructing a welding transformer and controlling its operations automatically with a control circuitry having over temperature shutdown. The transformer is immersed in oil for cooling. A lamp is connected to aid welding in the dark while the compartment housing the welding transformer and coolant is put on wheels for ease of transportation. The method of welding is that of positioning an electrode between one output of the welding transformer terminal (ground) placed on the work piece and the second terminal of the welding transformer for current to pass though the electrode, cause it to heat up, melt and deposit it on the work piece and allowing it to cool. This is done with absolute concentration and precautions with the eyes being shielded from the inevitable sparks with protective goggles.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Michael faraday an American scientist made a very important discovery that when the magnetic flux linking a circuit is changing an electromotive force (em.f.) is induced in the circuit [2].

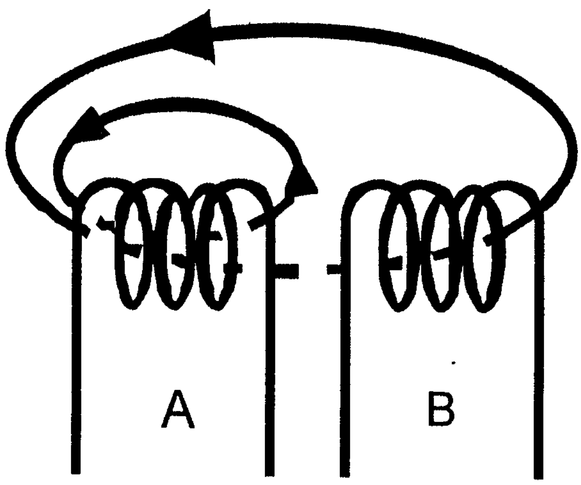


Fig 2.0.Mutual Flux

Referring to Fig 2.1 above, Coil A is carrying a current which sets up a magnetic field or flux around it. If coil B is moved away from or towards coil A so that the mutual flux through coil B changes then an em.f will be set up in coil B. The e.m.f. is detectable by connecting a voltmeter across the terminals of coil B. Alternatively, if the current through coil A is increasing or decreasing (alternating) so that the amount of flux linking coil B which is now stationary, then also an e.m.f will be observed during the instants when the flux is changing. The magnitude of the emf is found to be proportional to the number of turns on coil Band is taken as being proportional to the rate of change of flux through the coil [2].

An e.m.f is also induced in coil A when the current through it is changing; this is attributed to the changing self flux within coil A. It is found that the induced e.m.f is proportional to the product of the number of turns of the coil and the rate of change of flux .Mathematically this is expressed as:

$$e \propto N \times (\text{change in } \Phi) / (\text{change in } t) \quad (2.1)$$

Where e is the induced emf in volts

N is the number of turns of the coil

Φ is a Greek alphabet which represents magnetic flux in weber.

t is the time in seconds

Therefore,

$$e \alpha N \times (\partial\Phi/\partial t) \quad (2.2)$$

In calculus notation this becomes

$$e \alpha N (\partial\Phi/\partial t) \ \alpha \ \partial(\Phi N)/(\partial t) \quad (2.3)$$

Since N is constant, it means

$$e = K \times \partial (\Phi N)/(\partial t) , \quad (2.4)$$

Where, **K** is a constant of proportionality.

The product ΦN is referred to as the flux-linkages with the coil or circuit. The relationship between the induced e.m.f and the rate of change of flux linkages is often called faraday's second law of electrodynamics. A unit of flux, called the Weber (wb) is chosen so that the constant. K is unity, when e is in volts. Thus one Weber may be defined as the magnetic flux which when linking a single turn coil, induces in the coil an emf of one volt .When magnetic flux is reduced uniformly to zero in one second. The equation for induced emf then becomes;

$e = N \times (\partial\Phi) / (\partial t)$ **volts** ....**(2.6)**

Or

$e = N\times (\partial\Phi/\partial t)$ **volts**...**(2.7)**

Or

$e = \partial(\Phi N)/\partial t$ **volts**...**(2.8)**

From this $\partial\Phi = (e \times\partial t) /N$.....................................**(2.9)**

So that an alternative unit for magnetic flux is the volt – second

2.1 Principle of Operation of Transformers.

In a transformer coil A and B discussed above can be likened to the primary and secondary winding respectively both wound on laminated iron core that conducts the flux better than air .If two coils are wound on a common iron core as in fig below and one of them, the primary is supplied with an alternating current, then an alternating flux will link both coils and will induce emfs in both of them .The second coil is called the secondary. The transformer is a form of mutual inductance. The iron core greatly increases the flux produced by a given magnetizing current and increases proportion of main flux to leakage flux.

