DESIGN AND CONSTRUCTION OF A LABORATORY POLISHING MACHINE

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A

RESEARCH PROJECT

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CERTIFICATION

We certify that this project titled "Design and Construction of a Laboratory Polishing Machine" was carried out by OLUGBEMI ENIOLA MICHAEL with MATRICULATION NUMBER: MME/12/0877 and has been carefully supervised, read, approved and found satisfactory for the award of Bachelor of Engineering in Materials and Metallurgical Engineering, Federal University Oye-Ekiti, Ekiti State, Nigeria.

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....	....
Date	Date

DEDICATION

I hereby dedicate this project to the Almighty God, the Alpha and Omega, the Rose of Sharon, the **mightiest in** battle and the giver of grace.

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LIST OF ABBREVIATIONS

SiC	Silicon Carbide
Al_2O_3	Alumina Oxide
TEM	Transmission electron microscope
SEM	Scanning electron microscope
XRD	X-ray diffraction microscope
AFM	Atomic force microscope
NSOM	Near filled scanning optical microscopy
BSE	Back scattered electron imaging
CCD	Charge coupled device

ABSTRACT

One of the most useful pieces of equipment for the grinding and polishing of metallic materials in order to determine their physical structure using microscopy is metallographic specimen polishing machine. The objectives of the project are to design and construct a machine that will polish metal for physical metallographic determination. And also to design and construct a machine using locally available materials to produce a flat, smooth and mirror-like surface of any metallic materials in order to determine their physical structure using microscopy. The machine consists of motor, pulleys, belt, rotating shaft, wooden disk plate, bush bearing, pillow bearings, metal clip, and metal casing. All of these components are assembled to form the polishing machine. The testing and evaluation of the machine involves test running of the machine at each speed rate without placing any metallic specimen on and also running after that metallic specimen was introduced for grinding and polishing. The machine has the ability to grind and polish metal, it is simple to operate, and requires minimum maintenance. The metallographic specimen polishing machine can be used in the material laboratory for the grinding and polishing of any metallic materials.

CHAPTER ONE

INTRODUCTION

The laboratory polishing machine is an equipment used for the grinding and polishing of metallic materials in order to examine their physical structure with the use of microscope in the laboratory. The machine is used to create a mirror like appearance on metals after grinding has taken place (Erinle *et al.*, 2011). In metallography and metallurgy, polishing is used to create a flat, defect-free surface for examination of a metal's microstructure under a microscope (Venkannah, 2004). The surface condition of the material at hand determines what type of abrasive would be applied. At first stage, if the material is unfinished, grinding may start with a rough abrasive, such as 60 or 80 grit and subsequent stages uses a finer abrasive, such as 120, 180, 220, 240, 320, 400 and higher grit abrasives, until the desired finish is achieved. The rough (i.e. large grit) passes remove imperfections within the metal surface like pits, nicks, lines and scratches. There are different categories of emery paper used for polishing and grinding of metals. Emery papers of different grit sizes such as 100, 120, 200, 400, 600, 800 grits are used for the grinding of the metals, while emery papers of 1000 and 1200 grit grade are used for polishing. The lower the emery paper number, the coarse the surface and the higher the emery number, the smooth the surface.

A common belief is that a polished surface has a mirror bright finish, however most mirror bright finishes are actually buffed. Polishing is often used to enhance the looks of an item, prevent contamination of items, remove oxidation, create a reflective surface, or prevent corrosion. Silicon-based polishing pads or a diamond solution can be used in the polishing process. Several models of laboratory polishing machines have been made so far, however, they are costly due to the fact that they are imported and making of the machine locally is not being encouraged as a result of our attitude to local products.

1.1. Background of Study:

The rationale behind this project is to design and fabricate a portable laboratory polishing machine that will be suitable for grinding and polishing of metals so as to be able to produce a mirror like appearance was borne out of its unavailability in the departmental metallographic laboratory. Observations on previous metallographic polishing machine produce locally revealed that the major setback they had is the size of the machine which is bulky and heavy due to the weight. As a result of this, the weight and size of this one to be fabricated was taken into consideration during construction so that the machine will be portable. Another major setback faced by most polishing machine made locally is that they are not properly damped thereby causing the machine to vibrate uncontrollably which also leads to loud noise. Due to this, the present work has been designed to ensure that the machine was well damped thereby reducing the noise when in use. The work is also to encourage the fabrication of metallographic polishing machine locally in order to reduce importation which is on high increase in terms of cost as a result of the foreign exchange rate and more importantly encouraging local technological development.

1.2. Statement of the Problem

The major reason behind the construction of metallographic polishing machine is because there is no polishing machine in the institution metallography laboratory and due to the challenges faced by students in terms of adequate practical exposure. This work is expected to aid the students in bridging the gap between the practical and theory being taught in class.

1.3. Aim of the Project Work

i. The aim of the project work is to design and construct a laboratory polishing machine

1.4. Objectives of the work

The objectives to achieve the aim of the project work are to:

i. design the machine and its components;

ii. fabricate the polishing machine; and

iii. carry out the evaluation test.

1.5. Contribution to Knowledge:

This project is going to impart more knowledge on students and the society on the usefulness of the laboratory polishing machine in the grinding and polishing of metals and the process involved in metallographic preparation of specimen. The project will give better understanding to the student on metallographic related courses being taught in school.

1.6. Justification of work:

This field of research is very important to the polishing and grinding of metals, as it will impart knowledge on students on the process used in the polishing and grinding of metals to produce a mirror like appearance. It is important to work on this topic so as to produce a metal with a mirror like appearance with zero defect by designing and constructing a laboratory polishing machine.

1.7. Scope of Project:

The scope of this work will be limited to the designing of the essential components (rotating disc, shaft, pulley, cover plate, metal clip and frame) that makes up the laboratory polishing machine used for the grinding and polishing of metals. It also entails the acquisition of parts (mild steel, galvanized steel etc.) that will be used for the fabrication of the laboratory polishing machine, after which the machine will then be fabricated using various processes including cutting, shaping, drilling, machining, screw-fastening, welding and painting. After the fabrication of the machine, evaluation test will then be carried out to determine its suitability for use in the laboratory.

CHAPTER TWO

LITERATURE REVIEW

2.1. Metallography

Metallography is the study of the microstructure of metals and alloys by means of microscopy. Metallography can also be said to be the study of the structural characteristics or constitution of a metal or an alloy in relation to its physical and mechanical properties (Belan, 2012). It is an art and science of preparing, analyzing, and interpreting microstructures in materials, to better understand materials behaviours and performances. The method is used for the evaluation of metallic materials in the various industries, including the aerospace industry, automotive and parts of the construction industry. It is also used for process control including the examination of defects that appear in finished or partly finished products, as well as the studies of parts that have failed during service. Analysis of material's microstructure aids in examining if the material has been processed correctly and is therefore a critical step for determining product reliability and why a material failed (Kallol and Vivek, 2016).

A well prepared metallographic specimen is a representative sample. It is sectioned, ground and polished so as to minimize disturbed or flaw surface of metal caused by mechanical deformation, and thus to allow the true microstructure to be revealed by etching. The specimens are usually free from polishing scratches, pits and liquid staining, and they are flat enough to permit examination by microscopes.

2.2. Preparation of Metallographic Specimens

The preparation of metallographic samples generally requires five major operations which are:

i. Sectioning and Cutting;
ii. Mounting (which is necessary when the sample cannot be held properly due to its shape and/or size, while polishing);
iii. Grinding;
iv. Polishing;
v. Etching.

2.2.1. Sectioning and cutting:

Sectioning is the most important step in preparing specimens for physical or microscopic analysis. Sectioning becomes necessary when studying parts that have failed in service where specimen has to be taken from a large block of material. Therefore, metallographic studies of such samples usually involve more than one sectioning operation. Separate test pieces attached to castings or forgings should be designed so that a minimum of sectioning is required for producing metallographic specimens (Kallol and Vivek, 2016). Depending upon the material, sectioning operation can be obtained by abrasive cutting (metals and metal matrix composites), diamond wafer cutting (ceramics, electronics, biomaterials, minerals), or thin sectioning with a microtome (plastics). Proper sectioning is required to minimize damage, which may alter the microstructure and produce false metallographic characterization. Proper cutting requires the correct selection of abrasive type, bonding, and size; as well as proper cutting speed, load and coolant (Zipperian, 2013).

2.2.2 Mounting of specimens

The primary purpose of mounting is to make it convenient to handle specimens of arbitrary shape and/or small sizes during various steps of metallographic sample preparation and examination. A secondary purpose is to protect and preserve extreme edges or surface defects during metallographic preparation. Specimens may also require mounting to accommodate various types of automatic devices used in metallographic laboratories or to facilitate placement on the microscope stage (Kallol and Vivek, 2016).

The most common mounting method used in specimen preparation are;

i. Compression mounting;

ii. Cold mounting.

2.2.2.1. Compression mounting:

It is the most common mounting method, which involves molding around the metallographic specimen by heat and pressure using the molding materials such as bakelite, diallyl phthalate resins, and acrylic resins. Bakelite and diallyl phthalate are thermosetting, and acrylic resins are thermoplastic and it is not all materials or specimens that can be mounted in thermosetting or thermoplastic mounting. The heating cycle may cause changes in the microstructure, or the pressure may cause delicate specimens to collapse or deform. The size of the selected specimen may be too large to be accepted by the available mold sizes. These difficulties are usually overcome by cold mounting (Kallol and Vivek, 2016).

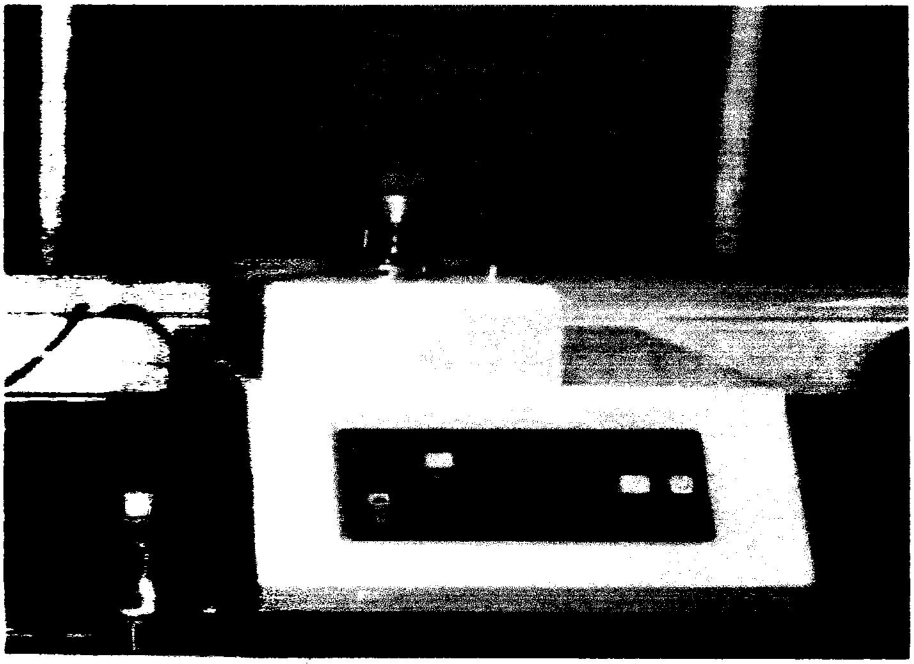

Figure 2.1: A Hot Mounting Press **Source:** (Venkannah, 2004)

2.2.2.2. cold mounting:

Cold mounting requires no pressure and little heat, and is a means of mounting large numbers of specimens more rapidly than possible by compression mounting. Epoxy resins are most widely used as cold mounting materials. They are hard, and adhere tenaciously to most metallurgical, mineral and ceramic specimens. The mounting operation accomplishes three important functions which include:

i. It protects the specimen edge and maintains the integrity of materials surface features
ii. Fills voids in porous materials
iii. Improves handling of irregular shaped samples, especially for automated specimen preparation. Most of the metallographic specimen mounting is done by encapsulating the specimen into a compression mounting compound (thermosets - phenolics, epoxies, diallyl phthalates or thermoplastics - acrylics) (Zipperian 2013).

