DESIGN AND CONSTRUCTION OF AN ALTERNATING CURRENT SINGLE PHASE, 5KVA ELECTRIC ARC WELDING MACHINE

BY

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DEDICATION

This project is dedicated to the memory of Late Mr. Yakubu Mohammed may his soul rest in peace (Amen), also to my relatives and people outside there, for their moral and spiritual assistance throughout my course of studies.

CERTIFICATION

This is to certify that this project work was carried out by Abubakar Murtala Muhammed in the department of Electrical and Electtronic Computer Engineering under School of Engineering and Engineering Technology (SEET), Federal University of Technology, Minna.

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Firstly, I give glory to almighty for Allah for his infinite love and mercies over me and making this project a reality. Also members of my family, loved ones and everyone.

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ABSTRACT

This paper presents the design and construction of 5KVA electric arc welding machine using locally available tools and materials. The A/C electrical welding machine which has a step down transformer on testing shows efficiency of 95 % voltage regulation of 86% and power factor of 0.795. The cost of this locally fabricated welding machine would cost Only N30,000 as compared with approximate N50,000 which is the current of the imported welding machine of similar capacity

DEVELOPMENT OF ELECTRIC ARC - WELDING

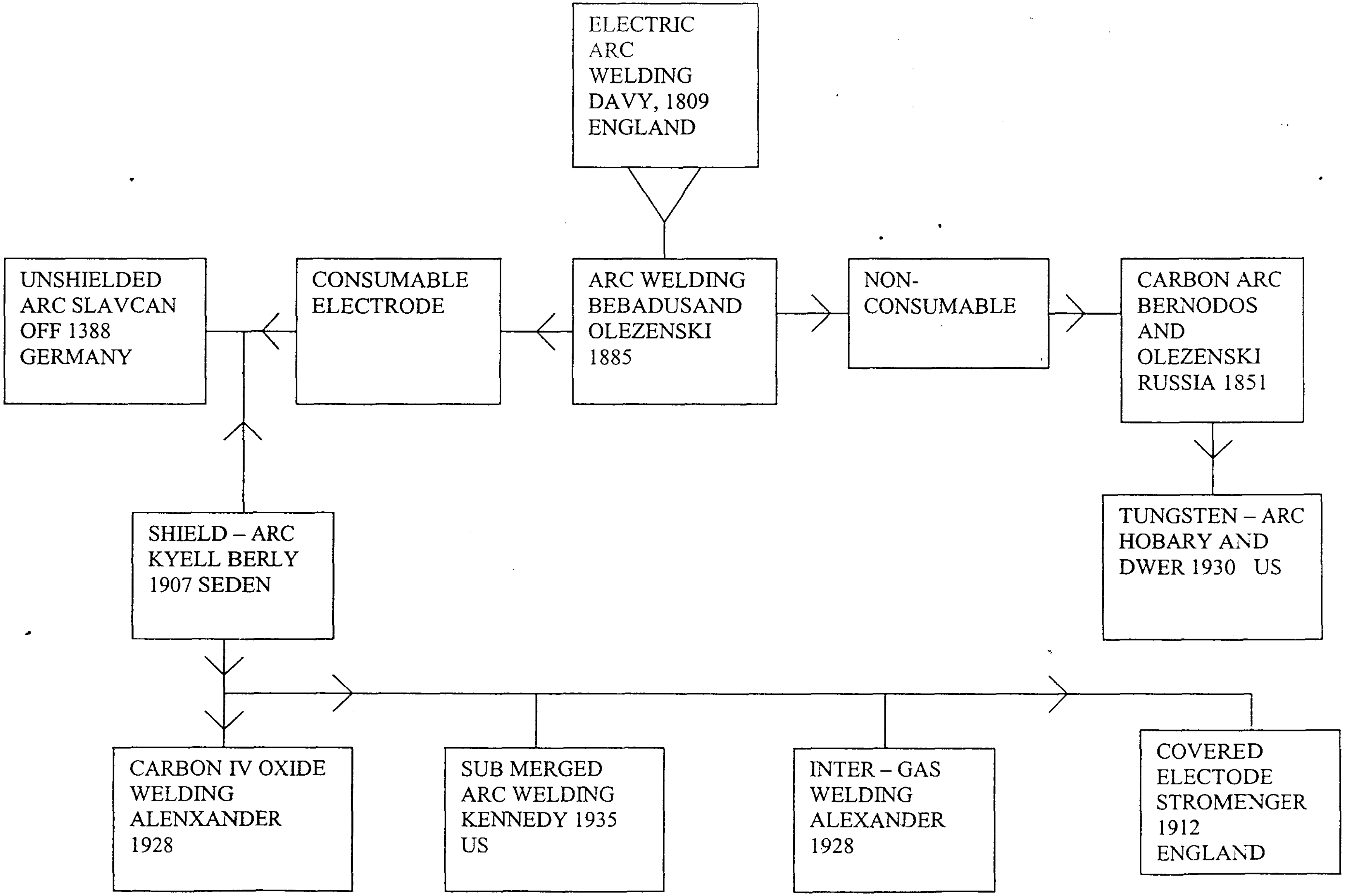


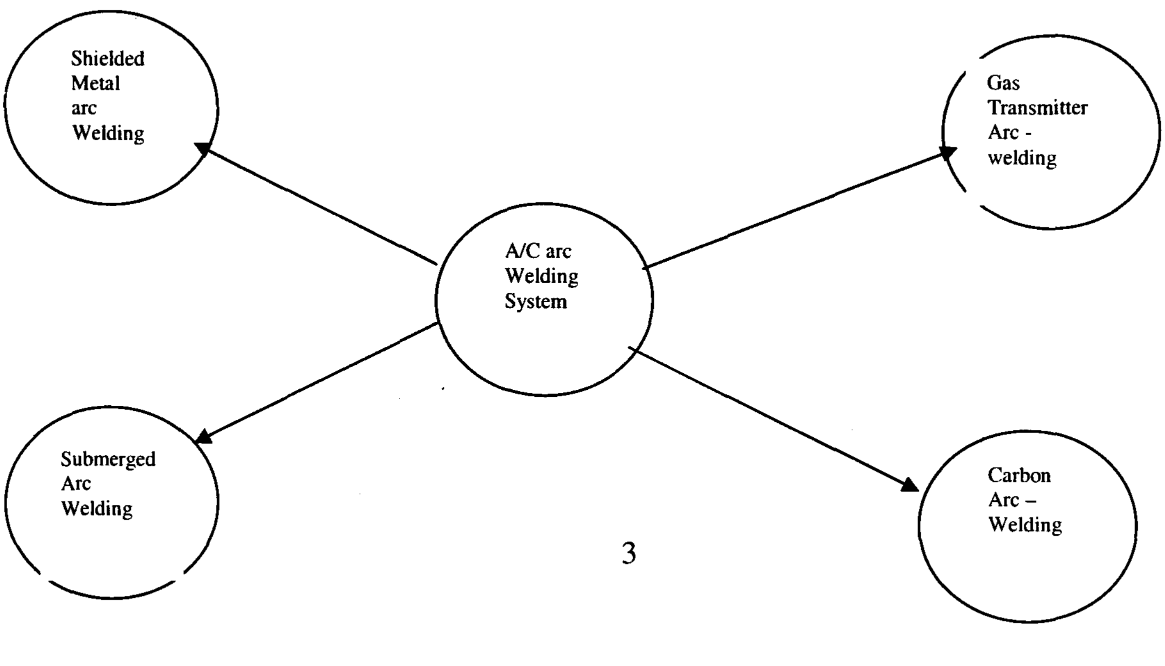
FIG 1. Diagram Representation of the historical Development of Electric Arc Welding Processes

CHAPTER ONE

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 is so important that it cannot be ever emphasized. This is owing to the fact that hardly our metal work can be carried our without the need arising of a welding machine. The process is most widely used for furious metals in the building construction, automobile and other product industries as raw materials or machine parts cutlery, ornamental gates doorknocker and other domestic [product are made of furious metal. The beauty of this ferrous metal product lies on the fabrication and getting a good weld. Obtaining a good weld from the melting and tubion is achieved by using A/C electric are welding machine. Electric arc which is found not useful in the case of circuit breaker are found wide useful in the welding industries. The heat generated, which is up to $6,000^0$c, has the tendency of welding any metals.

The electric arc 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. This machine has a voltage range that fall between 80 – 90v and a current up to 1000 amp. Welding in this case started momentarily to touching the positive electrodes (anode) to the negative (plate) and the withdrawing. It to about 3 – 6mm from the plate. When the electrode first touched the plate, a large short circuit current flows and as it is later withdraw from the plate, current continues to flow in the form of a spark across the gap so formed. As a result of this spark, the air in the gap become ionized and glows across the gap in form of an arc. The arc is composed of high temperature gases approximately 6,000^{0}c mainly obtained from flux coating. The force of the arc help the melted droplets of metal into the pool where they sodify and protect covering of silage. Welding is done with the use of welding machine, as it is never done directly from the supply [1] Arc welding could either be a d/c type or a/c type. In d/c type of welding set, we have three types such as constant current welding generator, constant voltage welding generator and combination of generator that permits the selection of either constant voltage or constant current. However, in this project work, a single-phase a/c arc – welding machine shall be considered. The welding machine used a step down transformer to reduce the voltage with increase in amperage. The arc welding machine is going to be oil cooled and three – way switch for current selection. This machine is going to be free from the effect of magnetic blow, which is very common to that of d/c welding set. An a/c arc welding machine is cheaper in terms of cost and more economical to run, during operation, the machine is practically silent an maintenance cost is negligible. Hence, the operation efficiency is very high. Some situation were a/c arc welding are of great important is shown in the diagram below.