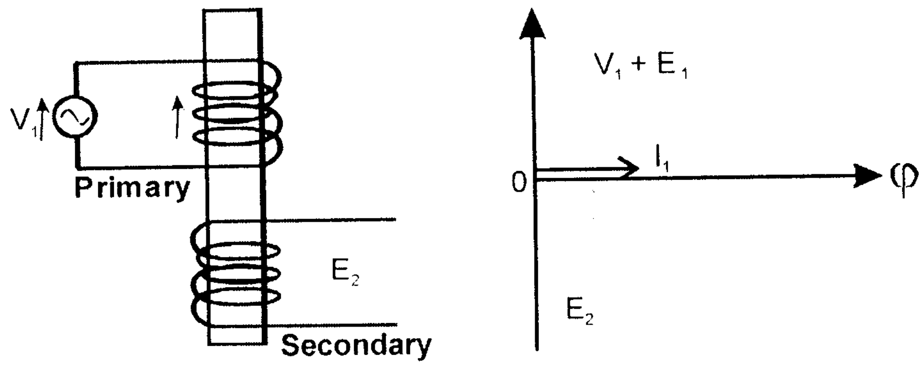


FIG. 2.1: Transformer on No Load

Consider a perfect transformer which has no losses .if the primary voltage is sinusoidal, the flux produced will also be sinusoidal, and the flux produced will also be sinusoidal. Let the flux be

$\Phi = \Phi m Sinwt$ Wb...(2.10)

Where **Φm** is the peak flux .If the primary coil has N1 turns then the emf induced in the primary $e_1 = \partial(\Phi N1)/\partial t$ ....**(2.11)**

2.2 Historical Background

After much experimentation by others in the early 1800's an English man named Wilde obtained the first electric welding patent in 1865. The successfully joined two small pieces of iron by passing an electric current through both pieces producing a fusion weld. Approximately twenty years later, Bernado, a Russian, was granted a patent for an electric arc welding process in which he maintained an arc between a carbon electrode and the pieces to be joined. Fusing the metals together as the arc was manually passed over joint to be welded [14].

During the 1990's, arc welding was accomplished with bare metal electrodes that were consumed in the Molten Puddle and became part of the weld metal. The *welds* were of poor quality due to the nitrogen and oxygen in the atmosphere forming harmful oxides and nitrides in the weld metal. Early in the twentieth century, the importance of shielding the arc from the atmosphere was realized. Covering the electrode with a material that decomposed in the heat of the arc to form gaseous shield appeared to be the best method to accomplish this end. As a result, various methods of covering electrodes such as wrapping and dipping were tried. These efforts culminated in the extruded coated electrode in the mid 1920's greatly improving the quantity of the weld metal and providing what many consider the most significant advance in electric arc welding.

Today shielded metal arc welding also known as electric arc welding, manual metal arc welding or stick welding, is the most widely used of the various welding processes. Welding is performed with the heat of an electric arc that is maintained between the end of a coated metal electrode and the work piece. The heat produced by the arc melts the base metal, the electrode core rod, and the coating. As the molten metal droplets are transferred across the arc and into the molten weld peddlers the arc is shielded from the atmosphere by the gases produced from the decomposition of the flux coating. The molten slag floats to the top of the weld puddle where it protects the weld metal from the atmosphere during solidification [14].

2.3 Definitions and Theory of Operation of Components Used.

Apart from just the welding transformer modern welding machines make use of other electronic component devices such as;

(1) **Resistors**:

Resistors are electronic components that offer opposition to flow of current in an electronic circuit they are usually used as current limiters or voltage dividers. The standard unit value of a resistor is ohm. [3] .A resistor could either be of a fixed resistance type or variable resistance type. The thermistor is a variable resistor whose change in resistance is proportional to its temperature.

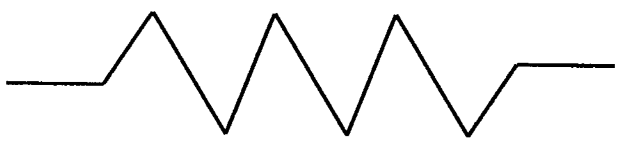


Fig 2.2 circuit symbol of a resistor

(2) **Capacitors**:

A capacitor is an electronic component that is capable of storing charges. Capacitors serve many purposes, including removing traces of alternating current ripple in a power supply , delaying the action of some portion of the circuit or removing harmful glitches

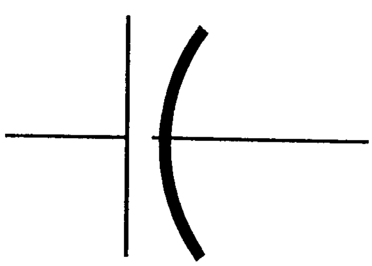


Fig 2.3 circuit symbol of a capacitor

(3) **Diodes:**

Diodes are electronic components that allow current to flow only in one direction they are used to convert alternating current to direct current. They can be connected to form full wave or half wave rectifier. The major advantage of the full wave rectifier used in this project design over the half wave rectifier is that it has higher rectification efficiency and it produces a more constant rectified output [6]

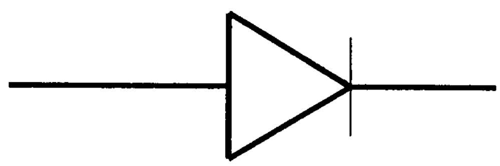


Fig 2.4 Circuit symbol of a diode

(4) **Transistor:**

Transistors are electronic components whose major function is either to amplifier or to switch a signal on and off. the fixed bias configuration which is the simplest form of transistor [7] is used in this project design to function as a switch.