2.2.3. Grinding:

Grinding step is done to remove damage from cutting, planarize the specimens, and to remove materials affecting the surface of the specimen. It is accomplished by abrading the specimen surface through a sequence of operations using progressively finer abrasive grits. Grit sizes ranging from 60 mesh to 150 mesh are usually regarded as coarse abrasives, and grit sizes ranging from 180 mesh to 600 mesh as fine abrasives. Grinding should commence with the coarse grit size for making initial flat surface and remove the effects of sectioning. Hack-sawed, band-sawed, or other rough surfaces usually require abrasive grit sizes in the range of 80 to 150 mesh. It is done sequentially starting from the coarser one to finer one. A satisfactory grinding sequence might involve grit sizes of 180, 240, 400 and 600 mesh. The purpose of grinding is to remove the oxide layer, or damaged layer or uneven surfaces that might have deformed during last sectioning operation. It is a cold worked operation, however, the depth of the cold worked metal is roughly inversely proportional to the hardness of the specimen and may be 10 to 50 times the depth of penetration of the abrasive particle. Surface damage can be eliminated by prolonged grinding. However, prolonged grinding should be avoided because it can lead to excess heating or surface damage (Kallol and Vivek, 2016).

To ensure the complete elimination of the previous grinding scratches found by visual inspection, the direction of grinding must be changed by 90^0 from one stage of grinding to the next stage. This is because the effectiveness of grinding usually have effect on the microscopic examination. Each ground surface should have scratches that are clean-cut and uniform in size, with no evidence of previous grinding scratches. Cleaning before going to next stage grinding is always helpful.

Table 2.1: Particle Size vs. Common Grit Sizes for Abrasive Paper

European (P-grade)	Standard grit	Median Diameter, (microns)
60	60	250
80	80	180
100	100	150
120	120	106
150	150	90
180	180	75
220	220	63
P240	240	58.5
P280		52.2
P320	280	46.2
P360	320	40.5
P400		35
P500	360	30.2
P600	400	25.75
P800		21.8
P1000	500	18.3
P1200	600	15.3
P2400	800	6.5
P4000	1200	2.5

Source: (Zipperian, 2013)

2.2.3.1. Grinding media:

Grinding media are silicon carbide (SiC), aluminium oxide (Al_2O_3), emery (Al_2O_3- Fe_3O_4), and diamond particles. All these except diamond are generally bonded to paper or cloth backing material of various weights in the form of sheets, disks, and belts of various sizes. The abrasives may be used also in the powder form by charging the grinding surfaces with loose abrasive particles (Kallol and Vivek, 2016).

2.2.4. Polishing

Polishing is the final step in producing a surface that is flat, scratch free, and mirror-like in appearance. Such surface is necessary for subsequent accurate metallographic interpretation, both the qualitative and quantitative. The polishing technique used should not introduce extraneous structure, such as disturbed metal, pitting, dragging out of inclusions, and staining. The two most polishing method used in specimen preparation are:

i. Mechanical Polishing;
ii. Electrolytic Polishing.

2.2.4.1. mechanical polishing:

Mechanical polishing is frequently used to describe the various final polishing procedures involving the use of cloth-covered laps and suitable polishing abrasives basically Al_2O_3 slurry. The laps have either a rotating or a vibrating motion, and the specimens are held either by hand, mechanically, or merely confined within the polishing area. Polishing is done in a relatively dust-free area, preferably removed from the area for sectioning, mounting and rough grinding. (Kallol and Vivek, 2016)

2.2.4.2. electrolytic polishing:

With the most careful mechanical polishing, some disturbed metal, even in small amount may remain after preparation of a metallographic specimen. This is no problem if the specimen is to be etched for structural investigation because etching is usually sufficient to remove the slight layer of disturbed metal. However, if the specimen is to be examined in the polished condition, or if no surface disturbance can be tolerated, then either electrolytic polishing or chemical polishing is preferred. The basic principle involved in this technique is anodic dissolution of surface of the sample which results in a leveling and brightening of its surface. Electro polishing does not disturb any metal on the specimen surface, and therefore, ideally suited for the metallographic preparation of soft metals, most single phase alloys, and alloys that works harden readily. The disadvantages of electro polishing include preferential attack in multiphase alloys caused by differences in electrical potential between phases. However, proper choice of electrolyte and operating conditions will minimize these disadvantages (Kallol and Vivek, 2016).

2.2.4.3. polishing cloths

There are three types of polishing clothes; woven, non-woven and flocked.

i. Woven cloths offer 'hard surface' polishing properties and guarantee flat pre-polishing without deterioration of the edges.
ii. Non-woven cloths are used on very hard materials for high precision surface finishing such as glass, quartz, sapphire and semi-conductors.
iii. The flocked cloths, guarantee a super-polished finish. They are used for polishing fabrics for metal, optical glass and fiber optics.

2.2.5. Etching:

The purpose of etching is to optically enhance microstructural features such as grain size and phase features. Metallographic etching is used to reveal particular structural characteristics of a metal. This is essential since these structural characteristics are not visible in the polished mirror like surface in the metal. Etching selectively alters these microstructural features based on composition, stress, or crystal structure. Before a specimen is etched, it should be inspected for polishing defects such as scratches, pits, pulled out inclusions, and voids. The most common technique for etching is selective chemical etching and numerous formulations have been used over the years. Other techniques such as molten salt, electrolytic, thermal and plasma etching have also found specialized applications (Kallol and Vivek, 2016).

2.2.5.1 Chemical etching:

Chemical etching is accomplished by immersing the specimen in (or swabbing it with) a suitable etchant until the required structure is revealed. Etching is done in petri-dishes or in other suitable containers with loose covers to prevent excessive evaporation of the solvent, particularly alcohol solutions. Glass containers can be used for all etchants except hydrofluoric acid solutions, where the container should be made of polyethylene or other suitable material. By the use of tongs or other convenient handling device, the surface of the specimen is immersed in the etchant with some agitation to ensure that fresh etchant is in contact with the specimen all the times. During etching, most metals lose their bright appearance, indicating that etching is taking place. If the etching procedure calls for swabbing, the surface of the specimen can be swabbed with cotton saturated with the etchant, or the specimen can be immersed and swabbed while in the solution. When etching is complete, the specimen is rinsed in running water and then in alcohol, followed by drying in a stream of warm air (hand dryer). After etching the specimen surface is observed under the optical-microscope for studying its microstructure. Care should be taken while etching so that the hand is not affected by the etching (Kallol and Vivek 2016).

Table 2.2: common types of Etchants, their Compositions and Applications

Etchant	**Composition**	**Applications**	**Conditions**	**Comments**
Keller's etch	190 ml Distilled water 5 ml Nitric acid 3 ml Hydrochloric acid 2 ml Hydrofluoric acid	Aluminium alloys	10-30 second immersion. Use only fresh etchant	
Kroll's Reagent	92 ml Distilled water 6 ml Nitric acid 2 ml Hydrofluoric acid	Titanium	15 seconds	
Nital	100 ml Ethanol 1 -10 ml Nitric acid	Carbon steels, tin, and nickel alloys	Seconds to minutes	
Kallings reagent	40 ml Distilled water 2 grams Copper chloride ($CuCl_2$) 40 ml Hydrochloric acid 40-80 ml Ethanol (85%) or Methanol (95%)	Wrought stainless steel, Fe-Ni-Cr alloys	Immerse or swab for few seconds to a few minutes	

Lepito's Reagent	50 ml Acetic acid 50 ml Nitric acid	High temperature steels	Swab	
Marble's Reagent	50 ml Distilled Water 50 ml Hydrochloric acid 10 grams Copper sulfate	Stainless steels, Nickel alloys	Immersion or swab etching for a few seconds	
Murakami Reagent	100 ml Distilled Water 10 grams $K_3Fe(CN)_8$ 10 grams NaOH or KOH	Wrought Stainless steel, tungsten alloys, silver alloys, SiC, B_4C	Immerse or swab for seconds to minutes	Use fresh
Picral	100 ml Ethanol 2-4 grams Picric acid	Iron and steel, tin alloys	Seconds to minutes	Do not let etchant crystallize or dry explosive

Vilella's Reagent	45 ml Glycerol 15 ml Nitric acid 30 ml Hydrochloric acid	Stainless steel, carbon steel, cast iron	Seconds to minutes	

2.3. Polishing Machine

A polishing machine is a machine designed for polishing the surface of a metal to give a fine and mirror like appearance to the metal with the use of emery paper. The machines differ in their sizes, functions, speed, machine requirement, calibrations, structures and design.

2.3.1 Types of polishing machine

Some of the common polishing machine include:

1. **MODEL MP-2B Metallographic Polishing Machine:**

Model MP-2B Metallographic specimen grinding and polishing machine is equipped with double discs and features steeples speed changing grinding and polishing. It can finish the whole process of rough grinding, fine grinding, rough polishing and finishing polishing for specimen preparing. By adjusting the transducer, it can realize the rotating speed of grinding and polishing disc adjustable from 50 to 1000 rpm. It is equipped with cooling device, used to cooling the sample when grinding, to prevent the sample overheating and destroy metallographic organization. The technical specifications of the model include:

i. Diameter of grinding disc: Ø230mm, rotating speed 50-1000 rpm

ii. Diameter of polishing disc: Ø200mm, rotating speed 50-1000 rpm

iii. Diameter of sand paper: Ø200mm

2. **MOPAO 2DE Metallography Specimen Polishing Machine:**

The grinding-polishing machine is a double desktop, applicable to rough grinding, accurate grinding and polishing of metallographic sample. The machine has a cooling device to cool the sample during grinding and polishing, thus preventing the damage of the metallographic structure caused by overheats of the sample. Its technical specifications are:

i. It has microprocessor control system

ii. It has a steeples speed of 50 – 600 rpm

iii. The machine has two control systems, so it can be operated by two people meanwhile.

The difference between the MOPOA 2DE metallographic polishing machine and the MP-2B model metallographic polishing machine is that the MOPOA 2DE model has two control system, so it can be operated by two operators compared to the model MP-2B which can be operated by a single operator. Also, the MOPOA 2DE model is faster and saves times compared to the model MP-2B.

3. **MODEL MP-1B Metallographic Polishing Machine**

This grinding-polishing machine is a double-disc desktop, operated by two operator simultaneously, applicable to pre-grinding, grinding and polishing of metallographic sample. The machine regulates its speed by a frequency changer, with a speed of 50-1000rpm, thus widening its application. It is an indispensable equipment in making the metallographic sample. It has a cooling device to cool the sample during pre-grinding, thus preventing the damage of the metallographic structure caused by overheat of the sample. Its key specifications include:

i. Working Voltage: 220V 50HZ

ii. Diameter of Grinding Disc: φ230mm speed 50-1000rpm

iii. Diameter of Polishing Disc: φ203mm speed 50-1000rpm

4. **Model MOPAO 260E Metallographic Specimen Polishing Machine**

There are two optional types for Mopao 260E, that is, the 200mm and 250mm working discs. The machine also operates on two working condition based on the steep speed changing status or two level constant speed status. The direction at which the working disc rotates can be chosen at will. The technical specifications of the machine are:

i. The rotating speed of the working disc: 50 – 600 rpm (steeples speed changing) or 150/300 rpm (two level constant speed);
ii. Diameter of working disc: 200mm/250mm;
iii. Power supply: Single phase 220V 50Hz.