1.2 TYPES OF ELECTRIC ARC WELDING

The arc – welding group includes eight process, each separate and different from the others but in many respects similar.

i. Carbon arc welding (CAW)

The carbon arc welding process is the oldest arc welding process and is considered to be the beginning of arc welding. The welding society defines carbon arc welding as an arc welding process, which produces coalescence of metal by heating them with an arc between a carbon electrode and the work – piece, no shielding is used pressure and filter metal may or may not be used it has limited application today, but a variation or twin carbon arc welding is more popular, another variable uses compressed air cutting.

ii. Shielded metal arc welding (SMAW)

The development of the metal arc welding process soon followed the carbon arc developed into the currently popular shielded metal arc welding (SMAN) process defines an arc welding process which produces coalescence of metal by heating them with an arc between a covered metal electrode and the work piece shielding obtained from decomposition of the electrode, covering pressure is not used and filter is obtained from the electrode.

iii. Submerged arc welding (SAW)

Automatic welding utilizing bare electrode wire was used in the 1920's, but it was the submerged arc welding (SAW) process that made automatic welding popular submerged arc welding is defined as an welding process which produces coalescence of metals by heating them with an arc or arcs between a bare metal electrodes and the work

– piece. Pressure is not and filter metal is obtained from the electrode and sometimes from a supplementary welding it is normally limited to the flat or horizontal position.

iv. Gas tungsten arc welding (GTAW)

The need to weld non-ferrous metals, particularly magnesium and aluminium challenges the industry. A solution was found called gas tingstem are welding (GTAW) also know tungsten inert gas (TIG) welding and was defined as an arc welding which produces coalescence of metals by heating them with an arc between a (non – consumable) electrode and the work – piece shielding is obtained gas or gas mixture.

v. Plasma arc welding (PAW)

Plasma arc welding (PAW) is defined as " an arc welding process which produces a coalescence of metal by heating them with a constructed arc between an electrode and the work piece (transferred arc) or the electrode and the constricting nozzle orifice which may be supplemented by an auxiliary source of shielding gas " shielding may be an inert gas or a mixture of gases. Plasma welding has been used for joining some of the thinner materials.

vi. Metal arc welding (MAW)

Another welding process also related to gas tungsten arc welding is known as metal arc welding (GMAN). It was developed in the late 1940's for welding aluminum and has become extremely popular. It is define as an arc welding processes which produces coalescence of metals by heating them with an arc between a continuous filter metal (consumable) electrode and the work piece. Shielding is obtaining entirely from an externally supplied gas or gas mixture" the electrode were for GMAW is continuous fed into the arc and deposited as weld metal. This process has many variations depending on the type of shielding gas. The type of metal transfer, and the type of metal welded.

vii. Flux – Cored Arc Welding (FCAW)

A variation of gas metal arc welding has been become a distinct welding process and is known as flux – cored arc welding (FCAN) it is defined as "an arc welding process which produces coalescence of metals by heating them with an arc between a continuous filter metal (consumable) electrode and the work – piece shielding provided by a flux contained within the tubular electrode" additional shielding may or may not be obtained from a externally gas or gas mixture.

viii. Stud welding (SW)

The final process with the arc welding group of processes is known as stud welding (SW). This process is defined as an arc welding process which produce coalescence of metals by heating them with an arc between a metal stud or similar part and the work – piece" when the surface to be joined are properly heated they are brought together under pressure. Partially shielding may be obtained by the use of ceramic ferrule surrounding the stud.

1.3. Others welding process

The arc welding process has to be discuss here. But we have to bring to the notice of every body other means of welding. This are grouped under the following sub – group. Brazing, oxytual gas welding, resistance welding, solid state welding soldering and others.

i. **Brazing (B)**

Brazing is a group of welding process which produce coalscense of materials by heating them to as suitable temperature and by a using a filter metal, having a liquids above 450^0c and below the solidus of the base materials. The filter metal is distributed between the closely filter surface of the joint by capillary attraction.

Brazing is a very special form of weld, the base metal is theoretically not melted. There are seven popular different processes within the brazing group. The source of heat differs among the processes. Braze welding relates to welding processes. Using brass of bronze filter metal, where the fitter metal where the filter metal is not distributed by capillary action.

ii. **Oxy fuel gas welding (OFW)**

Oxy fuel gas welding is a group of welding processes which produces coalescence by heating materials with an oxy fuel gas flames with or without the application of pressure and with or without the use of filter metal"

There are four process within this group and in the case of two of them oxyacetylene welding and oxyhydrogen welding, the classification is base on the fuel gas used. The heat of the flame is created by the chemical reaction or the burning of the gases. In the third process air acetylene welding, air is used instead of oxygen and in the fourth category pressure gas welding, pressure is applied in addition to heat from the burning of gasses. This welding process normally utilizes acetylene as the fuel gas. The oxygen thermal cutting processes have much in common with this welding processes.

iii. **Resistance welding (RW)**

Resistance welding is a group of welding process which produce of the work to electric metals with the heat obtained from résistance work is a part, and by the application of pressure" in general, the different among the resistance welding process has to do with the design of the weld and the type of machine necessary to produce the weld. In almost all cases the processes are applied automatically since the welding machines incorporate both electric and mechanical functions.

iv. Soldering (S)

Soldering is a group of joining processes which produces coalescence by heating them to suitable temperature and by using a fitter metal having a temperature exceeding $450^0c(840^0f)$ and below the sodium of the bas materials. There are distributed between the closely filter surfaces of the joint by capillary attraction. There are surface of the joint by capillary attraction. There are a number of different soldering processes and methods.

v. Solid state welding (SSW)

Solid state welding is a group of welding processes which produce coalescence at temperature essentially below the meting point of the base materials being joined without the addition of a brazing filler metal. Pressure may or may not be used. The oldest of all welding processes forge welding belong to this group. Others include cold welding, diffusion welding explosion welding, friction welding, hot pressure welding and ultrasonic welding, these processes arc all different and utilized different forms of energy for making welds.

vi. Other welding processes

This group of processes includes, those which are not best defined under the other groups, it consist of the following processes i.e. electron beam welding, laser beam welding, thermit welding and other miscellaneous welding processes in condition to electrode lag welding which was mentioned previously.

1.4 AIMS AND OBJECTIVES

The aimed and objective of this project is to design and construction of an alternation current A/C arc welding machine it was constructed using the core type single-phase, concentric coil windings, step down transformed. The machine is of 50HZ, 230v input, 62v out put and 5KVA rating. The arc welding machine was constructed locally, using available material in the country. The test result for the welding is also presented it will also create job opportunities for individual who desire to be self – employed.

1.5 METHODOLOGY

The major purpose of electric arc welding machine is usually a welding transformer welding electrode an a means of cooling the most are; 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 construction a welding transformer and controlling its operations automatically with a control circuitry having over temperature shut down. 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 case 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 thought the electrode, cause it to heat up, melt and deposition it on the work piece and allowing it to cool. This is done with absolute concentration and precaution with the eyes being shielded from the inevitable sparks with protective goggles.

CHARPTER TWO

2.0 LITERATURE REVIEW

Michael Faraday an American Scientist made a very important discovery that when the magnetic flux linking a circuit is changing an electromotive force (Emf) is induced in the circuit. [ ] the figure 2.0 show the schematic diagram of a two-winding transformer on no-load

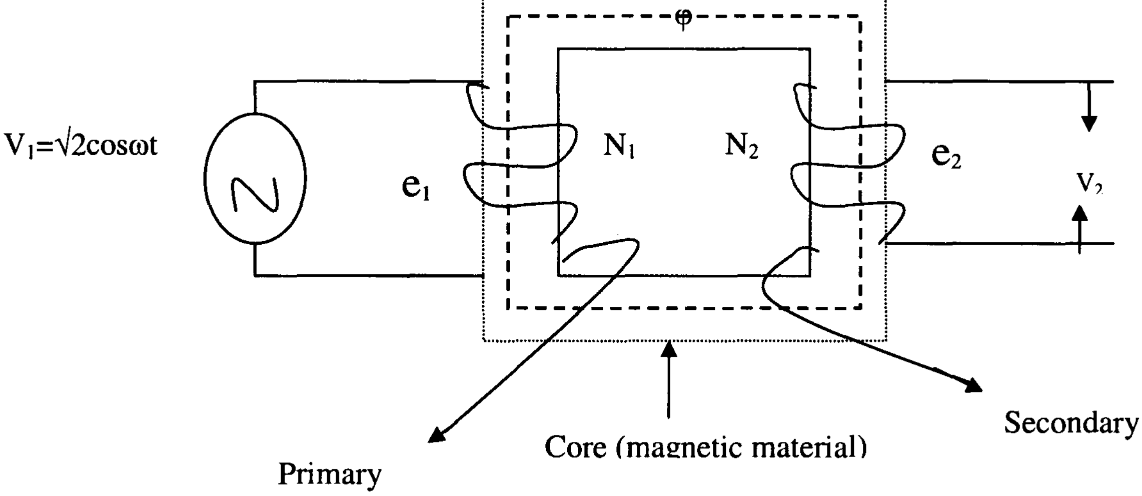


Fig 2.0 transformer on no-load

This is the secondary terminals are open while the primary is connected to a source (230V) of constant sinusoidal voltage of frequency F (50 Hz). The simplifying assumption that the resistance of the winding are negligible, will be made.