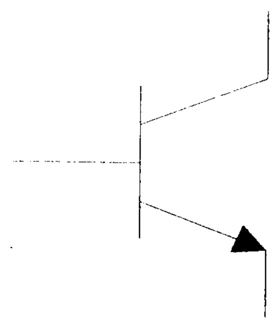


Fig 2.5 Circuit symbol of a transistor

(5) **Operational Amplifier:**

The integrated circuit forms the back bone of the electronic revolution. They comprise many transistor, diodes resistors and even capacitors. As its name implies, the integrated circuit or IC is a discrete and a wholly functioning circuit in its own right [3]. In this project design the LM 741 operation amplifier (OP AMP) which is an integrated circuit is implemented as a comparator. The op-amp goes into positive or negative saturation according to the difference of the input voltage. Below is the circuit symbol of an operational amplifier [5].

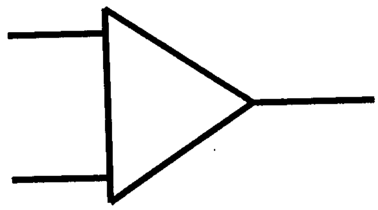


Fig 2.6 Circuit symbol of an operational amplifier

(6) **Relay:**

A relay is an electromagnetic switch whose contacts are closed or opened by the passage of current through its coil the major function of a relay is to function as a switch.

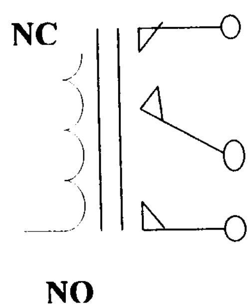


Fig 2.7 Circuit symbol of a relay

(7) **Transformer**:

A transformer is a device that transfers electrical energy from one circuit to another through a shared magnetic field. A changing current in the first circuit (the primary) creates a changing magnetic field; in turn, this magnetic field induces a changing voltage in the second circuit (the secondary). By adding a load to the secondary circuit, one can make current flow in the transformer, thus transferring energy from one circuit to the other.

The secondary induced voltage V_S is scaled from the primary V_P by a factor ideally equal to the ratio of the number of turns of wire in their respective windings:

Transformer could either be a step-up or step- down transformer a step down transformer has greater number of turns in the primary than the secondary while reverse is the case for step up transformer the type of the transformer implemented in this project design is step down transformer as the welding transformer while the a step up transformer is implemented in power supply to the control unit below is the circuit symbol for a transformer

The transformer operation is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism) and, second, that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). By changing the current in the primary coil, one changes the strength of its magnetic field; since the secondary coil is wrapped around the same magnetic field, a voltage is induced across the secondary.[15].

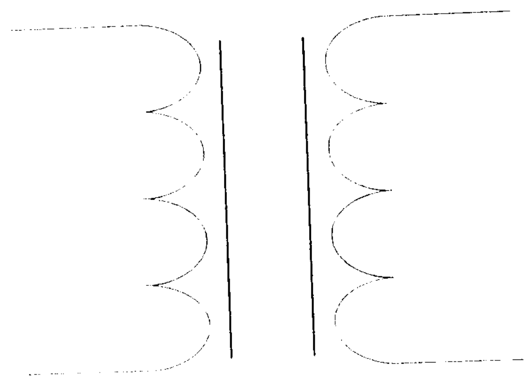


Fig 2.8 Circuit symbol of a Transformer

(8) Electrode for Metal Arc Welding

An electrode is a filler metal in the form of a wire or rod which is either bare or coated uniformly with flux the contact end of an electrode is left bare and clean to a length of 20-30mm for inserting it into electrode holder

Metal arc welding was originally done with bare electrode which consisted of a piece of wire or rod of the same metal as the base metal. However, due to atmospheric contamination, they produce brittle and poor quality welds.

Hence bare wire is no longer used except for automatic welding in which case arrangement is made to protect the weld area from the atmosphere by either powdered flux or an inert gas; coated electrodes are being used for shielded arc welding machine. They consist of a metal core wire surrounded by thick flux coating applied extrusion, winding or other processes. Depending on the thickness of the flux coating, coated electrode may be classified into:

1. Lightly dusted electrode(or dipped)
2. Semi coated(or heavily coated) electrodes[1]

Advantages of Coated Electrodes

The principal advantages of using electrode coating are as follows:

1. It stabilizes the arc because it contains ionizing agents such as compounds of sodium and potassium
2. It fluxes away impurities present on the surface being welded
3. It forms slag over the weld which (i) protects it from atmospheric contamination (ii) makes it cool uniformly thereby reducing the changes of brittleness and (iii) provides a smoother surface by reducing 'ripple' caused by the welding operation.
4. It adds certain materials to the weld metal to compensate for the loss of any volatile alloying elements or constituents lost by oxidation.
5. It speeds up the welding operation by increasing the rate of melting.
6. It prevents the sputtering of metal during welding.
7. It makes it possible for the electrode to be used on arc. supply. In arc. welding, arc tends to cool and interrupt at zero-current positions. But the shielding gases produced by the flux keep the arc space ionized thus enabling the coated electrodes to be used on arc. Supply.