5. **Model Mopao 1000 Automatic Metallographic Polishing Machine**

This machine has a digital display rotating speed, it is equipped with beautiful appearance machine shell and full stainless steel parts which never rust. The grinding and polishing discs have two functions: two-level constant speeds and steep speed changing. The discs head can be set to steeples speed changing status. It is equipped with grinding and polishing discs which can be changed swiftly and multi-specimen clamping holder. It has the ability to process six specimens at same time. The advantage it has over the MP-1B, MOPOA 260E, MOPOA MP-2B, and MOPOA 2DE is that it has the ability to process six specimens at the same time which then leads to reduction in production time and the machine is automated. This lead to a great reduction in error during polishing. It takes shorter time to prepare specimen. The machine also has the ability to withstand rusting compared to the other machines. Its specifications are:

i. It has a loading range of 1- 200N
ii. Specimen preparing time: 0 – 999 sec
iii. Max. diameter of specimen: Ø30mm

iv. Diameter of grinding & polishing disks: Ø250mm

v. Power supply: Single phase, 220V, 50Hz

6. Model Mopao 300S Metallographic Polishing Machine:

The Mopao 300S is equipped with a beautiful appearance machine shell and a full stainless steel part that never rust. It has a double working disc. The working discs can be changed and replaced swiftly. There are two-level constant speeds for working discs. The model has its technical specifications which include:

i. Rotating speed of working disc: 150 / 300rpm (two-level, constant)

ii. Diameter of working disk: 300mm

iii. Power supply: three phases, 380V, 50Hz

2.4. MICROSCOPES USED FOR METALLOGRAPHIC EXAMINATION

Some of the microscopes commonly used in the laboratories for metallographic examination of specimens are:

i. Transmission electron microscope (TEM);

ii. Scanning electron microscope (SEM);

iii. X-ray diffraction microscope (XRD);

iv. Atomic force microscope (AFM);

v. Near filled scanning optical microscopy (NSOM/SNOM);

vi. Back scattered electron image.

2.4.1 Transmission Electron Microscope:

Transmission electron microscopy (TEM) is a microscopy technique whereby a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a fluorescent screen, on a layer of photographic film, or to be detected by a sensor such as a CCD camera (Zinin, 2011). In TEM, a monochromatic beam of electrons is usually accelerated through a potential of between 40 and 100 kilovolts (kV) and passed through a strong magnetic field that acts as a lens. The resolution of a modern TEM is about 0.2 nm. This is the typical separation between two atoms in a solid. This resolution is 1,000 times greater than a light microscope and about 500,000 times greater than that of a human eye (Zinin, 2011). Transmission electron microscopes with resolution limit up to 0.2nm and magnification up to 800,000 times are used for observing crystal defects such as grain boundary, dislocations, stacking faults, twining etc. (Thomas, 1962). Some of its application includes:

i. Microstructure and nanostructure: size and morphology
ii. Cross-section analysis (layer thickness, interface quality)
iii. Crystal structure determination through electron diffraction
iv. Defect analysis (dislocations, stacking faults, etc.)
v. High resolution images (~0.2 nm resolution)

2.4.2. Scanning Electron Microscopy (SEM):

The scanning electron microscope (SEM) is one of the most versatile instruments available for the examination and analysis of the microstructure morphology and chemical composition characterizations (Weilie *et al.*, 2013).The surface to be examined is scanned with an electron beam and the reflected beam of electrons is collected, then displayed at the same scanning rate on a cathode ray tube (Goldstein, 2003). The image that appears on the screen, which may be photographed, represents the surface features of the specimen. The surface may or may not be polished and etched, but it must be electrically conductive; a very thin metallic coating must be applied to non-conductive materials. Magnifications ranging from 10 to in excess of 50000 diameters and also very great depths of field are possible (Venkannah, 2004). Some of its applications include:

i. It can be as essential research tool in fields such as life science, biology, gemology, medical and forensic science, and metallurgy.
ii. It has practical industrial and technological applications such as semiconductor inspection, production line of very small products and assembly of microchips for computers.
iii. Scanning electron microscope can detect and analyze surface fractures, provide information in microstructures, examine surface contaminations, reveal spatial variations in chemical compositions, provide qualitative chemical analyses and identify crystalline structures.
iv. SEM is also widely used to identify phases based on qualitative chemical analysis and/or crystalline structure (Argast *et al.*, 2004).

2.4.3. X-RAY Diffraction Microscope:

X-ray microscope uses electromagnetic radiation in the soft x-ray band to produce magnified images of objects. Since it penetrate most objects, there is no need to specially prepare them for microscopy observations (Moore, 1997). Unlike visible light, x-rays do not reflect or refract easily, and they are invisible to the human eye. Therefore, the basic process of an x-ray microscope is to expose film or use a charge coupled device (CCD) detector to detect these rays that pass through the specimen. It is a contrast imaging technology using the difference in absorption of soft x-rays in the water windows region (wavelength: 2.34-4.4nm, energies: 280-530 eV) by the carbon atom (main element composing the living cell) and the oxygen atom (main element for water) (Kirstein and Stefan, 1999). Its applications include:

i. determine crystal structures using Rietveld refinement;
ii. It can be used to make textural measurement, such as the orientation of grains in a polycrystalline sample;
iii. determine of modal amounts of minerals (quantitative analysis);
iv. characterize thin films samples by:
    a. determining lattice mismatch between film and substrate and to inferring stress and strain;
    b. determining dislocation density and quality of the film by rocking curve measurements;
    c. measuring super lattices in multilayered epitaxial structures; and
    d. Determining the thickness, roughness and density of the film using glancing incidence X-ray reflectivity measurements. (Klug and Alexander, 1974)

2.4.4. Atomic Force Microscope (AFM):

Atomic force microscopy is a high resolution type of scanning probe microscopy that allows us to see and measure surface structure in length scale 10nm-100μm with unprecedented resolution and accuracy (lateral resolution~30 nm, vertical resolution~0.1 nm). Atomic force microscope provides height information of the sample, it also Provides a three-dimensional surface profile (ability to magnify in the X, Y, Z axes) (Bullen, 2010).

The advantages of Atomic Force Microscopy includes:

i. It provides a three dimensional image of a sample;

ii. Samples viewed by AFM do not require any special treatments (such as metal or carbon coatings) that would irreversibly change or damage the sample.

The disadvantages of Atomic Force Microscopy includes:

i. It possesses a single scan image size

ii. Compared to the SEM which can image an area on the order of square millimeters with a depth of field on the order of millimeters, the AFM can only image a maximum scanning area of about 150x150 micrometers and a maximum height on the order of 10 – 20 micrometers

iii. The AFM is slow in scanning image compared to the SEM (Bryant *et al.,* 1988)

2.4.5. Near-Field Scanning Optical Microscopy (NSOM/SNOM):

Near field scanning optical microscopy is based on scanning an arbitrarily small aperture which is illuminated from the backside at a close but constant distance across a sample surface and recording optical information pixel-by-pixel collecting either transmitted, reflected, or fluorescence light to form an image. The resolution of the optical image is solely defined by the size of the aperture due to the strong localization of the light to the aperture size at close distances, which is called the near-field (Kirstein and Stefan, 1999).

Advantages of Near-Field Scanning Optical Microscopy

i. NSOM provides simultaneous measurements of the topography and optical properties (fluorescence) between surface nano features and optical/electronic properties; and
ii. It useful for the studying the inhomogeneous materials or surfaces, like nanoparticles, polymer blends, porous silicon, biological systems.

Limitations of Near-Field Scanning Microscopy

i. Practically zero working distance and an extremely small depth of field;
ii. Extremely long scan times for high resolution images or large specimen areas;
iii. Very low transmissivity of apertures smaller than the incident light wavelength;
iv. Only features at the surface of specimens can be studied;
v. Fiber optic probes are somewhat problematic for imaging soft materials due to their high spring constants, especially in shear-force mode (Davidson and Cummings, 2015).

2.7.6. Back Scattered Electron Imaging:

Backscattered electron (BSE) imaging of biological sample has long been employed as a complementary technique to secondary electron (SE) imaging in scanning electron microscope (SEMs). This provide an image of material that has a high atomic number located on or in the sample. A BSE is defined as one which has undergone a single or multiple scattering events and which escapes from the surface with an energy greater than 50 eV (Weilie *et al.*, 2013). When a primary beam electron interacts with one or more atomic nuclei, reversing its direction of travel but resulting in little energy loss, causing it to escape from the surface of the specimen, it is referred to as a backscattered electron (Gwynn and Richards, 1995). Its applications include:

i. It is used to detect contrast between areas with different chemical compositions.
ii. It can be used to form an electron backscatter diffraction (EBSD) image that can be used to determine the crystallographic structure of the specimen.

2.5. Design and Fabrication

2.5.1 Manufacturing Process

The following are the various manufacturing processes used in fabrication;

i. **Primary Shaping processes:** These processes are used for the preliminary shaping of the machine components. The common operations used are casting, forging, extruding, rolling, drawing, bending, shearing, spinning, powder metal forming, squeezing, etc.
ii. **Machining processes:** These are used for giving final shape to the machine component, according to planned dimensions. Some of the common operations used for this process are turning, planning, shaping, drilling, boring, reaming, sawing, broaching, milling, grinding, etc.
iii. **Surface finishing processes:** They are used to provide a good surface finish for the machine component. The common operations used for this process are polishing, buffing, honing, lapping, abrasive belt grinding, barrel tumbling, electroplating, super finishing, sherardizing, etc.
iv. **Joining processes:** The common operations used for this process are welding, riveting, soldering, brazing, screw fastening, pressing, sintering, etc. they are used for joining machine components.
v. **Processes effecting change in properties:** These processes are used to impart certain specific properties to the machine components so as to make them suitable for particular

operations or uses. Such processes are heat treatment, hot-working, cold-working and shot peening (Khurmi and Gupta, 2004).

2.5.2. Design parameters

Large number of materials are available for engineering applications. The choice of a material for a given application can determine, to a large extent, the ultimate success or failure of the system as it is the final practical decision in the design process. The physical properties of the materials were used as the basic parameters guiding the selection. The factors, properties to be considered include cost effectiveness, availability, high or low tensile, strength as may be required, rigidity and/or flexibility, heat and corrosion resistance, etc. The function, objective and the constraint of each unit of the polishing machine must be known for the selection of the candidate material. This will be used in selecting appropriate material for the construction of the laboratory polishing machine.

2.5.2.1 The polishing frame

The function of the polishing frame was to provide housing for the component such as the electric motor, the shaft, the two pulley, the belt and the ball bearing. It provides rigidity, strength, ability to carry its own weight and ability to retain high strength even after shaping. The constraint considered was cost. The polishing frame requires a material that is durable, moderately strong and that can withstand its own weight that was why galvanized steel was used in the fabrication. It must possess good fabricability, readily available and not expensive, and they serve as a basis for the choice of material that was eventually recommended for the design of the polishing frame of the machine.

Cost Price: The price of the material that will be chosen must be relatively cheap.

Weldability: To enhance proper joining of the flat sheets as well as fabricability the material must be easy to weld.

2.5.2.2 The rotating disc

The function of the rotating disc is to hold the emery paper that will affect the grinding and polishing of the metals so as to give a mirror like appearance. This is determined by considering some factors such as the speed of the rotating disc, the diameter of the disc. The design factors that influenced the selection include the strength, corrosion resistance. The major constraints considered were cost and availability. Since cost is a crucial factor, locally available candidate material must be given consideration.

2.5.2.3 The shaft

The purpose of the shaft is to transmit rotational motion from the pulley to the rotating disc. The objective is that it should be able to withstand the stress and the weight of the other components attached to it, and it must also have the ability to withstand twisting due to torque moment and compressive force due to weight of other components attached to it. Generally, Cost and availability of the material was a major constraint considered in selecting the appropriate candidate material.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Materials

The following materials were obtained for the construction of the laboratory polishing machine, which were all purchased from various places in Ladipo Market, Owode-Onirin in Lagos State.

i. Mild steel of 1mm thickness was used for the cover plate.
ii. Galvanized steel of 1mm thickness was used for the metal clip
iii. Stainless steel 200mm diameter was used for the rotating disc;
iv. Angle bar galvanized steel sheet of 3mm thickness for the frame (metal casing);
v. Impregnated rubber for the belt;
vi. Circular rod bar mild steel for the shaft; and
vii. Mild steel for the pulley.

3.2 Equipment

The equipment used during the course of this project for fabricating the machine components include:

i. Lathe machine;
ii. Hack saw;
iii. Hand grinding machine;
iv. Electric arc welding machine;
v. Hand drilling machine;
vi. Scriber;
vii. The gelatin cutting machine;

viii. The folding machine;

ix. Measuring tape; and

x. Bench vice.