The primary winding draws small amount of alternating current (AC) of instantaneous value i_o called the exciting current, from the voltage source with position direction as indicating on the diagram.The exciting current established flux in the core (positive direction marked on diagram) all of which is confined to the core, that is there is no leakage of flux.

The primary winding has flux linkages,

$$\lambda = N_1\Phi \text{ .... } 2.1$$

Which induce emf in it is given by

$$e_l = \frac{d\lambda_1}{dt} = N_1\frac{d\phi}{dt} \text{ .... } 2.2$$

As per Lenz's law, the position direction of this emf opposes the position current direction and is show by + and – polarity marks on the diagram. According to kirchhoff's law

V, = e, (winding has zero resistance)

And $\phi = \phi$ max sin wt 2.3

Where ϕ max = Maximum value of core flux

W = 2∏f rad/s (f = frequency of voltage source)

The e m f induced in the primary window is

$$e_l = N_1\frac{d\phi}{dt} = \omega N_1\phi_{max} \cos\omega t \text{ .... } 2.4$$

From equation (2.3) and (3.4) it is found that the induced e m f leads the flux by 90. The r m s value of the induced e m f is

$$E_l = \sqrt{2}\Pi f N_1\phi_{max} = 4.44fN_1\phi_{max} \text{ .... } 2.5$$

$$\text{Therefore } \phi_{max} = \frac{E_l}{4.44fN_1}$$

According to equation 2.6 the flux is fully determined the applied voltage, its frequency and the number of winding turns. All the core flux ϕ of also links the secondary coil (no leakage flux) causing in an induced e m f

$$\text{of } E_2 = N_2\frac{d\phi}{dt} \text{ .... } 2.7$$

An as secondary is open – circuited, its terminal voltage is given as $V_2 = e_2$

An we have the induced emf ratio of the transformer winding

$\frac{E_1}{E_2} = \frac{N_1}{N_2} = a$ (ration of transformer) [ ]

2.1 HISTORICAL BACKGROUND

Arc welding began with sir Humphrey Davy in 1809 in England. In 1881, there was the use of arcs from non – consumable carbon electrode. Shortly after wards, in 1888 a Russian Na Slavianoff, used consumable bare steel rod as an electrode and he is generally accepted as the inventor of metal arc welding, Engr. Iscarkjellbery introduced the first flux coated electrode in 1907. Messrs Alexander Strohmonger Kennedy and other brought arc welding to the present form of using flux covered (consumable electrode) in wire form or rod as electric current passes through it kin and is contact with the metal to be welded.

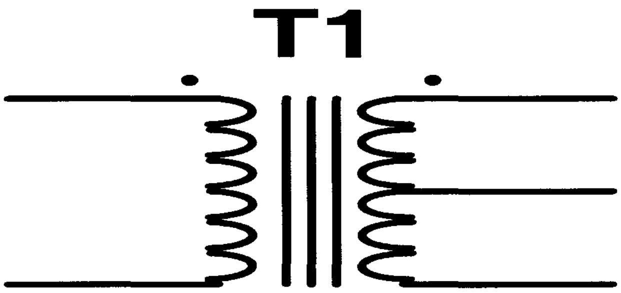
2.2 Transformer

A transformer is device that transfer electrical energy from one circuit to another through a shared field. A changing current in the first circuit (primary) create 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 be make current flow in the transformer, thus transferring energy from one circuit to the other.

Transformer could either be a step – up or step down transformer, and for this project design, we used step down transformer, because of the secondary voltage is less than the primary voltage, an also the number of turn in the secondary is less than the number of turn in the primary.

The transformer operation is based on two principles. First, that an electric current can produce a magnetic field (electromagnetic) and second, that a changing magnetic field within a coil of wire induces a voltage across the end of the coil (electromagnetic induction).

By changing the current in the primary coil, once 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 [3]



2.2 Principle of Operation of Transformer

In a transformer coil A and B can be liked to the primary and secondary winding respectively both wound on laminated iron core that conducts the conducts the flux better than air, if two coils are wound on a common iron core as in fig. 2.0 and one of them, the primary is supplied with an alternative 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 iron core greatly increased the flux produced by a given magnetic current and increase proportion of main flux to leakage flux – consider a project transformer which has no losses. If the primary voltage is sinusoidal, the flux produced will also be sinusoidal. [3]

Another one common design of laminated core is made from interleaved stacks of E – shape steel sheets capped with I – shape pieces, leading to its name of E – I transformer, [5] such a design tends to exhibit more loses, but is very economical to manufacture. The cut – core or core type is made by winding a steel strip around a rectangular form e.m.f. then bounding the layers together.

2.3 ARC WELDING CONSUMABLES

THE ELECTRODE:- This is the chief consumable in electric arc welding from its earliest conception as a carbon electrode, it had metamorphosed into a multi chemical, vaporized mineral and covered with cellulose, made of sodium silicate base. Electrode are of verying size (8,10, 12) to serve different purpose. Positions and processes from being a mere auxiliary filter rod, it is now a consumable electric current carrier.

2.4 FACTOR AFFECTING WELDING

Variation in current:- If the welding current is too large, a flat wide beads with coarse ripples results from the increased arc force, also this force produces a deep penetration pattern accompanied by an excessive amount of sparter. If the welding current is too low, the arc is difficult to control and often the electrode and fuses to plate.

The cause a short circuit and the electrode becomes red hot due to resistance heating unless it is broken off.

2.5 VARIATION IN VOLTAGE AND ARC LENGTH

It is the striking voltage that initiate the arc during welding. An arc voltage is not constant and fluctuates with the arc length during welding. When the arc length increased, the arc voltage decreases and the current rises, thus the total power remain unaffected [5]

2.6 ELECTRIC ARC WELDING PROCESSES

The production of an electric between the work an electrode resulting to a welded joint of high mechanical strength is the primary objective of welding process. Electrons are forced from the end of the electrode into the base metal (work piece) by means of electrical charge disrupted atomic structure. The arc column is established by touching the electrode and the base metal together and with drawing to create an arc length. As the ions travel this air gap, they collide with the arc in the atmosphere, which produce a thermal ionization layer.

2.7 COMPONENT SELECTION CONSTRUCTION / ASSEMBLY

2.7.1 COMPONENT SELECTION

Considering the component to be used for the construction of electric arc welding machine, the choice of materials must be taken into consideration.

CHOICE OF MATERIALS

1. **Materials for core**

The core of the transformer is structurally the most important component, since all the other parts are supported by it an it goes through many circle while the transformer is in use. The choice of materials should be ensure that the core does not reach magnetic saturation easily during alternate half cycle at low voltage. It depends upon achieving the best characteristic. The materials must have the following characteristic.

i. Low hystresis loss

ii. High permeability as low value of magnetic field for the purpose of the project, mild steel of gauge 0.7mm, which is most locally available, was used

2. **Material of the coil**

The most important conductor materials employed in electrical; engineering are copper and aluminum however for the purpose of this project enameled coated copper wire of gauge 2.28mm for the primary and gauge 4.89mm for the secondary are used. The coil has the following properties

i. Low resistance

ii. It is ductile, thus easily shape

iii. Relatively high corrosion resistance

3 Supply Leads

When selecting a cable for arc welding process, it should not be too small for the current that will flow through it. So that it will not cause over heat and power loss. A larger cable is necessary to carry the required current otherwise there will be an excessive voltage drop.

4 Electrode holder

This is simply a damping device for holding and transferring the welding current into the electrode. The holder must be selected or designed in such a way that it can hold the electrode securely in position , get permit easy change of electrode and provide good electrical contact.

2.8 Construction

The materials used for the general construction are listed below:

1. Mild steel sheet swG 22
2. Binding tape 10
3. Copper wire swG
4. Super glue
5. Industrial switch
6. Electrode holder (welding tong)

7. Electrode lead and earth lead
8. Wooden former
9. Vanish.

2.9 Plug

The plug used in welding set must be capable of with standing excessive current so that it will not burn. A plug of current rating of 1AMPS was used in this project.