It is worth noting that efficiency of all coated (or covered) electrodes is impaired by dampness. Hence, they must always be stored in a dry space. It dampness is suspected, the electrodes should be dried in a warm cabinet for a few hours [1].

2.3 Duty Cycle:

All welding machines are rated according to their duty cycle. Duty cycle is based upon a ten minute time period. At rated voltage, a power supply with a 100%duty cycle rating can operate continuously at or below its rated current. A 60% duty cycle does not mean that it can operate 60% of an indeterminate time at rated current and voltage .it means that the welder should operate only 6 out of every 10 minutes at that current and voltage. It should be allowed to idle 4 out of every 10 minutes for cooling. Machines rated for less than 100% duty cycle can be used continuously by decreasing their current rating. The machine with 100%duty cycle has bigger copper conductor and better coolant. [16]

Calculating duty cycle of a power source can be estimated by the following formula

$$\text{Percent duty cycle} = \frac{(\text{rated current})^2}{(\text{Load current})^2} \times \text{rated duty cycle} \quad \text{....................................(2.12)}$$

CHAPTER THREE

CIRCUIT DESIGN AND IMPLEMENTATION

3.0 Circuit Design

This chapter contains the steps taken in the design. The mode of operation of each module (unit) of the design is carefully explained with the reason for the use of each component stated.

3.1 Control Unit

The electronic control unit circuitry is basically an electronic thermostat to sense the operating temperature and automatically disconnect the welding transformer should its temperature exceeds a safe limit. This would prevent damage to the transformer due to overheating as a result of short circuit or exceeding of its duty cycle. In this way, the life span of the welding device is increased .transformer T2 is a step-down transformer rated 240/12V. The stepped down voltage is rectified by the full wave bridge rectifier D1, D2, D3, and D4. The rectified voltage is smoothened by an electrolytic capacitor C1 and fed to the input of a 12volts positive regulator IC1: the output of this regulator is a 12volt regulated voltage which powers the rest of the control circuitry. The temperature monitoring action is achieved with an operational amplifier (op amp) IC2, a thermal resistor TH1, a variable resistor VR1 and resistors R3, R4 and R5. The voltage at the non-inverting terminal (+) is made constant at about 415 volts by help of the voltage divider action of R4 and R5 while the voltage at the inverting terminal (-) is made variable depending on the voltage divider action of TH1, VR1 and R3 the output of the op amp would go high if the voltage at the non-inverting terminal is higher than that of the inverting terminal. The output would go low if the voltage at the inverting terminal is higher if the voltage at the inverting terminal is higher VR1 is adjusted such that under normal temperature conditions less than 80 ^{0}C chosen for this design , the voltage at pin 2 is higher than that at pin 3 keeping the output of the op amp low under this condition transistor TR1 is cutoff and no collector current flow and so relay RY1 is not activated power supply from the AC mains is passed across the closed contacts of RY1 to the welding transformer if S1 is closed under this condition LED2 is of indicating normal operating condition. If the temperature of the welding device should exceed 80 ^{0}C the output of the op amp goes high and TR1 is turned on, this energized RY1 and LED2 glows indicating abnormal operation and the power supply to the welding transformer is cutoff . L1 is the welding lamp and is controlled by switch S2 LED1 is a power indicator that comes on if S1 is closed R1 is current limiting resistor to LED1