3.3 Methodology

This section describe the process that were used in the construction of the laboratory polishing machine

3.3.1 Description of the method used in the construction and manufacturing process of the polishing machine

i. **The cover plate:** The cover plate used is made of thin mild steel sheet. The sheet metal were cut with the use of the gelatin machine (plate 3.6) into various sizes. After which the sheet were cut into various sizes required for the production of the polishing machine, the sheet plate were then taken to the folding machine (plate 3.7) so as to fold the sheet into the required shape needed.

ii. **Rotating disc:** The rotating disc is made up of stainless steel. The disc underwent grinding and cutting process with the use of the hand grinding machine (plate 3.8) so as to cut the disc into the required size and to remove the rough edges. After this, the disc was then taken to the turning section were the surface of the disc was then smoothen. The last process was the drilling of the rotating disc to a diameter of 20mm with the use of a tailstock quill (plate 3.12) so as to enable proper fitting with the shaft.

iii. **Frame:** The frame purchased was a long angular bar galvanized steel. The frame were held together by a bench vice (3.9) after which hand grinding machine (plate 3.8) was used to cut the frame into the required length suitable for the design of the polishing machine, after the cutting, the edges of the frame that were cut were then polished so as to remove the rough edges.

iv. **The shaft:** The shaft as obtained was a long cylindrical rod. The shaft used was ductile material made of mild steel. The rod was then cut to the required length with the use of the electric hand cutting machine (plate 3.8). After the cutting, the shaft was then taken to the lathe machine (plate 3.10) for further processing. On the lathe machine, the shaft was chamfered, after chamfering it was then knurled. The purpose of the shaft is to transmit power from one place to another

v. **The rotating belt:** the rotating belt used had a diameter of 430mm. V-belt was used because it provides a longer life and it can be easily installed and removed and one major advantage of the belt is that its operation is quiet

vi. **The key:** the key used was a mild steel. The key was cut using the hand grinding machine (plate 3.8) and it was inserted between the shaft and the hub in other to prevent relative motion between them.

3.3.2 Assemblage of the Machine Component

i. **The rotating disc, the shaft and the pulley:**

In assembling the machine, the shaft was fastened to the disc and then precisely positioned. Bearings and the main shaft were assembled and then installed in the bearing housing. After that the polishing disc was mounted on to the shaft, and the motor was connected to the shaft through the pulleys, belt and coupling.

ii. The frame and the cover plate:

The frame and the cover plate were assembled together by welding process and by joining process (bolt and nut) which involves the process of drilling the cover plate and the frame with a drill bit of 5mm (plate 3.15) and then joined together with a screw of 5mm diameter.

3.3.3. Pictures of different components of the Laboratory Polishing machine and it assemblage in 2D and 3D

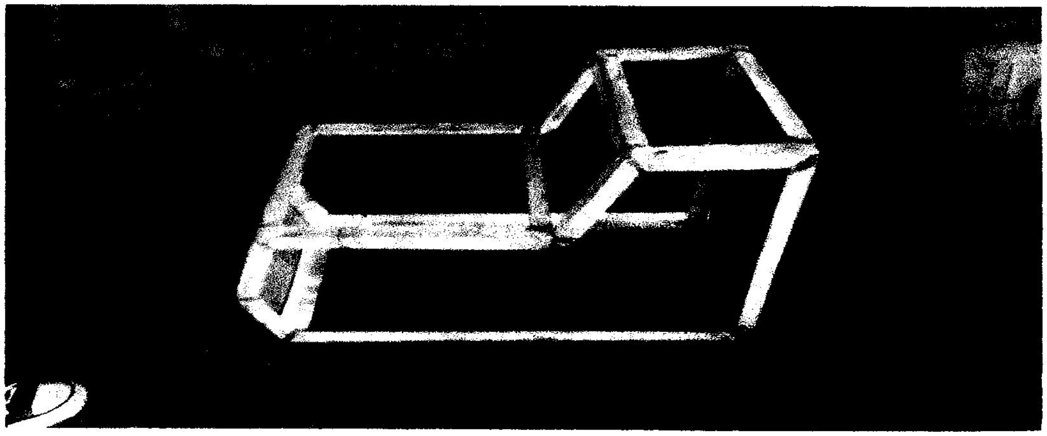

Plate 3.1: The angular bar of the Polishing Machine.

Plate 3.2: The electric motor of 1hp and bigger pulley

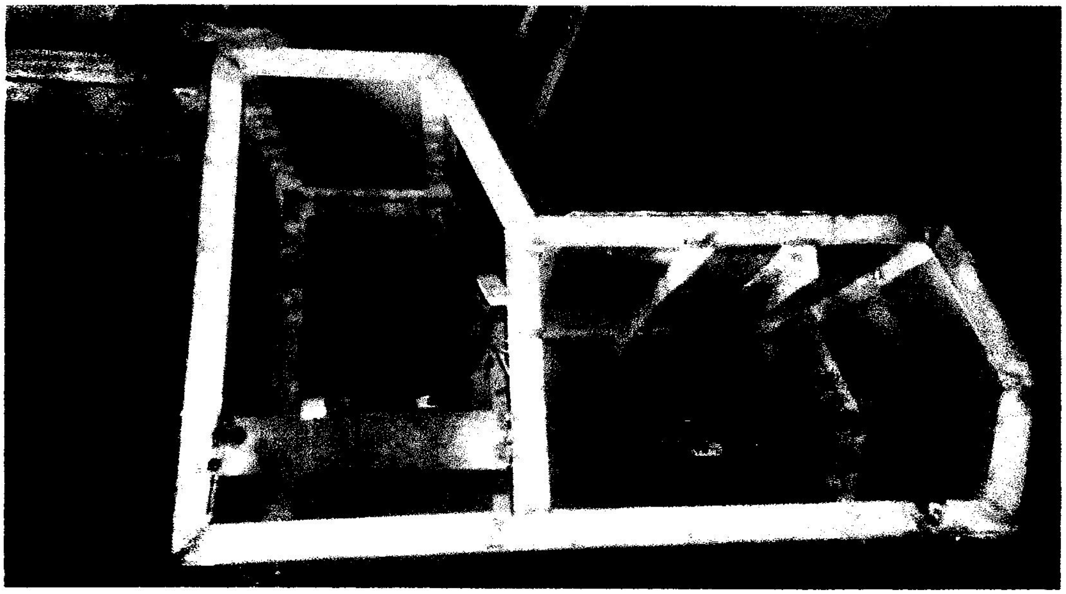

Plate 3.3: The assembly of the motor, the shaft, the pulley, the belt and the connecting rod.