2.10 CONSTRUCTION PROCEDURE

Lamination

The lamination were constructed by making out the giving dimension and the metal sheets cutting machine was then used to cut the marked sheet. The lamination are E and I shape. They were laminated using vanish – Also, allowed to dry after which they are inter – linked to form limb and yoke through over lap as shown in the diagram 1 and 2 below:

Window limb = 21.4 x 3.6 cm
External limb = 21.4 x3.6cm

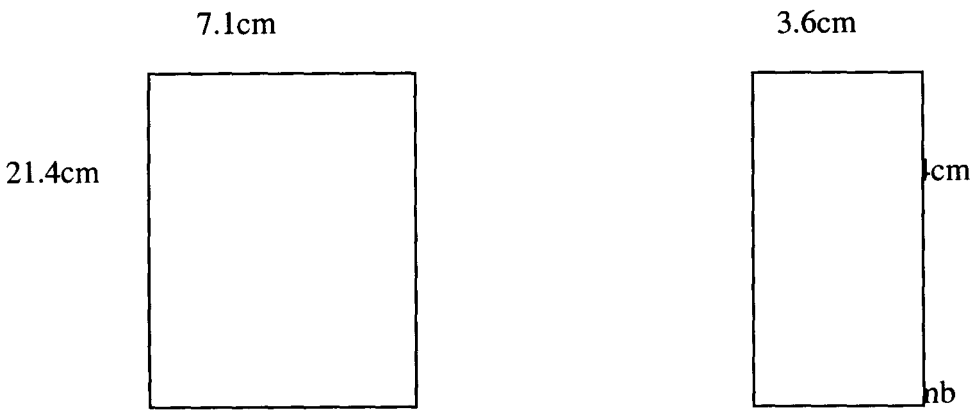


Fig. 4.1a

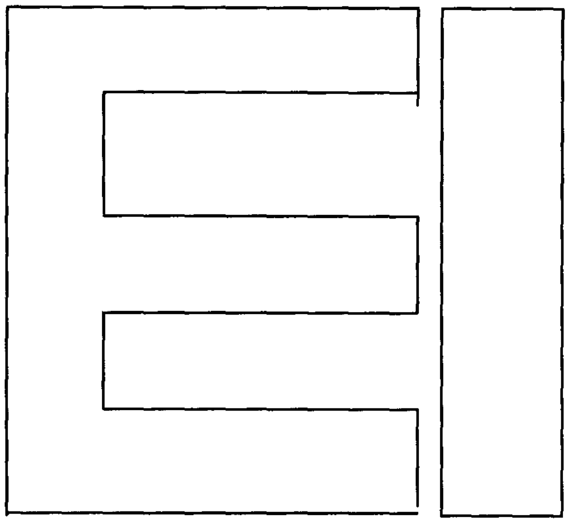


Fig. 4.1b the E and I shape

2.11 Construction of window

The construction of the window can either be a plastic or wooden former on which the coil is wound for the purpose of this project, the wooden former was used. The wooden former was constructed to suit the size or dimension for the window limb – the former was provided with three guides of the same dimensions, one of the guide was placed in the middle of the former, this separates the primary winding from the secondary winding. The other two guides were placed at the edges of the former to prevent the winding from falling. This is later implemented into the transformer oil. This is shown in the diagram below:

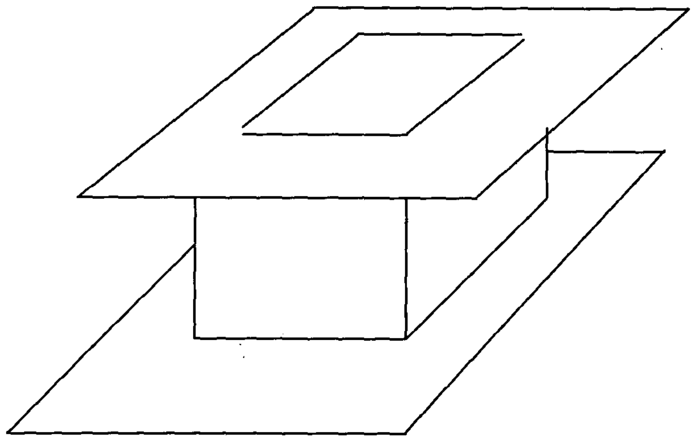


Fig 4.2 bobbin former

The dimension of the former as shown in the figure are

Length------------------- 13cm

Breath------------------- 7.1cm

Height------------------- 5cm

This ionized gas column or arc acts as a high resistance conductor that enables more irons to flow from the work piece to the electrode.

2.12 ADVANTAGES OF ELECTRIC (AC) WELDING

i. The arc force make overhead welding possible

ii. Better weld joint efficiency

iii. Welding transformer are easier to maintain than generator

iv. It entails less heat loss and less oxidations

v. Good control possibility and ability to weld without a filter metal.

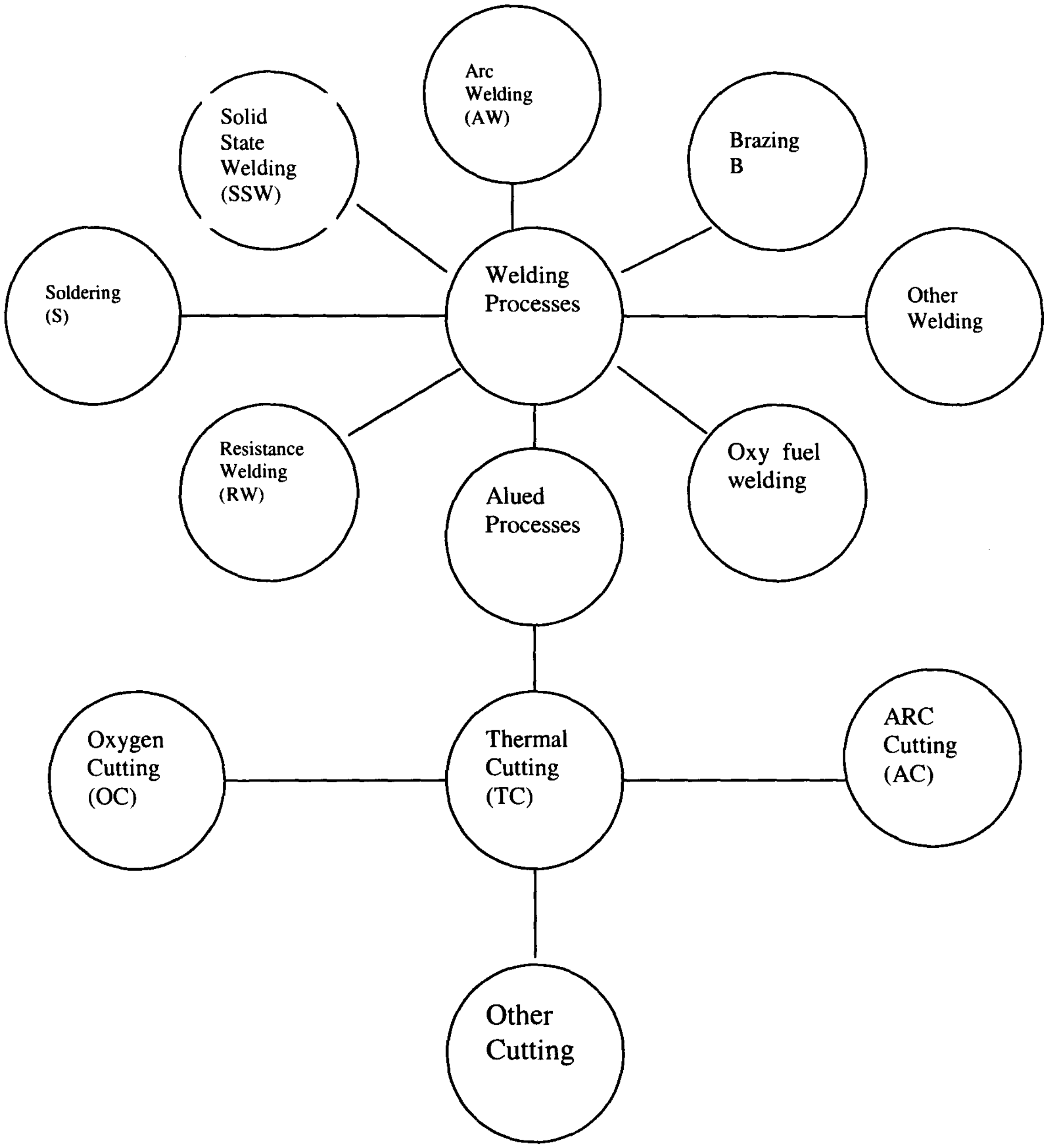


Fig. 2.2 Arc Welding System Master Chart Of Welding And Allied Processes.

CHAPTER THREE

3.0 DESIGN ANALYSIS

Open circuit voltage (voltage when the machine is running and no welding is being done) is one of the factor influencing the performance of a single – phase A/C arc welding machine, Generally open circuit voltage (OCV) varies between the current and the arc voltage. The voltage to maintain an electric arc welding varies between.

i. A welding machine which is characterized by steep volt ampere dropping characteristic by which a relatively constant supply of current is produced with only a limited charge in voltage load and

ii. A welding current setting which depends on the metal gauge of the work piece and the electrode type and its diameter, it also depends on the arc length, which facilitate an effective delivery of current.

3.1 DESIGN CONCEPT

The design of a successful welding transformer requires the selection of a core structure such that the coil would be easy to wound, the magnetic gravity will be easy to built with the mean length of the winding. The magnetic gravity should be short as possible, so that the amount of materials required and looses should be low as possible.