3.1.1 The DC Power Supply Unit

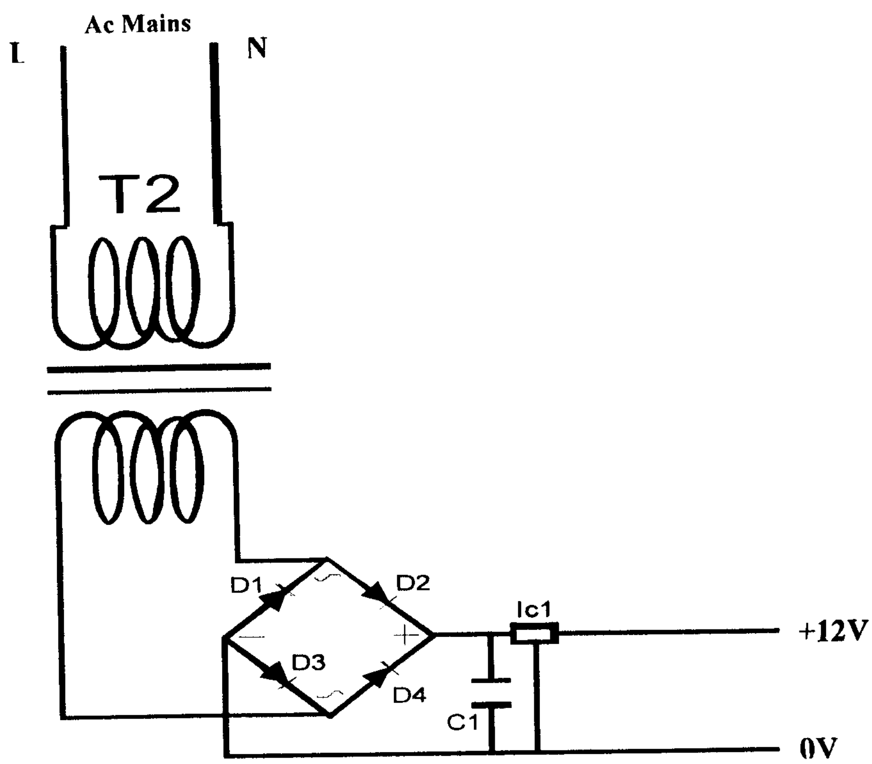


Fig 3.1 circuit diagram of dc power supply unit

It is desired to operate the control circuitry on a 12 volts DC regulated power supply. Regulation is to be achieved with a 12volt positive regulator IC LM7812.For normal functioning of this IC it is required that the input voltage must be about three volts greater than its voltage rating. A step down transformer of 240/12 volts was chosen.

Peak output secondary voltage of the transformer V_P is given by $\sqrt{2}$ X root mean square secondary voltage (V_{RMS})

$V_P = \sqrt{2} X12 = 16.97V \approx 17$ volts...3.1

V_P = is the input to the bridge rectifier of D1, D2, D3 and D4 for safe operation the peak inverse voltage (PIV) rating of these diodes must be greater than V_P. 1N4001 with PIV rating of 50 volts was chosen. The output voltage of the rectifier V_{DC} is given by

$V_{DC} = V_P - V_{DROP}$...3.2

Where V_{DROP} the is the voltage drop across the bridge rectifier diodes for a full wave rectifier voltage drop is about two diode which is about 1.2 volts of silicon diodes having a 0.6 voltage drop each.

$V_{DC} = 17 - 1.2 = 15.8$ volts...**3.3**

V_{DC} is the input voltage to the 12 volt positive regulator. The ripple component of this voltage are filtered by an electrolytic capacitor C1 the value of the filter capacitor is given by

$C = \frac{I}{VF}$...3.4

Where C= capacitance of the capacitor.

I= the maximum current through the filter capacitor.

V= the allowable peak to peak voltage

F= frequency of the ripple voltage.

Here the maximum load current rating is limited to 0.5A

For a full wave rectifier the ripple frequency is twice the line voltage frequency, 50 Hz in this case hence F_R=2X50 = 100 Hz...3.5

For ripple voltage of 1.5volts peak value or 3 volts peak to peak.

$$C = \frac{0.5}{3X100} = 1.66X10^{-3}F = 1.667X10^{-6}\ F = 1667\mu F \qquad ...3.6$$

For the ripple voltage to be limited to 3 volts peak to peak the maximum capacitance required is 1667μf

The voltage rating of the capacitor for safe operation must exceed **V_{DC}** a standard capacitor of 25 volts 2200 μF was chosen to achieve filtering

3.1.2 Thermal Sensing and Actuating Unit

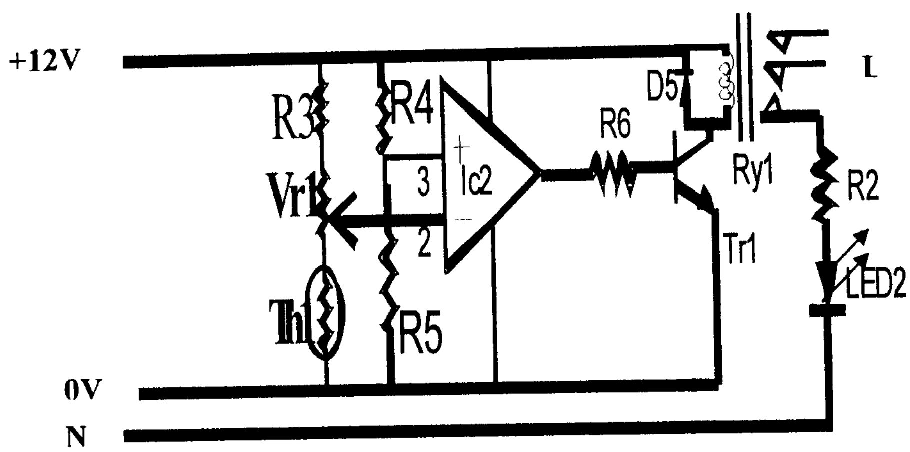


Fig 3.2 circuit diagram of thermal sensing and actuating unit

The heart of this circuit is the LM741 operational amplifier operating as comparator. The following specifications are given for the LM741 OP AMP below.

Voltage supply V_S= 4.5V to 18VMAX

Maximum output current I_{CMAX} =250mA.

Maximum power dissipation P_{DMAX}= 500mW

The pin out diagram is shown below

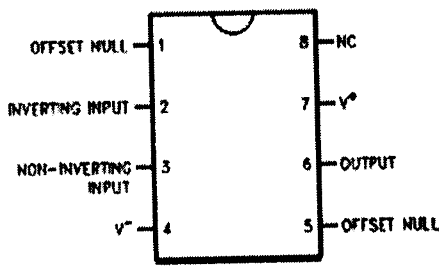


Figure 3.3 Pin out of the Lm741 op amp

This IC is connected in the open loop mode and so has infinite gain. A small voltage applied to its differential inputs pin 3 and pin2 would be amplified infinite times but of course the output voltage is limited to supply voltage value of 12volts The output of the OP AMP is high if the voltage at the non inverting terminal is higher than that at the inverting terminal and is low if the voltage at the inverting terminal is higher.R4 and R5 are chosen of the same value of 10kΩ so that by voltage divider action the voltage at pin 3 is 6 volts.