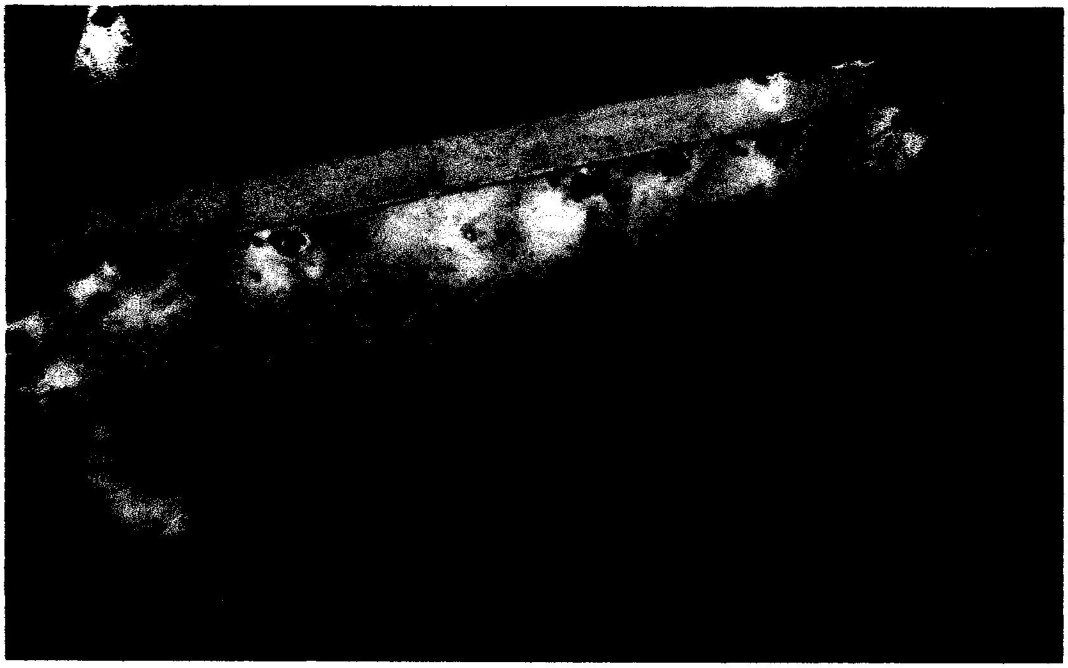

Plate 3.4: The welded plate and the angular bar

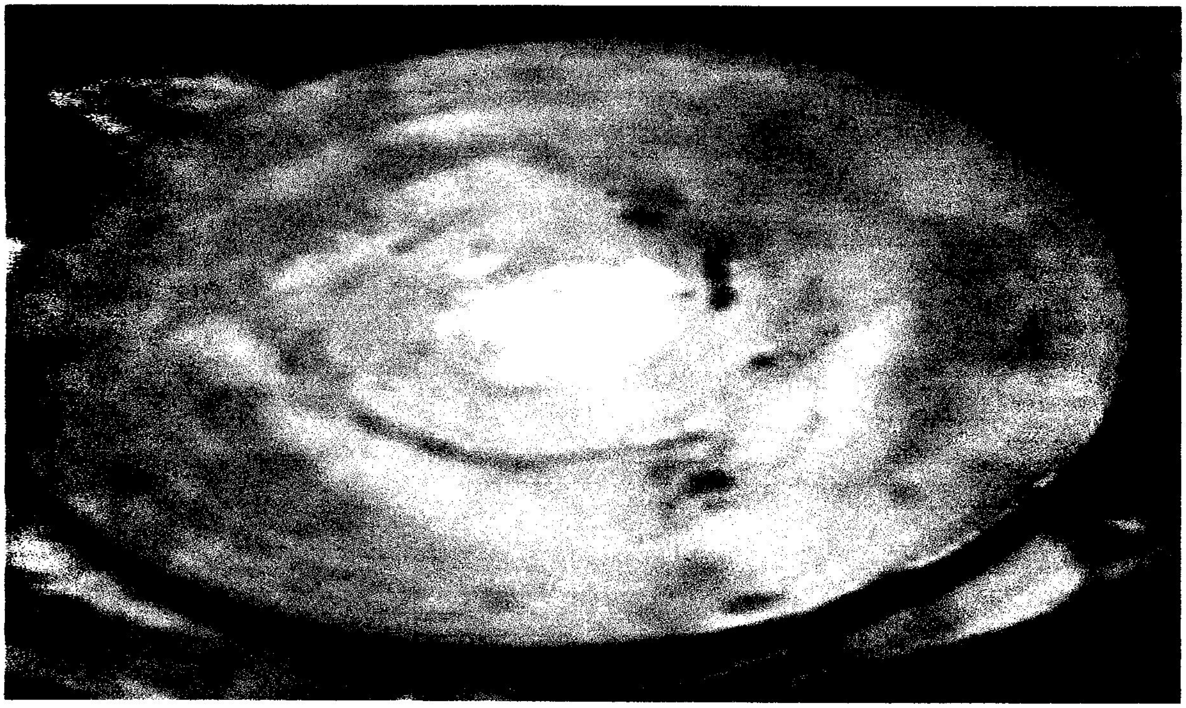

Plate 3.5: The rotating disc made of stainless steel

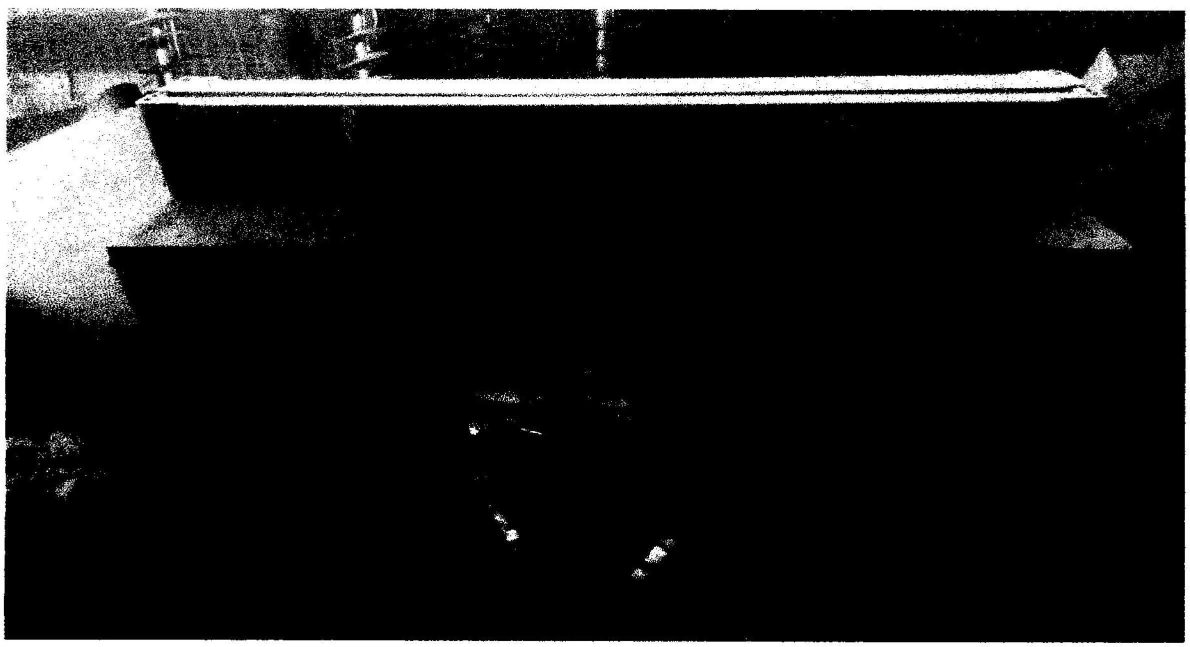

Plate 3.6: The Gelatin Machine used for cutting sheet plate

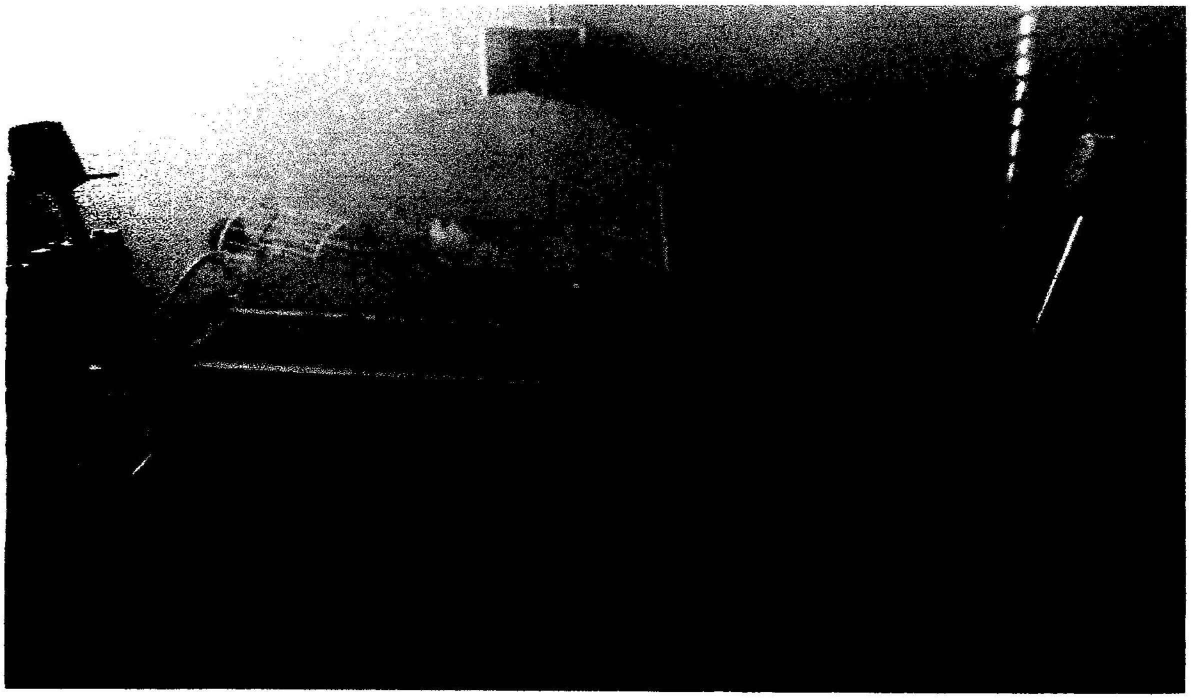

Plate 3.7: The Folding Machine used for bending sheet plate

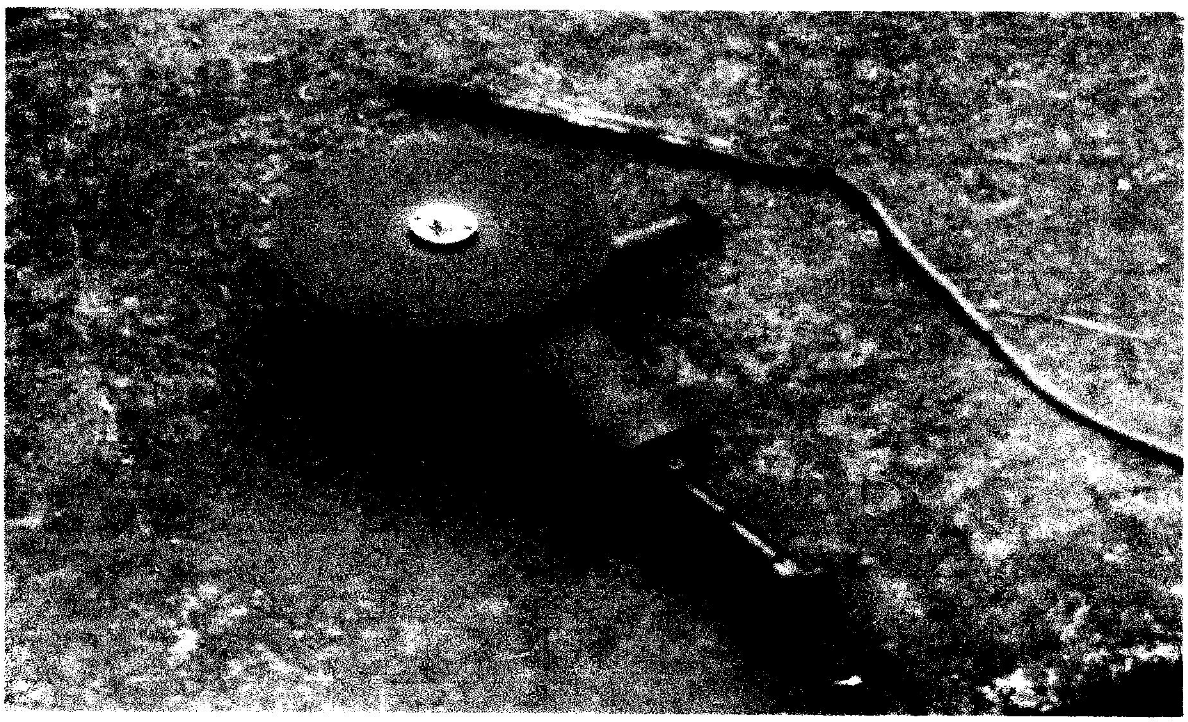

Plate 3.8: The hand grinding machine used for cutting and grinding

Plate 3.9: The bench vice used for holding the angular bar

Plate 3.10: The Lathe machine

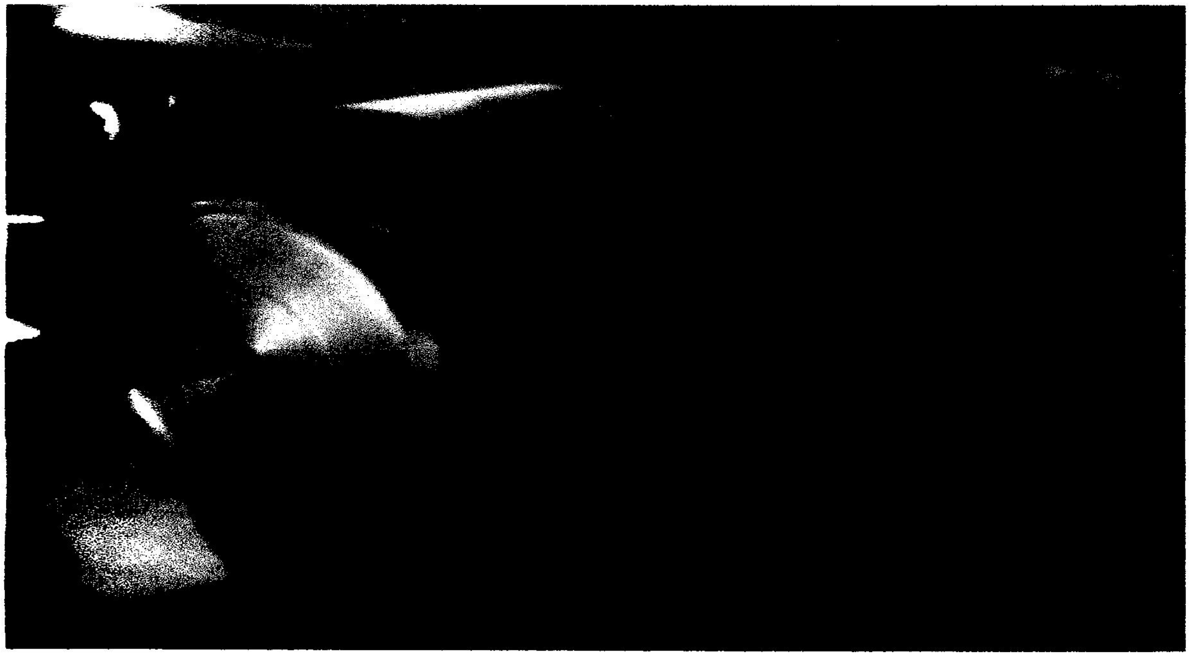

Plate 3.11: The rotating disc held by the spindle

Plate 3.12: The Tailstock quill used for drilling the rotating disc