3.2 DESIGN SPECIFICATION

Power reaction		5KVA (5000VA)
Primary (input) voltage	E_1	230 Volt
Secondary output voltage	E_2	62 Volt
Primary current	I_1	22 amps
Secondary current	I_2	81 amps

Frequency	f	50 Hz
Current density	j	1.8 – 30 A/mm2
Window space factor	A_w	0.6
Maximum flux density	ϕ_m	1.5 wb /m2
Stacking factor		0.9
Cooling medium		Forced air (artificial)
Material used for core		Silicon steel
Shape of core cross section		Square
Number of winding		concentric coil
Number of phase		One
Clamping		Bolt and nuts
Net area core	Ai	36.91 cm2

3.3 THE DESIGN OF THE WELDING TRANSFORMER

The most important parameter governing the design of the transformer are summarized as follows:

i. Power rating of the transformer: in this design power rating of 5KVA is choosing

ii. Current rating of the copper conductor for the primary and secondary winding

iii. The primary and secondary voltage (230 and 62v) may be consider, since this design is going to be using a step down transformer

iv. The supply frequency f. of 50Hz

v. The maximum flux density Bm must also to be considered as $1.5 wb/m^2$

vi. Current density j of 1.8 – 30 A/mm^2, but $3.0 A/m^2$ will be considered.

vii. Space factor 0.6 will be considered

viii. Type of construction is going to be core type

ix. Cooling medium: transformer oil is used in this design

3.4 DESIGN CALCULATION

The root mean square value of the induced e.m.f. in the primary winding of transformer is given as

$E_l = 4.4\ FN1\phi_m$ where $\phi_m = B_m\ A_I$ ------------------ 1

One of the mutual induction between the primary and secondary winding liked by a common magnetic flux, the r.m.s. value of the induced e.m.f. in the secondary winding is

$E_2 = 4.44\ FN_2\ \phi_m$ -------------------------- 2

Equation (1 & 2) can be obtained from the following. It is assured that Φ_m varies sinusoidally with frequency, for E_l

$E_l = N_l \dfrac{d\phi}{dt}$ ------------------ 3

and

$E_2 = N_2 \dfrac{d\phi}{dt}$ ------------------- 4

but $\phi = \phi_m$ sin t for the primary and

$\phi = \phi_m \cos \omega t$ for the secondary

Substituting this into equation 3&4

Then $E_l = N \dfrac{d}{dt}(\phi_m \sin \omega t)$----------------------5

and $E_2 = N \dfrac{d}{dt}(\phi_m \cos \omega t)$ -----------------------6

Given that r.m.s. of the primary is

$E_1 = \frac{1}{2} \omega N_1 \phi_m$ where $\omega = 2\Pi f$

$E_1 = 0.707 \times 2nf \times N_1 \phi_m$

$E_1 = 4.44 N_1 f \phi_m$ and

$E_2 = 4.44 Nf \phi_m$

When the window area is considered, it is given in equation 1&2 as shown above.

3.4.1 VOLTAGE TRANSFORMER RATIO (K)

The voltage transformer ration is achieved from equation 1& 2

$$K = \frac{E_2}{E_1} = \frac{N_2}{N_1} = 0.46 \text{ ------------------------ } 7$$

If K is > 1 it indicate a step-up while K< 1 indicate a step-down of voltage current are in the inverse ration of (voltage) transformer as indicated by equation 8.

$$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{1}{K} \text{ ------------------------ } 8$$

3.4.2. EQUATION FOR VOLTAGE PER TURN

The equation for voltage per turn is given as

$$VT = 4.44 f \phi N \text{ ------------------------------ } 9$$

Putting the value of the flux Q in form KVA (kilovolt amperes) gives

$$KVA = E \times I \times 10^{-3} \text{ ---------------------------- } 10$$

$$= 4.44 fN\phi \times I \times 10^{-3} \text{ --------------------- } 11$$

$$= 4.44 f\phi 2/r \times 10^{-3}$$

Where $r = \phi/IN$ = magnetic load / electric loading$)^2$

$\phi^2 = [(r/4.44f \times 10\text{-}3) \times KVA]^{1/2}$

Substituting the value of ϕ in equation 9

$Vt = 4.44f \times [(r/4.44f \times 10^{-3}) \times KVA]\ 1/2$

$Vt = 4.44f \times 10{+}3 \times r \times KVA)\ 1/2$

$Vt = C\ (KVA)\ ½$

Where $C = 4.44f \times 10{+} \times r)\ ½$

The value of C is given the range of constant between 0.55 – 0.65 depending on the type of transformer construction and use. For this project design, we used 0.55

$Vt = C(KVA)\ ½$

$Vt = 0.55\ (5)\ ½$

= 1.229 volt per turn.

3.4.3 DESIGN CALCULATION OF THE WINDING PARAMETER

For an ideal transformer, the power of the primary circuit is equal to the secondary.

i. Number of turn at the primary

$Vt = \frac{E_1}{N_1}$ where E_1 = primary voltage
N_1 = primary number of turns

$N_1 = \frac{E_1}{Vt} = \frac{230}{1.229} = 187.14 = 187$ turns

ii. Number of turn at the secondary

$VT = \frac{E_2}{N_2}$ where E_2 = Primary voltage
N_2 = Primary number of turns

$N_2 = \frac{E_2}{Vt} = \frac{62}{1.229} = 50.54 \approx 51$ turns

iii. **Current at the primary**

$VA = V_1 I_1 \quad = \quad$ Maximum power

$$I_1 = \frac{VA}{V_1} = \frac{5000}{230} = 21.74A = 22A$$

Primary current – 22A from the power relation.

iv. **Current At The Secondary**

$V_1 = V_2 I_2$

$I_2 = V_1/V_2$ = Secondary Current

$$I_2 = \frac{230 \times 21.74}{62} = 80.6 \approx 81 \text{ AMP}$$

v. **Core Design Calculation**

The core area is of Square cross section. The gross area $Ag = o.5d^2$ the effective

core area $Ai = 0.9 \times 0.5d^2$

Therefore $Ai = 0.45d^2$

Where 0.9 is the stacking factor

The effective Core area is calculated as

$Vt = 4.44f\phi$ where $\phi = BAi$

Taking flux density B_m 1.5 wb/m^2

$Vt = 4.44 \times f\, BAi$ ----------------- 12

There fore $1.229 = 4.44 \times 50 \times 1.5 \times Ai$

$Ai = 1.22\,9/4.44 \times 50 \times 1.5$

$Ai = 0.00361m^2$

$= 36.91\ cm^2$

$= (6.07 \times 6.07)\ cm^2$

Now $Ai = 0.45d^2$

$$d^2 = Ai/0.45 = \frac{36.91}{0.45} = 82.02$$

$$d = \sqrt{82.02} = 9.02cm$$

vi. CALCULATION OF THE WIDTH OF LAMINATION

The width of lamination for square section is

$Wc = 0.71d$

$= 0.71 \times 9.02$

$Wc = 6.42cm = 6cm$

vii. DETERMINATION OF THE WINDOW AREA

The window area is calculated from kva-ph

$Kva\text{-}ph = [4.44f\ \phi \times (Kw\ Aw\ J/2)] \times 10^{-3}$

Where Kva = total kilovolt ampere of a phase transformer

= 5 Kva

f = 50Hz

Ai = cross sectional area = $36.91cm^2$ = 0.00 3691 mm

Aw = window area

J = current density = 3.0 A/m^2

Kw = window space factor = 0.6

$5 = 4.44 \times 50 \times 1.5 \times 0.003691 \times 0.6 \times Aw \times 3.0 \times 10^{-3}/2$

$Aw = 0.0045204m^2 = 45.20cm^2$

Taking the ration of the height (length) of the window to the width of the as

$L/w = 3.2$

$L = 3.2\ w$

But $Aw = L \times W = 3.2w \times w = 3.2w^2$

$$W = \sqrt{45.20/3.2} = 3.758 \text{ cm}$$

The length of window is given as

$$L = Aw/w = \frac{45.20}{3.75} = 12.03\text{cm}$$

VII. STACK HEIGTH

The height of the stack as shown is equal to 0.71d for a square cross-section area

$Hs = 0.71d = 0.71d \times 9.05 = 6.43$ cm

$Hs \cong 6$cm

The number of lamination sheet is given by

Ns = height of stack/thickness of sheet

The power equation for a 100% efficiency system is

$V_1 I_1 = V_2 I_2$ -------------------- 13

Assuming an efficiency (?) of 95% for this design and the power ration this

efficiency=5KVA

$$\therefore \text{Input P}, = \frac{5KVA}{0.95} = 5.26 \text{ KV}$$

At this output, the primary current

$I_1 = P_1/V_1 = 5.26 \times 1000/230 = 22.86A$

From equation 13, secondary current is gotten as

$230 \times 22.86 = 62 \times I_2$

$$\therefore I_2 = \frac{230 \times 22.86}{62} = 84.80A$$

The mean value of current between the output powers

$$I_1 = \frac{22.76 \times 21.74}{2} = 82.7A$$

Gauge of wire = 105WG = 8300mm^2 = 3.25mm

Current carrying capacity = 25A

J =I/a = 25/8.3 = 3.01A/mm^2

For the secondary winding resistance = 0.000525Ω/m

Area of wire = 32.2mm

Diameter = 6.4mm^2

Current capacity = 97A

3.5 THE BOBBIN OF FORMER

The bobbin width for each limb is given by

$$\text{Bobbin width} = \frac{\text{space force x perimeter of window}}{\text{Number of window units.}}$$