R3 is chosen at 1kΩ to limit the current through VR1 to a safe value.VR1 is chosen at 22 kΩ to form a variable voltage divider so that an appropriate temperature

Voltage equivalent can be set. TH1 is thermistor of about 300Ω when the temperature of the welding transformer exceeds the value set by VR1.

As the temperature of the welding transformer rises, the resistance of the thermistor TH1 decreases, when the temperature rises to the limit set byVR1, the voltage at pin2 falls below 6volts and this causes the output at pin3 to go high. Under normal temperature condition the output of the OP AMP is low. A low from the output reverse biases transistor TR1 and so it remains cut of. The normally closed contacts of RY1 supplies current to the welding transformer and welding operation can be carried out. As the temperature rises above the safe limit set by VR1 the voltage at pin 2 falls below 6volts, the voltage at pin 3. This is because the resistance of the thermistor forming part of the voltage divider network at pin 2 falls and consequently the voltage drop across it also falls. The output at pin 3 goes high and TR1 turns on, collector current flows through the relay coils and the relay contacts are activated. The normally closed contact is opened and power supply to the welding transformer is cut off until the temperature falls back within a safe range. For TR1 to operate properly as a switch it must be driven into saturation.

Saturation collector current $I_{CSAT} = \frac{V_{CC}}{R_C}$ 3.7

Where Vcc is the supply voltage and RC is the collector resistance.

In this case RC is the relay coil resistance of RY1 which is about 400Ω..

I_{CSAT} = 12/400 =0.03A..3.8

The saturation base current I_{BSAT} is given by

$I_{BSAT} = ICSAT / \beta$ 3.9

Where; β is the current gain of the transistor.

For $\beta = 200$

$I_{BSAT} = \frac{0.03}{200} = 1.5 \times 10^{-4}$ A 3.10

The required base biased resistance for saturation to occur $R_{BSAT} = \frac{V_{CC} - V_{BE}}{I_{BSAT}}$ 3.11

Where V_{BE} is the voltage drop across the base emitter junction of the transistor. For an NPN silicon transistor $V_{BE} = 0.6V$

$R_{BSAT} = \frac{12-0.6}{1.5 \times 10^{-4} A} = 76000\Omega = 76k\Omega$ 3.12

But 76kΩ is not a standard value, the nearest available standard is 68kΩ which is the value used.

D5 is a free wheeling diode; its function is to protect TR1 from damage due to back EMF produced from the relay coil. The value is IN4001.

The data sheet specification for TR1 is given below.

Part Number PN 2222

Type: NPN Silicon

$V_{CEO} = 40V$

$I_{CMAX} = 0.6V$

$P_{DMAX} = 0.5$ watts

$\beta = 200$ typical

$F_T = 200$ MHz

Where,

V_{CEO} is the maximum collector emitter voltage with base open.

I_{CMAX} is the maximum collector current.

P_{DMAX} is the Maximum power dissipation of the transistor.

β is the current gain of the transistor

F_T is the transition frequency.

3.2 Design of Welding Transformer

1. Size of unit iron core = 7 by 2 inches and 5 by 1.5 inches was chosen

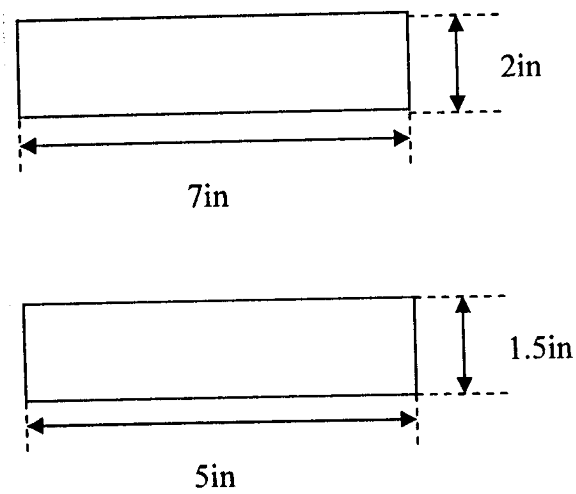


Fig 3.2: Dimension of unit iron core

2. Gauge of iron core = gauge 22(about 1mm thick) was chosen
3. KVA rating of machine = 6 KVA
4. Supply voltage =240 Vac
5. Frequency of supply voltage = 50HZ
6. Primary winding gauge = SWG 14
7. Secondary winding gauge = SWG 9
8. For 6 KVA at Vp =240V then Ip = 6000/ 240