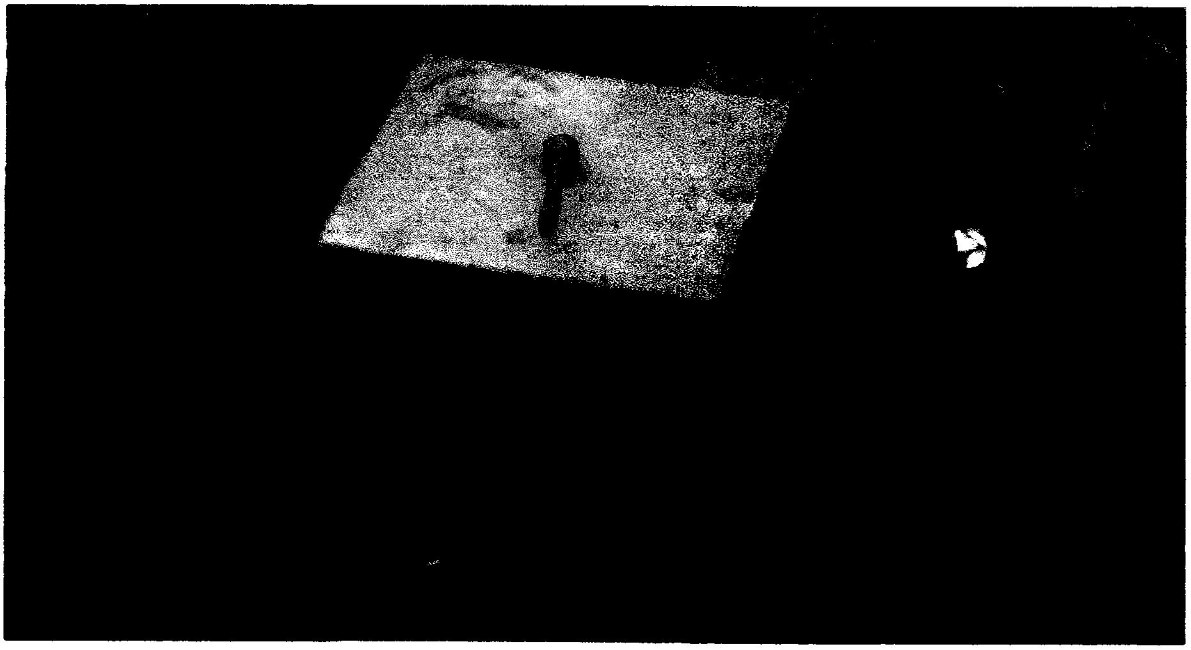

Plate 3.13: The electric arc welding machine used

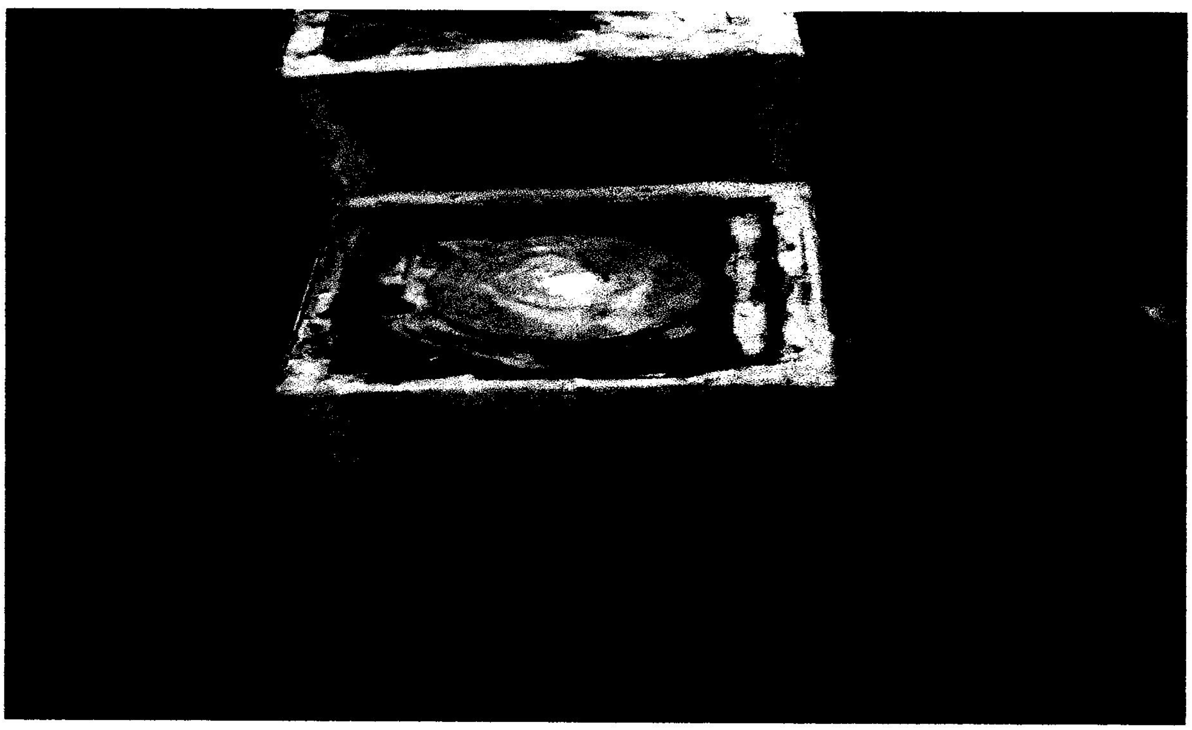

Plate 3.14: The front view of the polishing machine showing the body filler at the edges

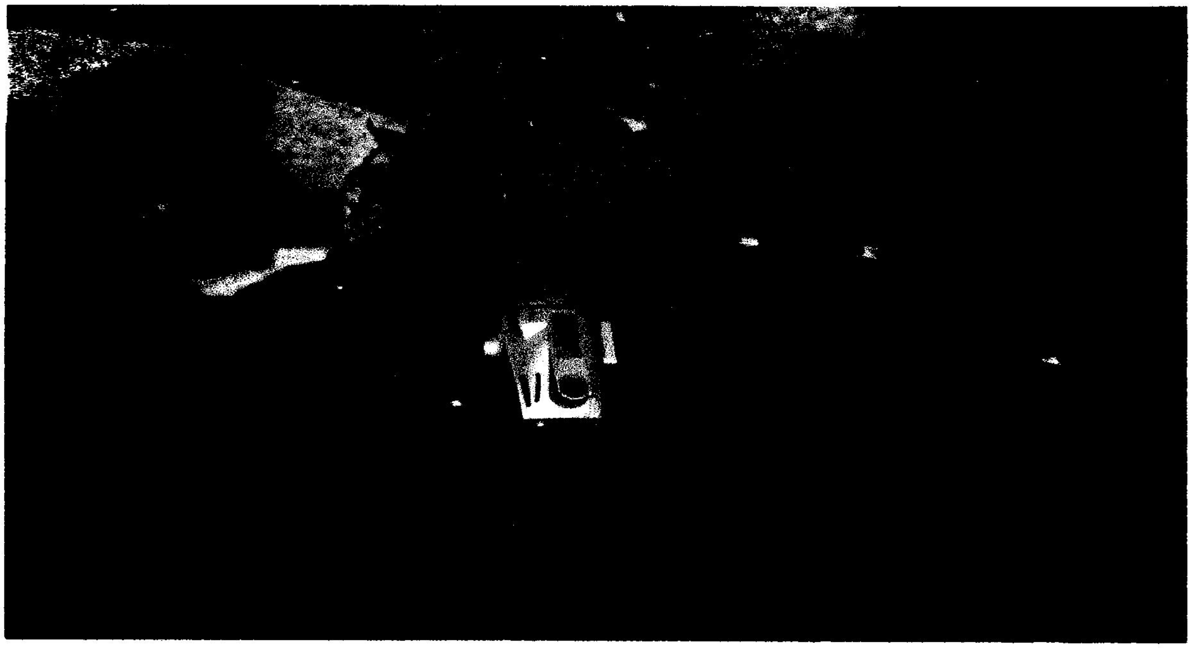

Plate 3.15: The drilling machine with drill bit of 5mm used for drilling

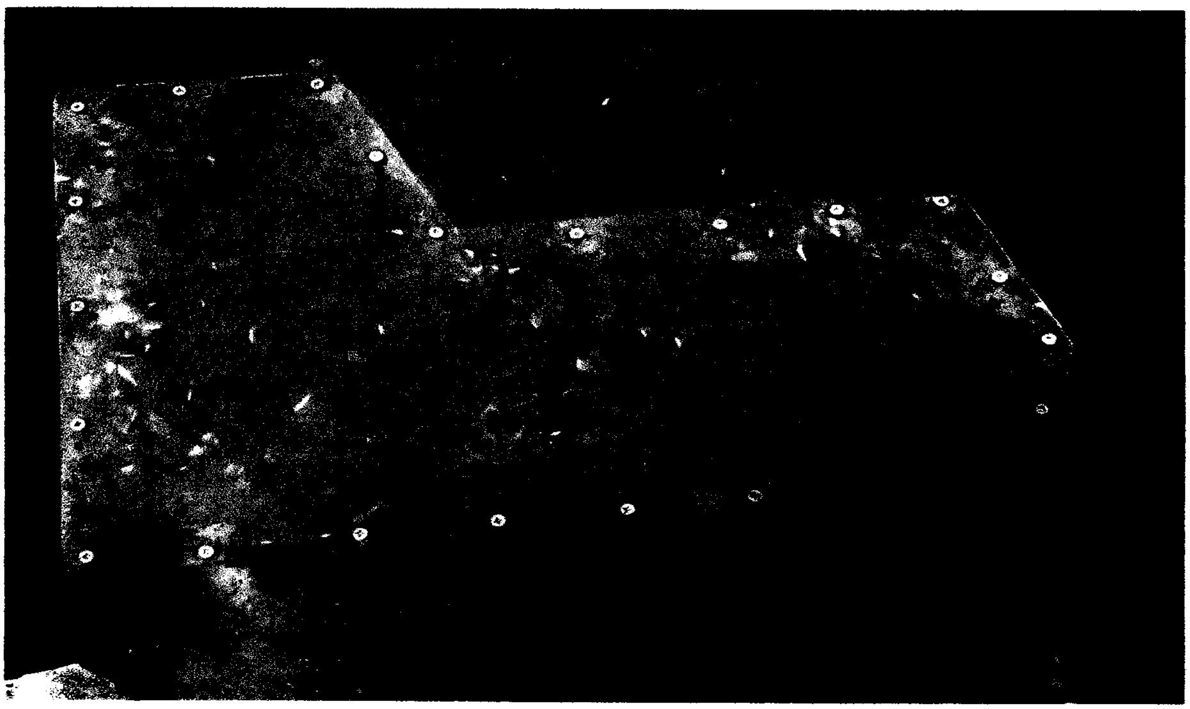

Plate 3.16: The cover plate showing the bolt used for joining the cover plate and the angular bar

2D DESIGN OF THE VARIOUS SECTION OF THE LABORATORY POLISHING MACHINE.

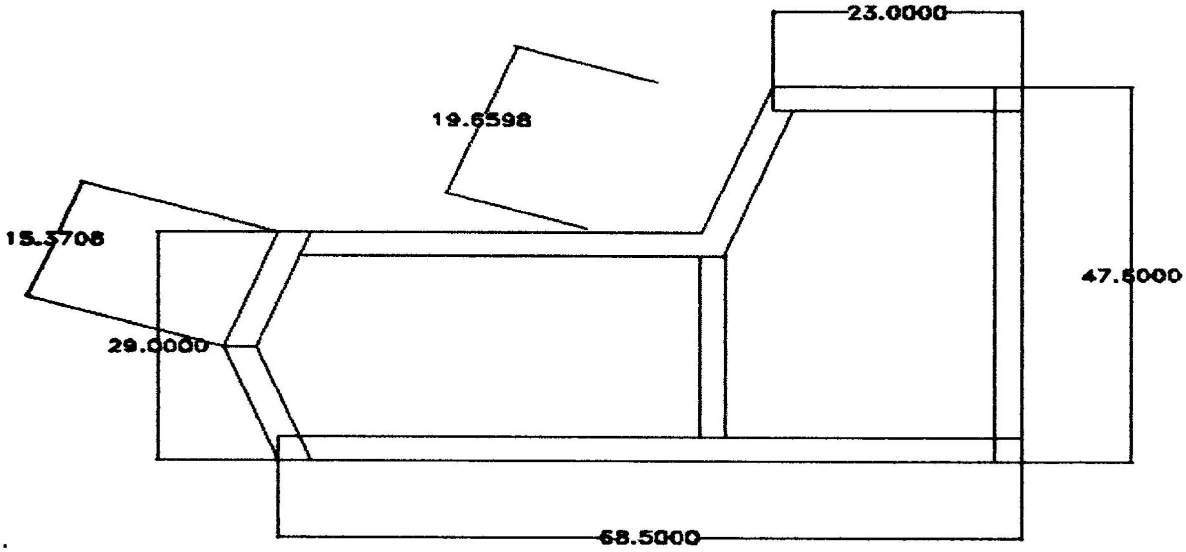

Figure 3.1: 2D Design of the body of the Laboratory Polishing Machine

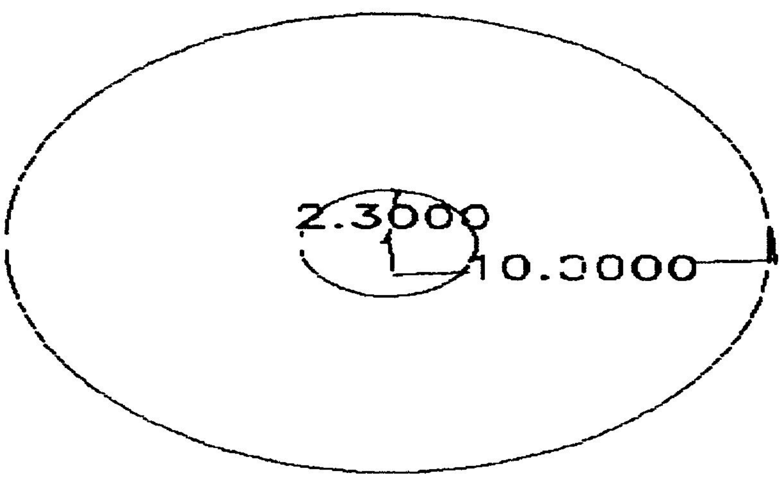

Figure 3.2: 2D design of the rotating disc of the Polishing Machine of radius 10cm