Number of each winding is 4 with 2 units on each limb as shown

Space factor Kw = 0.6

Perimeter of window L + W = (12.03 + 3.758) cm

$$\therefore \text{ Width of bobbin} = \frac{2\,[0.6\,(3.758 + 12.03)]\text{ cm}}{4}$$

=4.736cm = 47.36m

3.6 NUMBER OF TURNS PER LAYER

This is given as the ration of the width of the bobbin (former) to the conductor diameter, applying a factor of 0.5 as allowance for insulation on the conductors.

$$\text{i.e primary number of turn per layer} = 0.85 \text{ x } \frac{\text{width of bobbin}}{\text{Coil diameter}}$$

$$\text{For the primary side, turn per layer} = 0.85 \text{ x } \frac{47.36}{3.25} = 12.39$$

$\cong$ 12 turns

Total number of layer of the primary layer scale = 187/12

= 15.58 $\cong$ 16 layers

This means 8 layers for limb

For the secondary, the secondary number of turns/layers

$= (0.83 \times 47.3)/6.40 = 6.28 \cong 6$ turns/layer

$\therefore$ Number of layer = 50/6 = 8 layer approx.

3.7 THE COIL DEPTH AND LENGTH

The radial is given as follow

(height of each limb x number of layers) + (total no of thickness of interlayer wraps) + (winding allowance of 0.75mm)

Where for the primary

Height of turn = diameter of coil = 3.25mm

Thickness of interlayer wrap = 0.15mm

Radial depth = (6.40 x 8) + (0.15 x 6) + 0.75mm = 52.85mm

Denoting the, length of conductor of the primary as Lp and that of the secondary by Ls.

$$Lp = N \frac{(\text{radial height} + \text{stalk height} + \text{bobbin thickness})}{2}$$

$\therefore$ Lp = 8 (Hr + Hs + Bt) N/2

The factor 8 is gotten from the fact that stalk height is in four different directions and the radial depth is in your sides at the core.

$\therefore$ Bt- bobbin thickness = 0.2 = 2mm

Hs- number of turns in primary sides

Hr- radial height = 27.2

Lp = 8 (27.2 +64 +2) 187/2 = 69713.6 = 69.71m

For the secondary Ls = 8 (26.5 + 64 + 2) 50/2 = 18500mm = 18500mm = 18.5m

Thus, for wire gauge of 10 copper resistance = 0.00204Ω/m

And a wire gauge of 3(copper) resistance = 0.000525Ω/m

Therefore the resistance winding of the primary can be gotten by multiplying the length of the primary winding and its resistance per meter.

$$Rp = Lp \times 0.00204\Omega/m$$

$$Rp = 69.71 \times 0.000525\Omega/m = 0.1422\Omega$$

Similarly for the secondary resistance

$$Rs = Ls \times 0.000525\Omega/m$$

$$Rs = 18.5 \times 0.0025 = 0.0097\Omega$$

3.8 COPPER LOSS

The copper loss in the primary side is given as

Pcu loss = $I_1^2 R_1$

Using the properties of copper and relation with the current given

Pcu loss = $I_1^2 R_2 = (21.74)^2 \times 0.1422 = 67.21$watts

For secondary, copper loss

Pcu loss = $I_2^{2\,R}{}_2 = (80.60)^2 \times 0.0097 = 67.21$ watts

The total copper loss

Pcu l = $pcul_1 + pcul_2$

$$67.21 + 63.02 = 130.23 \text{ watts}$$

3.9 VOLTAGE DROP

From the ohms law, total voltage drop is given as voltage drop

V = IR

For the primary $Vd_1 = I_1 R_1$

$21.74 \times 0.1422 = 3.09$ volts

For The Secondary $Vd_2 = I_2 R_2$

$= 80.60 \times 0.0097 = 0.7818$ volts

The total voltage drop is

$Vd = Vd_1 + Vd_2 = 3.09 = 0.7818$

$= 3.8718$ volts.

For the secondary $Vd_2 = I_2 R_2$

$= 80.60 \times 0.0097 = 0.7818$ volts

The total voltage drop is

$V_d = V_{d1} + V_{d2} = 3.09 + 0.7818$

$= 3.8718$ Volts

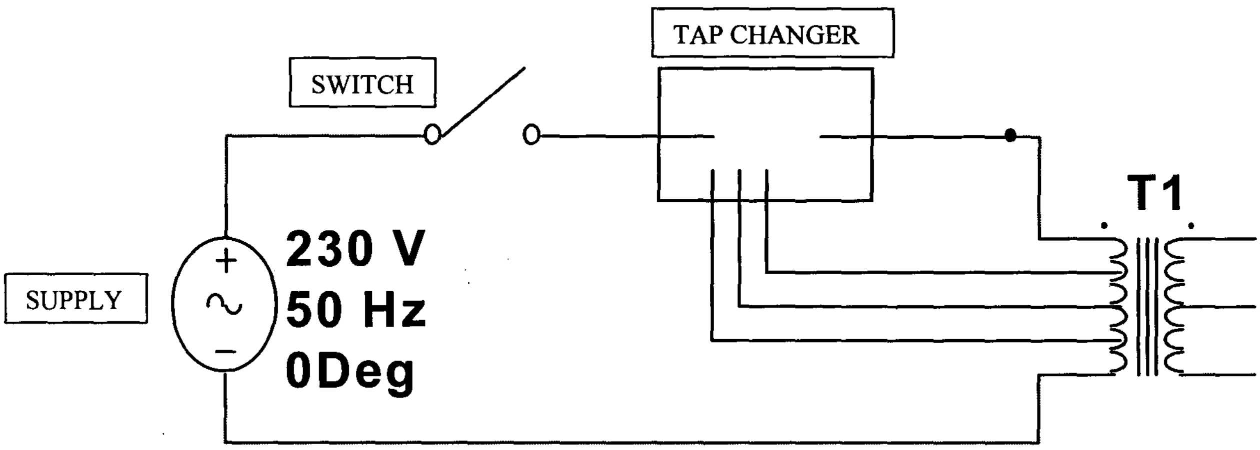


Fig a

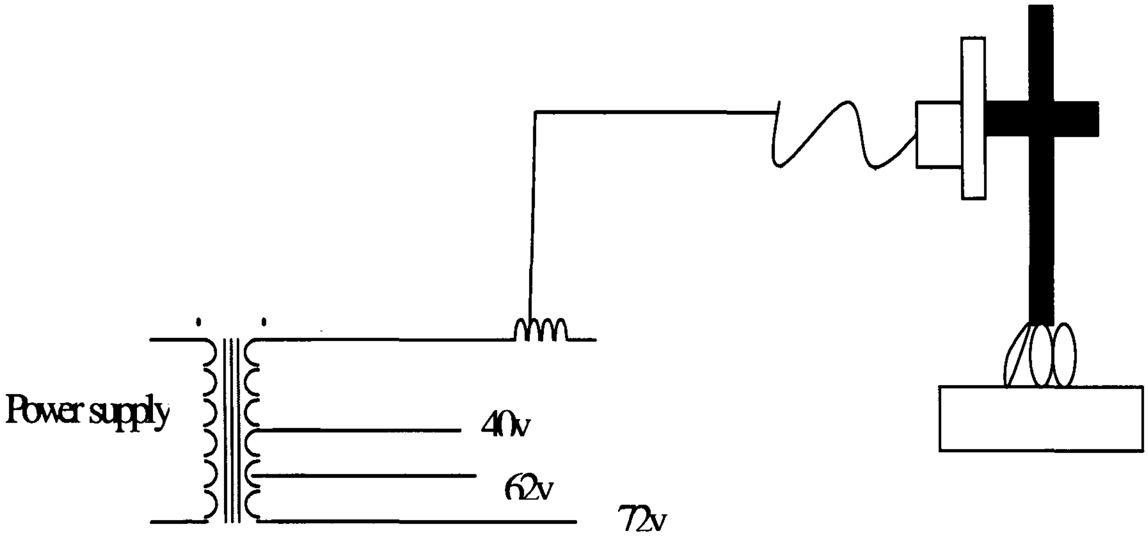


Fig b

Fig a and b show the circuit of an electric arc welding machine.

The dimensions of the former as shown in the figure are: -

Length 13cm

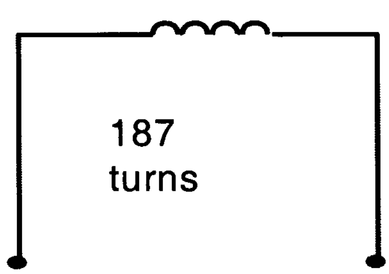
Breath 7.1cm

Height .... 5 cm

3.10 WINDING

The insulated copper wire (Primary & Secondary) was wound on the former. This has a gage 10 having current carrying capacity of 20A for the primary and gage 12 having a current carrying capacity of 100A is used for the secondary. The primary and secondary winding were made on a separate bobbing.

(i) THE PRIMARY WINDING:- The primary winding which has 153 turns was wound or the former and two terminals was brought out to be reconnected to the supply.