   Where, Vp= primary voltage,

I_p= primary current

Impedance of primary winding **Zp = Vp/Ip** =240/25 = 9.6Ω............3.13

9. Perimeter of former =30cm = 0.3m

i.e. 5cm by 10cm and about 7cm high

10. For 300 turns in primary; length of coil ≈ 300 ×0.3 =90m

11. Resistance/meter of primary coil ≈ 0.05Ω

For 90m, resistance =90 × 0.05 =4.5Ω

12. Inductance of single turn = 0.00009H = 90μH

13. Inductance of 300 turns = $90\times10^{-6}\times300$ =0.02H

14 Impedance of coil in ohms Ω Z_c=2ΠfL

Where **f** = frequency of supply

L = Inductance of coil in Henry H

Z = 2Π×50×0.027

= 8.482 Ω

15 Resultant impedance of primary winding

$Zp=\sqrt{R^2+L^2}$..3.14

$Zp=\sqrt{(4.5^2+8.5^2)}$..3.15

$Zp=\sqrt{(20.25+72.25)}$..3.16

$Zp=\sqrt{(92.5)}$...3.17

Zp=9.62≈9.6 Ω..3.18

16 The number of turns of coil in secondary winding.

By transformer action,

$E_1= 4.44N_1f\varphi$..3.20

$E_2=4.44N_2f\varphi$ 3.21

Where, E_1= voltage induced in primary winding

E_2= voltage induced in secondary winding

N_1= no of turns in primary winding

N_2= no of turns in secondary winding

But $4.44f\varphi$= constant.

Dividing through 3.2.1 by equation 3.2.0

$(E_1/E_2)= (N2/N_1) = K$ 3.22

The required secondary voltage = 100V and 80V

For E_2=100 V, E_1=240V

N_1= 300T

N_2=?

From (3)

$N_2= (N_1E_2)/ E_1$ 3.23

$N_2= (300\times100)/125$ 3.24

=125turns

For E_2=80V, E_1=240V

N_1= 300T

$N_2= (N_1E_2)/ E_1$ 3.25

$N_2= (300\times80)/240=100$turns 3.26

18. Secondary current

From transformer action,

$(I_1/I_2) = (N_1/N_2)=K$ 3.27

But,

$K = (N2/N_1)=100/300=0.333$ 3.28

I_1=25A= primary current

$I_1/I_2=0.333$ 3.29

$I_2= I_1/0.333=25/0.333=75.75A \approx 76A$ 3.30

3.3 Implementation

The implementation of the electrical arc welding machine was carried out as follows:

- 22 gauge steel sheet was cut into many sizes about 100 measuring 7 x 2 inches and 5 x 2 inches each.
- The iron sheets where arranged to form the step down transformer core with two limbs.
- A ceiling board was cut to form four rectangular formers measuring about 4 by 2.2 inches each.
- The primary and secondary coils were then worn on the formes, each making use of two formers.
- The windings made on the former were then inserted into the limbs of the transformer with primary and secondary windings interleaved.
- The primary windings on each limb were connected while the secondary windings were also connected.
- Varnish was dripped on the windings and iron core to improve the insulations.
- The casing was cut from a steel sheet of gauge 18 with the following dimensions 30cm x 30 x 30cm and an attached compartment measuring 30cm x 6cm x 7cm to house the control unit.

- The casing was welded with care to make sure it had no leakages.
- The transformer oil coolant was poured inside the casing.
- The transformer was now lowered into the casing then sealed.
- The casing was then painted and finishing touches were done on the construction work.

The control unit circuit components were connected on a bread board and tested to b okay before they were transferred and soldered permanently on a bread board.