(ii) THE SEONDARY WINDING:- The Secondary winding has 60 turns was wound on the former four terminals brought out. The start is the earth, at 33 turns, the low terminal brought out, at 66 turns, the medium terminals was brought out finally, the high terminal on the end (finish) was brought out at 75 turns. The guage used for the secondary copper conductor was 2.

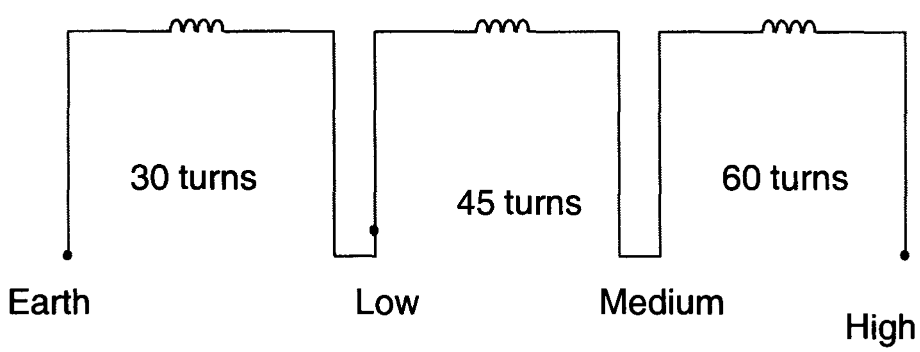


Fig. 4.4 Secondary Winding

3.11 WINDING PROCEDURE

When winding simple length of the conductor at the start is set aside to be used for power source connection, then the former is turn clockwise running or laying one layer of conductor through the breadth before starting a second line at the top of the last winding stop of the first layer in sequence. Care was taken not to scratch the enamel insulating coating the conductor and to produce a neat, compact and firm coil winding.

3.12 VANISHING

Vanished was applied all over the winding (primary and Secondary) with the aids of a brush. This necessary for copper adhesion of the winding turns thus vanishing help to prevent vibration on the winding.

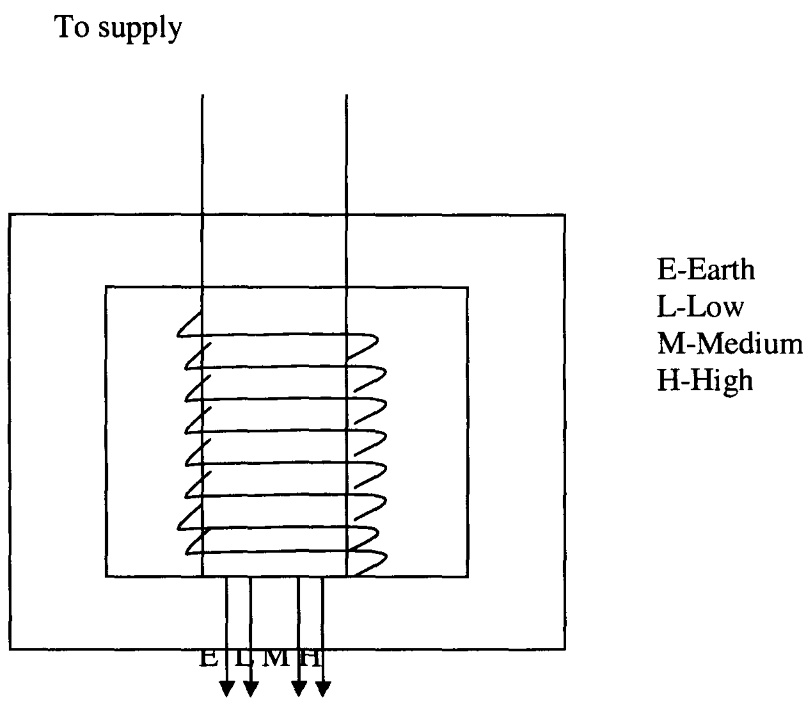


Fig 4.5 Construction of Welding Transformer

3.13 COOLING

In this project transformer oil is been used to aid in the cooling system. This help to be extracting the heat generated by the coil. That it self get heated up while the transformer remain cooled. This was achieved due to the fact transformer was implemented into the cooling oil.

3.14 CASING

A rectangular box made of mind steel with a vent on top serve as casing. The transformer and the cooling oil were housed in the casing. Double handle were provided for easy movement. This is shown in the diagram below: -

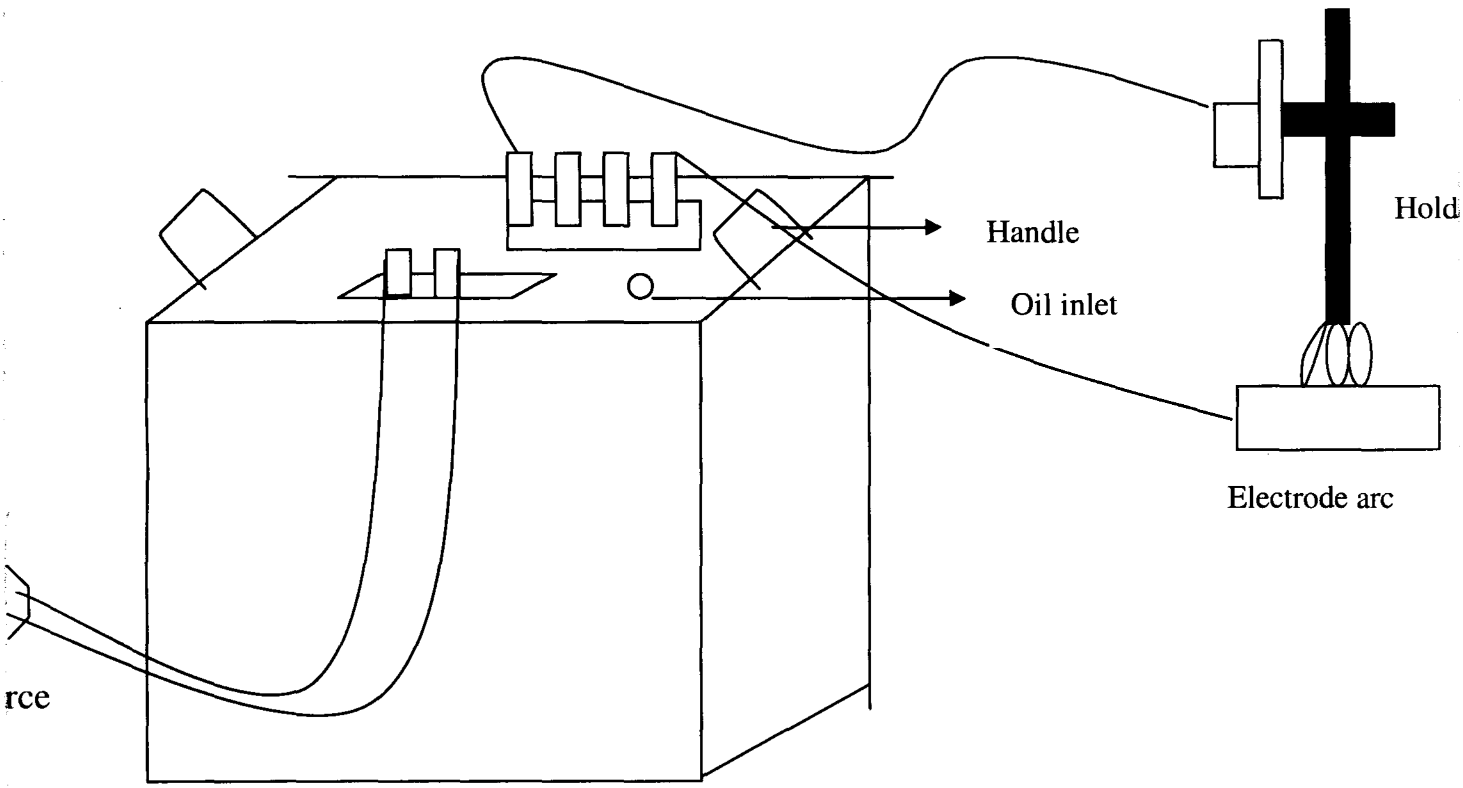


Fig. 4.6 5KVA ELECTRIC ARC WELDING MACHINE

3.15 OPERATION PRINCIPLE

In this project, the basic component of the welding machine is the transformer. The operational principle of the welding set is based on the principle of a transformer action. The primary circuit received 230V, 50Ht from he supply and boost the power, which set up a perpendicular magnetic field around the primary coil. This line of force induces a like force in the secondary winding, thereby causing a further boost in amperage. A switch (industrial) can control the amount of current output when the welding is about to begin. The output current with the aid of switch can adjusted to low (L), medium (M) or high (H) out put depending on the type of strength of the work pieces.

CHAPTER FOUR

THE FOLLOWING TEST WERE CARRIED OUT ON THE EQUIPMENT

4.0 SHORT CIRCUIT TEST OF A TRANSFORMER

The following were realized. .

TABLE 4A.

Voltage (v)		Current (A)		
Primary	Secondary	Primary	Secondary	
230	75	230	82	High
230	62	230	71	Medium
230	40	230	63	Low

The above table represent results, that was achieved when short circuit test was carried out on the transformer. Using various regulations i.e. high, (medium), low and the terminal.

4.1 OPEN CIRCUIT TEST

TABLE 4B

THE FOLLOWING RESULTS WERE ACHIEVED.

Voltage (v)		Current (A)		
Primary	Secondary	Primary	Secondary	
230	75	1.00	0	High
230	62	0.80	0	Medium
230	40	0.65	0	Low

For the four terminals. Based on the above test, we observed two major losses. Which were iron losses and copper losses.

4.2 SHORT CIRCUIT TEST OF A TRANSFORMER

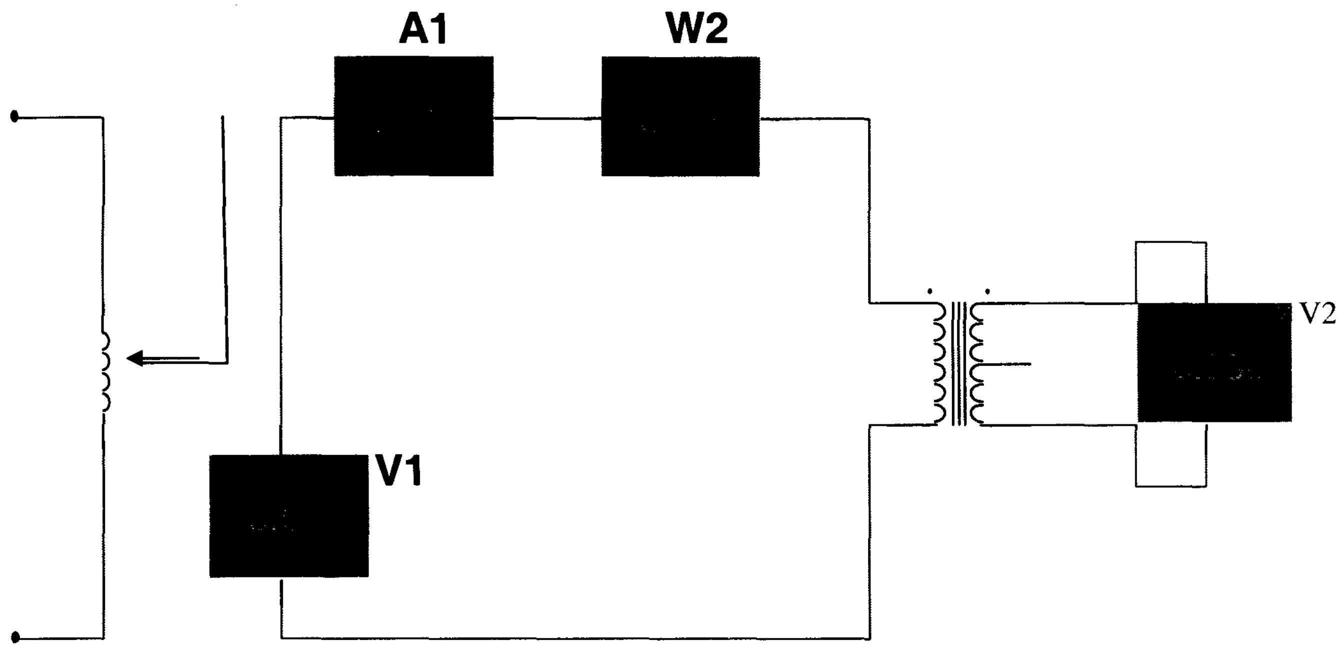


Fig.4 .1 Diagram of short circuit test

In the test, the transformer is connected as shown in the diagram above. The secondary winding is connected to ammeter and voltage applied to the other side of the transformer is gradually increased from zero to a given value. The short circuit test is used to determine the circuit series impendence with the secondary winding short-circuits with an ammeter. Due to the very high current in the secondary winding of the welding set, facilities for these test are rare.

4.3 OPEN CIRCUIT TEST.

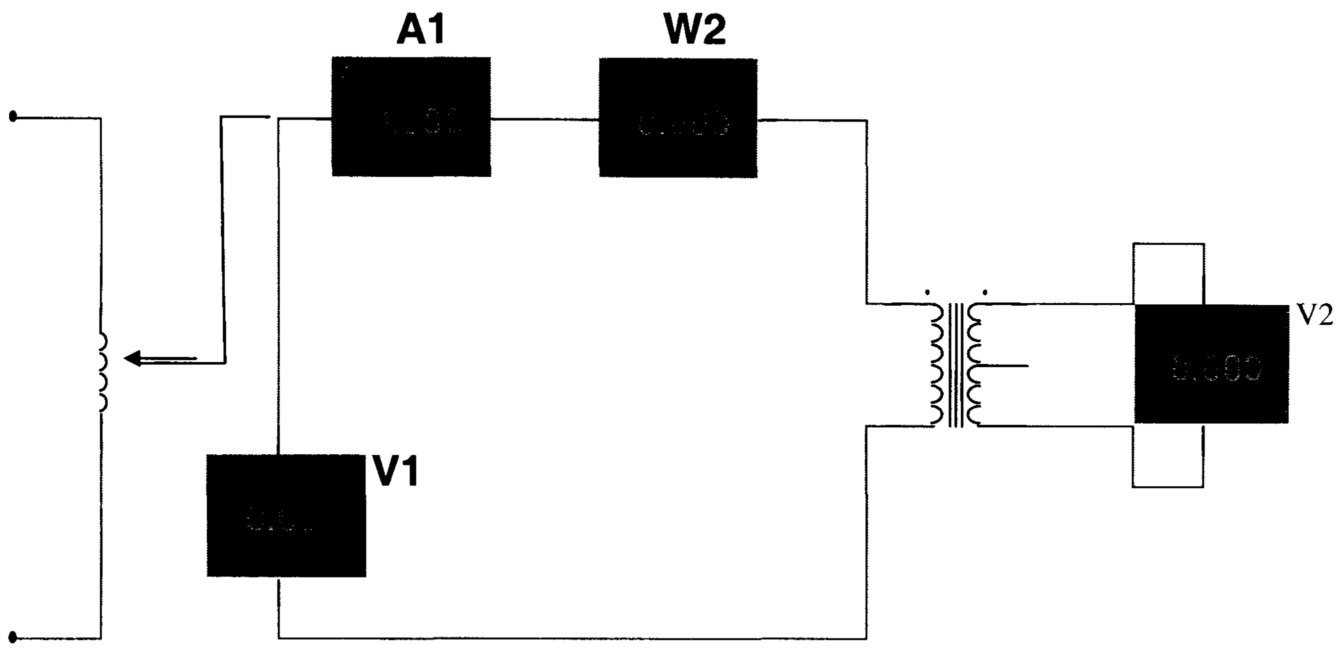


Fig 4.2 open circuit test diagram

The transformer is connected as shown in the diagram above, the input terminals are connected to a variable voltage at normal frequency. The input current, power and voltage on open circuit can be measured. Open circuit test enable one to determine the no load current and no load losses of the transformer. The losses includes:-

2. Iron loss – due to hysteresis and eddy – current losses.
3. Copper loss – due to copper in the primary winding.
4. Additional no load losses.

4.4 CONTINUITY

This is a guide against short and open circuit faults in the coils. This is alone using a meager tester, but primarily as a resistance test using an Avometer, it affords insulation resistance protection by electrical separation of the primary and secondary coil winding and also ensure continuity of protective conductor. Upon satisfactory test result, the lamination (E and I shapes) are assembled into the coil forms and held in position by bolts and nuts tightly clamped. The residual high conductors corresponding to the "start" and "finish" of each coil winding were electrically protected with insulation and a portion scrapped to be fed to a power source. The two leads "start" and "finish" of the secondary coil are put in form, using pliers and connected to the industrial switch for low, medium and high control.

4.5 VISUAL TEST

During the winding of the cool in the former, care was taken to ensure a neat and compact sequential wound. Visual inspection or test was done for possible extension of a coil turn so as to make contact with the transformer stamping. The conductor coil turns were insulated with adhesives tapes to prevent direct contact.

CHAPTER FIVE

5.0 CONCLUSION

The objective of 5kva, alternative current arc welding machine was realized with the welding machine functioning to the desired capacity, with a great deal of efficiency and weight of about 80-100kg. A provision was made for two person to lift it. Variation between the design (calculation) result and practical results were with the limit of tolerance. Different in the calculated values of the actual number of turns wounds was as a result of lower gauge of copper conductor used in pre-primary welding which is still developing in a developing country will continue to assist in the production of plants and machineries. As well as create job opportunities for graduate engineers an artisans involved in metal fabrication work.

5.1 PROBLEMS ENCOUNTERED

i. Sourcing for the size of wire gauge chooses in the design was a problem; smaller size wire gauge had to be combine to obtain re desired size.

ii. The inadequate supply of electricity from the public supply was a major challenge this caused delay in completions of the project work.

iii. High cost of electrical materials.

5.2 RECOMMENDATIONS

1. The welding machine can be improved upon to feature display for welding voltage and current
2. Use of materials with the best magnetic property for the core.

Very useful projects carried out by students should be mass produces and sold to members of the public in other to solve societal problems and so generate revenue for the department.

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