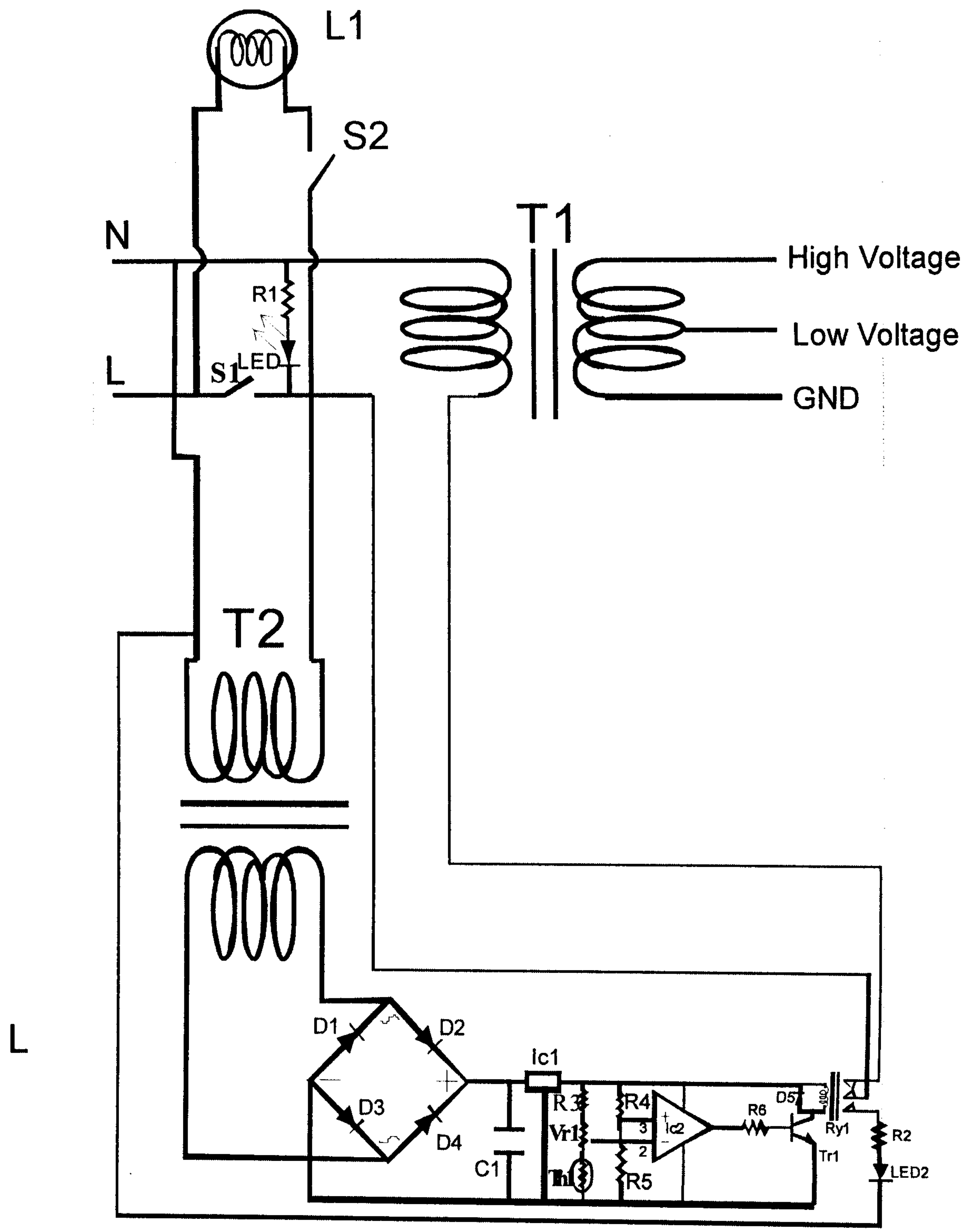


Fig. 3.3: Complete Circuit Diagram of Electric Arc Welding Machine

CHAPTER FOUR

TEST, RESULT AND DISCUSSION

4.0 Test:

After the welding transformer was completed, test for continuity of the transformer winding were carried out with the help of a digital multimeter dialed to the ohm meter range. It was then connected to the a.c. mains using thick copper wires and the output of the secondary windings were connected to thick copper wires one of the copper wires was attached to a metallic work piece position close another while the other was attached to an electrode through an electrode holder. An electric arc was strike and the electrode began to melt across the work piece, a molten pool was formed which then solidified into a hardened weld joint.

4.1 Results:

Table 4.1 Results Obtained

Quantity	Calculated Result	Result Obtained
1. High voltage welding output	100V	80V
2. Low voltage welding output	80V	50V
3. Automatic temperature shut down	To shut down at 80°C	Shut down was achieved
4. Duty cycle		50 %

4.2 Discussion of Results

The maximum welding output voltage calculated for was 100V when the supply voltage from the mains is 240V. In practice, what was measured was about 80Volts. This could be as a result of losses from the transformer, which caused the voltage to drop. This however, did not limit the performance of the machine. Even with this voltage level welding operations could be successfully carried out. 100V was simply chosen considering the fact that low voltage supply from the public supply mains is a common problem facing our country.

Hardly does the mains supply voltage approach 240volts. The output voltage was deliberately made high so that even in the event of low voltage from the mains welding could still be achieved.

Similarly, the low voltage output was calculated for 80volts but 50volts was obtained which is still okay for welding of light metals.

The automatic over temperature shut down responded as designed and also the duty cycle was found to be 50%.This means that the welding machine can only be operated continuously for 5 minutes in every 10 minutes.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Conclusions

In summary it can be concluded that the design and construction of an electric arc welding machine was successful. The automatic over temperature shut down operation was successfully implemented although the output voltage measured form the welding machine was lesser than that calculated in the design, this must be as a result of transformer losses and low voltage input from the public supply.

5.1 Problems Encountered.

1. Sourcing for the exact size of wire gauge chosen in the design was a problem; smaller size wire gauge had to be combined to obtain the desired size.

2. The inadequate supply of electricity from the public power supply was a major challenge. This caused delay in completion of the project work.

5.2 Recommendations

1. The welding machine can be improved upon to feature display for welding voltage and current.
2. Very useful projects carried out by students should be mass produced and sold to members of the public in other to solve societal problems and to generate revenue for the department
3. Good ideas and concepts conceived by the student in the course of their project work should be followed up by the department even if the student fails to

actualize them in the course of the project. This can be done by funding researches which may eventually lead to the actualization of these ideas.

4. Most importantly in a Federal University of Technology such as FUT Minna. Practical and research work should be taught on a fifty- fifty bases with the theoretical work. So that competent engineers can be produced for the technological advancement of our country Nigeria.

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