3D DESIGN OF THE VARIOUS COMPONENT OF THE LABORATORY POLISHING MACHINE

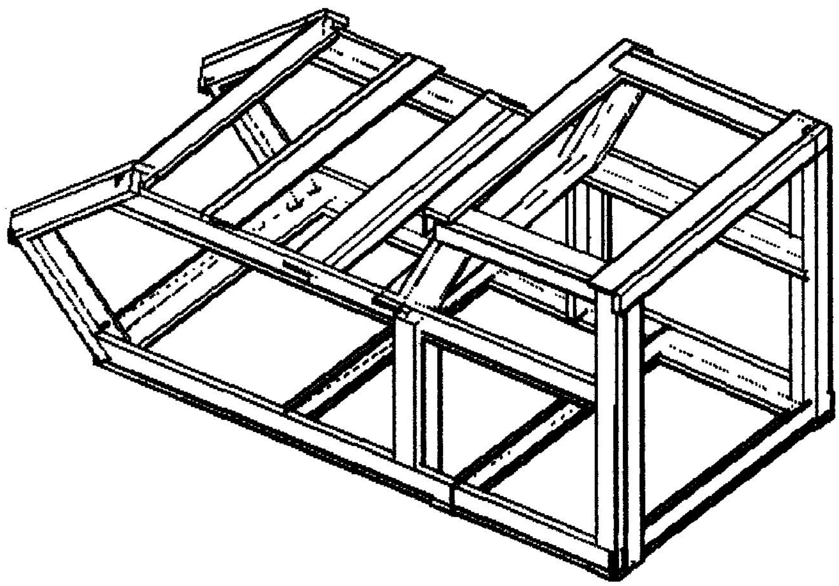

Figure 3.3: 3D Design of the frame of the Laboratory Polishing Machine

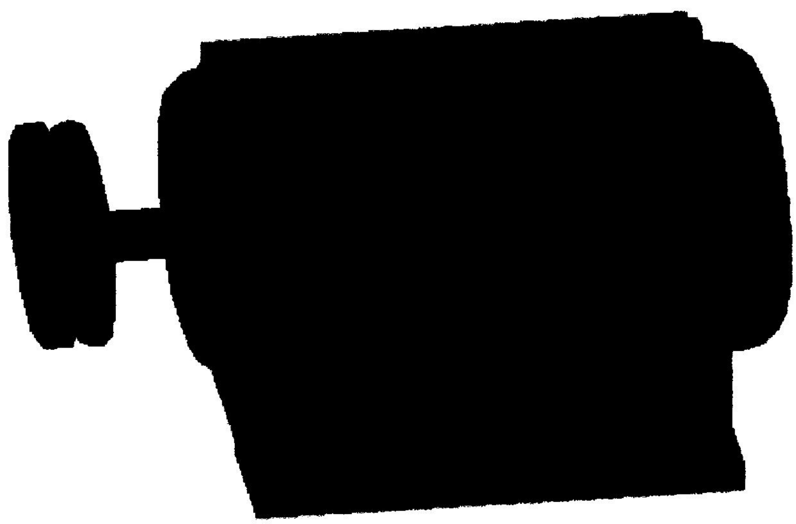

Figure 3.4: 3D representation of the Electric Motor with a Pulley

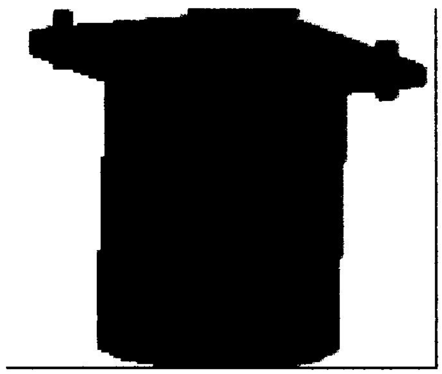

Figure 3.5: 3D representation of the Shaft Housing with the Bearing

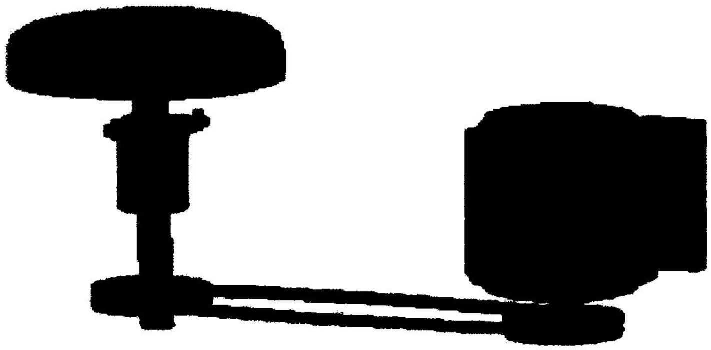

Figure 3.6: 3D Design of the Motor, the Shaft, the Pulley, the Belt and the Rotating disc connected together

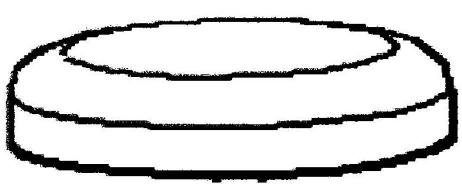

Figure 3.7: 3D Design of the Rotating disc with 200mm diameter

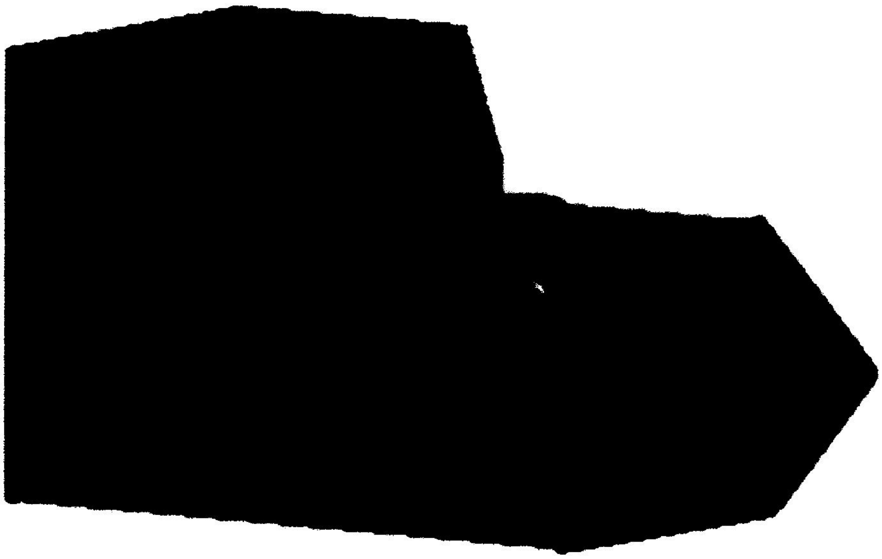

Figure 3.8: 3D Design of the Laboratory Polishing Machine

3.3.4 Design calculation for the development of a laboratory polishing machine

Technical parameters:

a) Polishing pad diameter: 200mm (Single disk)

b) Rotation rate: 1400 rev/min

c) Motor: IP44BINS.CR; 1HP; 0.75KW, 220V, 50HZ

i. Determination of the speed of the polisher:

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \quad \text{.......... 3.1}$$

Where:

N_1 = Speed of the motor in revolution per minute (rev/min)

N_2 = Speed of the polisher in revolution per minute (rev/min)

D_1 = Diameter of the motor pulley in millimeter (mm)

D_2 = Diameter of the polisher pulley in millimeter (mm)

Data:

$N_1 = 1500$ rev/min

$N_2 =??$

$D_1 = 80$ mm

$D_2 = 60$ mm

Using equation 1

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

$$\frac{1500}{N_2} = \frac{60}{80}$$

$$60 \times N_2 = 1500 \times 80$$

$$60 \times N_2 = 1500 \times 80$$

Making N_2 the subject of the formula

$$N_2 = \frac{1500 \times 80}{60}$$

$N_2 = 2000$ rev/min ………………………………………….. ………………….. 3.2

Therefore, the maximum speed for polisher N_2 is 2000 rev/min

ii. Tension in the belt:

T_1 =Tension in the tight side of the belt in Newton(N)

T_2 = Tension in the slack side of the belt in Newton (N)

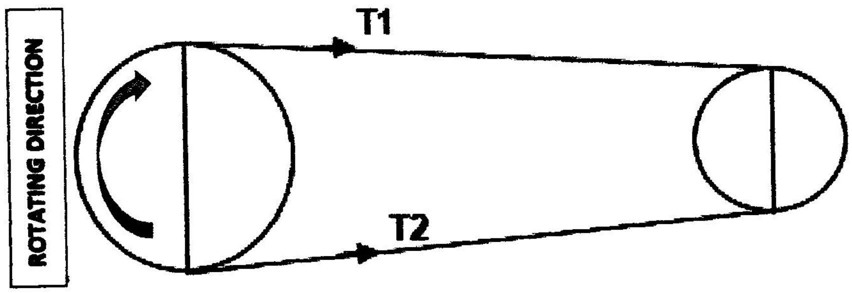

Figure 3.9: A Simple Belt and Pulley Drive

The tight side of the belt is usually at the top and the bottom and the centre line may be horizontal, vertical or inclined.

$$2.3\log\left[\frac{T_1}{T_2}\right] = \mu.\theta.\mathrm{cosec}\beta \quad (3.3)$$

$$\theta = 180° - 2\alpha \quad (3.4)$$

$$\sin\alpha = \frac{R-r}{c} \quad (3.5)$$

Where:

μ = Coefficient of friction between belt and pulley

θ = Angle of contact on the motor pulley in radian (rad)

β =Groove angle of the pulley in degree (°)

α =Coefficient of increase of the belt length per unit force in degree (°)

R =Radius of the motor pulley in millimeter (mm)

r =Radius of the polisher pulley in millimeter (mm)

c =Centre distance between the two pulleys

Centrifugal tension T_c: This is the force which tends to cause the belt to leave the pulley and reduces the power that may be transmitted. The speed of the V-belt must be 5 to 50m/s.

Maximum tension, T: This is highest tensional force that can be acted on the belt according to the (Khurmi and Gupta, 2004).

$T_c = mV^2$ 3.6

$T = \sigma A$ 3.7

$T_1 = T - T_c$ 3.8

$$V_1 = \frac{\pi N_1 D_1}{60}$$

$$V_2 = \frac{\pi N_1 D_1}{60}$$

$V_1 = V_2 = V$ 3.9

$m = \rho \times A \times L$ 3.10

$A = b \times t$ 3.11

T_c = Centrifugal Tension of the belt in Newton (N)

T = Maximum Tension of the belt in Newton (N)

m = Mass of the belt per meter length in kilogram per meter (kg/m)

V = Belt velocity in meter per second (m/s)

ρ = Belt density in kilogram per meter cube (kg/m^3)

A = Cross sectional area of the belt in square millimeter (mm^2)

b = Belt width in millimeter (mm)

t = Belt thickness in millimeter (mm)

α = Allowable stress in Newton per square millimeter (N/mm^2)

iii. Determination of maximum tension, T:

Data:

$\boldsymbol{\sigma = 1.7\ N/mm^2}$ For rubber belt 3.12

Assuming:

b = 15 mm, t = 10 mm

$\mathbf{A = b \times t}$

$\mathbf{A = 15 \times 10}$

$\mathbf{A = 150\ mm^2}$ 3.13

Recall:

$T = \sigma A$

$T = 1.7 \times 150$

$\mathbf{T = 255\ N}$.. 3.14

iv. Determination of mass of the belt, m

Data:

$\rho = 1250\ kgm^3$, Rubber density according to the (Allen and Alfred, 1983)

$A = 150\ mm^2$

$A = 150 \times 10^{-6}\ m^2$

$m = \rho \times A \times l$

$m = 1250 \times 150 \times 10^{-6} \times l$

$\mathbf{m = 0.1875\ kgm^{-1}}$ 3.15

v. Belt velocity, V:

Data:

$N_2 = 2000 rev/min$, The speed should not exceed $2000 rev/min$

Recall that:

$D_2 = 60\ mm$

$D_2 = 0.06\ m$

$$\mathbf{V = \frac{\pi N_1 D_1}{60}}$$

$$V = \frac{\pi \times 2000 \times 0.06}{60}$$

$\mathbf{V = 6.284\ m/s}$ 3.16

vi. Determination of speed centrifugal tension, Tc:

Data:

$m = 0.1875\ kgm^{-1}$ (From equation 15)

$v = 6.284\ ms^{-1}$ (From equation 16)

$T_c = mv^2$

$T_c = 0.1875 \times 6.284^2$

$\mathbf{T_c = 7.40\ N}$ 3.17

vii. Determination of tension in the tight sideT_1:

Data:

$T = 255\ N$ (From equation 14)

$T_c = 7.40\ N$ (From equation 17)

$T_1 = T - T_c$

$T_c = 255 - 7.40$

$\mathbf{T_1 = 247.59\ N}$ **3.18**

viii. Determination of coefficient of increase of the belt length per unit force,α

Data:

$$R = \frac{D_1}{2}$$

Where:

$D_1 = 80$

$$R = \frac{80}{2}$$

R = 40 mm.. 3.19

$$r = \frac{D_2}{2}$$

Where:

$D_2 = 60$

$$r = \frac{60}{2}$$

r = 30 mm **3.20**

Taken:

C = 300 mm (Assumption)

Recall:

$$\sin\alpha = \frac{R - r}{c}$$

$$\sin\alpha = \frac{40 - 30}{300}$$

$\sin\alpha = 0.0333$

$\alpha = \sin^{-1} 0.0333$

$\boldsymbol{\alpha = 2°}$.. 3.21

ix. Determination of angle of contact(θ):

Data:

Recall that: $\alpha = 2°$

$\theta = 180° - 2a$

$\theta = 180° - (2 \times 2°)$

$\theta = 180° - 4°$

$\theta = 176°$

$$\theta = \frac{176° \times \pi}{180°}$$

$\theta = 3°$ 3.22

To convert to radian that will be $3 \times 0.0175 = 0.054$ rad

x. Determination of Tension in the slack side (T_2):

Data:

$T_1 = 247.56N$ (From equation 3.18)

$\mu = 0.3$, For rubber material (Khurmi and Gupta, 2004)

$\theta = 3°$ (From equation 3.22)

$2\beta = 30°$, Groove angle of the pulley

$\beta = 15°$

$$2.3 \log\frac{T_1}{T_2} = \mu\theta\text{cosec}\beta$$

$$2.3 \log\frac{T_1}{T_2} = 0.3 \times 3 \times \text{cosec}15$$

$$2.3 \log\frac{T_1}{T_2} = 3.4773$$

$$\log\frac{T_1}{T_2} = \frac{3.4773}{2.3}$$

$$\log\frac{T_1}{T_2} = 1.5119$$

$$\frac{T_1}{T_2} = 10^{1.5119}$$

$$\frac{T_1}{T_2} = 32.5\ N$$

$$T_2 = \frac{T_1}{32.5}$$

Where $T_1 = 247.56$

$$T_2 = \frac{247.56}{32.5}$$

$\mathbf{T_2 = 7.6\ N}$ **3.23**

xi. Design analysis of the power transmitted per belt:

$\mathbf{P = (T_1 - T_2)V}$ **3.24**

P = Power transmitted in watt (W)

T_1 = Tension in the tight side of the belt (N)

T_2 = Tension in the slack side of the belt (N)

V = Belt velocity m/s^1

(Khurmi and Gupta, 2004):

xii. Determination of power transmitted, P

Data:

$T_1 = 247.56N$ (From equation 3.18)

$T_2 = 7.6N$ (From equation 3.23)

$V = 6.284ms^{-1}$ (From equation 3.16)

$P = (T_1 - T_2)V$

$P = (247.56 - 7.6)6.284$

$P = 1508\ W$ 3.25

xiii. Design analysis of the length of the belt, L

$\mathbf{L = \pi(R - r) + 2C + \frac{(R-r)^2}{C}}$ **3.26**

xiv. Determination of the length of the belt, L

Data:

R = 40 mm

r = 30 mm

C = 300 mm

$$L = \pi(R - r) + 2C + \frac{(R - r)^2}{C}$$

$$L = \pi(40 + 30) + (2 \times 300) + \frac{(40 - 30)^2}{300}$$

$$L = 70\pi + 600 + \frac{10^2}{300}$$

$$L = (70 \times 3.142) + 600 + 0.3333$$

L = 820 mm 3.27

3.3.4.1 Design analysis of the shaft:

Shaft is a rotating machine element which is used for the purpose of transmitting power from one place to another. It is a circular solid or hollow in cross section and is always subjected to torsional loads, bending loads and axial loads. The shaft used in this project was made of mild steel. Stresses were induced in the shaft such as:

a) shear stress due to torsional loads;

b) The bending stress (tensile or compressive) due to the forces acting upon machine element like pulleys as well as due to the weight of the shaft and other element to be rotated by the shaft.

Assumptions:

a) Fatigue and shock are considered

b) The belt on the pulley is at angle 450

Design of shaft of ductile material based on strength is controlled by the maximum shear theory according to the (Shugley, 1980). The maximum permissible shear stress for the mild steel ductile material is $42Nmm^{-2}$ with allowance for keyway according to the (Khurmi and Gupta, 2004). Hence, the shaft of this polishing machine is only subjected to twisting moment or torque due to torsional loads because the belt drive employs to transmit power.

For the belt drive, the torque, T

$T = (T_1 - T_2) R$.. 3.28

T_1 = Tension in the tight side of the belt

T_2 = Tension in the slack side of the belt

R= Radius of the motor pulley

T = Twisting moment or torque pulley in Newton-meter (Nm)

(Khurmi and Gupta, 2004).

xv. **Determination of the torque, T**

Data:

T_1 = 247.5 N (From equation 3.18)

T_2 = 7.6 N (From equation 3.23)

$$R = \frac{D_1}{2}$$

$$R = \frac{80}{2}$$

R = 40 mm **3.29**

$$T = (T_1 - T_2)R$$

$$T = (247.56 - 7.6)40$$

T = 9598 Nm **3.30**

Torsion Equation according to the (Khurmi and Gupta, 2004):

$\frac{T}{J} = \frac{\tau}{r}$ ……………………………………………………………… 3.31

Where:

T=Twisting moment of the torque

J= Polar moment of inertia of the shaft about the axis of rotation in millimeter square (mm^2)

τ = Torsional shear stress in Newton per millimeter square (Nmm^{-2})

r= Distance from neutral axis to the outermost fibre

$$r = \frac{d}{2}$$

Where:

d Is the diameter of the shaft in millimeter (mm)

xvi. Determination of the shaft diameter,d

Data:

T = 9598 N (From equation 3.30)

τ = 42 Nmm^{-2} (The maximum permissible shear stress for the mild steel ductile material is $42Nmm^{-2}$ with allowance for keyway according to the (Khurmi and Gupta, 2004).

$$\left(r = \frac{d}{2}\right)$$

$$\left(j = \frac{\pi d^4}{32} mm^4\right)$$

$$\frac{T}{J} = \frac{\tau}{r}$$

$$T = \frac{\pi \times 42 \times d^3}{16}$$

$$9598 = \frac{\pi \times 42 \times d^3}{16}$$

$42\pi d^3 = 9598 \times 16$

$d^3 = \frac{196720}{42\pi}$

$d^3 = 1163.9$

$d = \sqrt[3]{1163.9}$

$\mathbf{d = 10.51\ mm}$ 3.32

The polisher shaft diameter will be twice of the motor shaft diameter for efficiency of the machine.

Therefore, the diameter of the polisher shaft d is 21mm.

xvii. Design analysis of the key:

Key is a piece of mild steel inserted between shaft and hub to prevent relative motion between them and it is inserted parallel to the axis of the shaft. Key is subjected to considerable crushing and shearing stresses. Keyway is a slot in a shaft and hub of the pulley to accommodate a key.

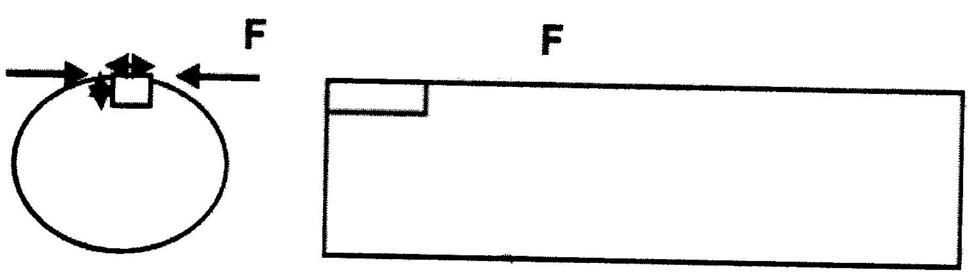

Figure 4.0: Design Analysis of a Key

Assumption:

If the exact position of the acting force is not known, so it is convenient to assume that it acts tangentially to the shaft. This force produces both shear and compressive stresses in the key according to the (Shugley, 1980). Shear stress = Force/Area (Nmm-2) according to the (Khurmi, 2004):

$$\tau = \frac{F}{A} \qquad 3.33$$

$$\mathbf{F = \tau \times A} \qquad 3.34$$

Cross sectional area = length × width (mm^2)

$$\mathbf{A = l \times b}$$

Torque = Force × radius (Nm)

$$\mathbf{T = F \times r} \qquad 3.35$$

$$\mathbf{T = \tau \times r \times A} \qquad \mathbf{3.36}$$

Where A = l × b

$$\mathbf{T = \tau \times r \times l \times b} \qquad \mathbf{3.37}$$

xviii. Determination of the torque for motor shaft, T

Data:

The maximum permissible shear stress for the mild steel ductile material is $42Nmm^{-2}$ with allowance for keyway according to the (Khurmi and Gupta, 2004).

$\tau = 42\ Nmm^{-2}$

d = 10.51 mm (From equation 3.32)

$$\frac{T}{J} = \frac{\tau}{r}$$

$$T = \frac{\pi \times 42 \times d^3}{16}$$

$$T = \frac{\pi \times 42 \times 10.51^3}{16}$$

$$\mathbf{T = 9574\ Nm} \qquad \mathbf{3.38}$$

xix. **Determination of the length of the key for motor shaft,l**

Data:

$T = 9574$ Nm (From equation 3.38)

From the (Khurmi and Gupta, 2004), Table 13.1 for 21mm diameter shaft, the width of the key, $b = 4.5$mm and the thickness, $t = 4.5$mm according to the (Khurmi and Gupta, 2004)

$$r = \frac{10.51}{2}$$

$$r = 5.255 \text{ mm}$$

$$T = \tau \times r \times l \times b$$

$$9598 = 42 \times 5.255 \times l \times 4.5$$

$$l = \frac{9598}{42 \times 5.255 \times 4.5}$$

$$\mathbf{l = 9.66\ m}$$

xx. **Determination of the torque for polisher shaft, T**

Data:

$$T = 42 \text{ Nmm}^{-2}$$

$$d = 21 \text{ mm}$$

$$\frac{T}{J} = \frac{\tau}{r}$$

$$T = \frac{\pi \times \tau \times d^3}{16}$$

$$T = \frac{\pi \times 42 \times 21^3}{16}$$

$$\mathbf{T = 76372\ Nm} \quad \text{...} \quad \mathbf{3.39}$$

xxi. **Determination of the length of the key for polisher shaft, l**

Data:

T = 76372 Nm (From equation 3.39)

From the ((Khurmi and Gupta, 2004), Table 1 for 22mm diameter shaft, the width of the key, b is 16mm and the thickness, t is 14mm according to the (Khurmi and Gupta, 2004) .

$$r = \frac{21}{2}$$

$$r = 10.51 \text{ mm}$$

$$T = \tau \times r \times l \times b$$

$$76372 = 42 \times 10.51 \times l \times 16$$

$$l = \frac{76372}{42 \times 10.51 \times 16}$$

$$\mathbf{l = 10.81 \text{ mm}}$$

CHAPTER FOUR

RESULTS

4.1 EXPERIMENTAL RESULTS

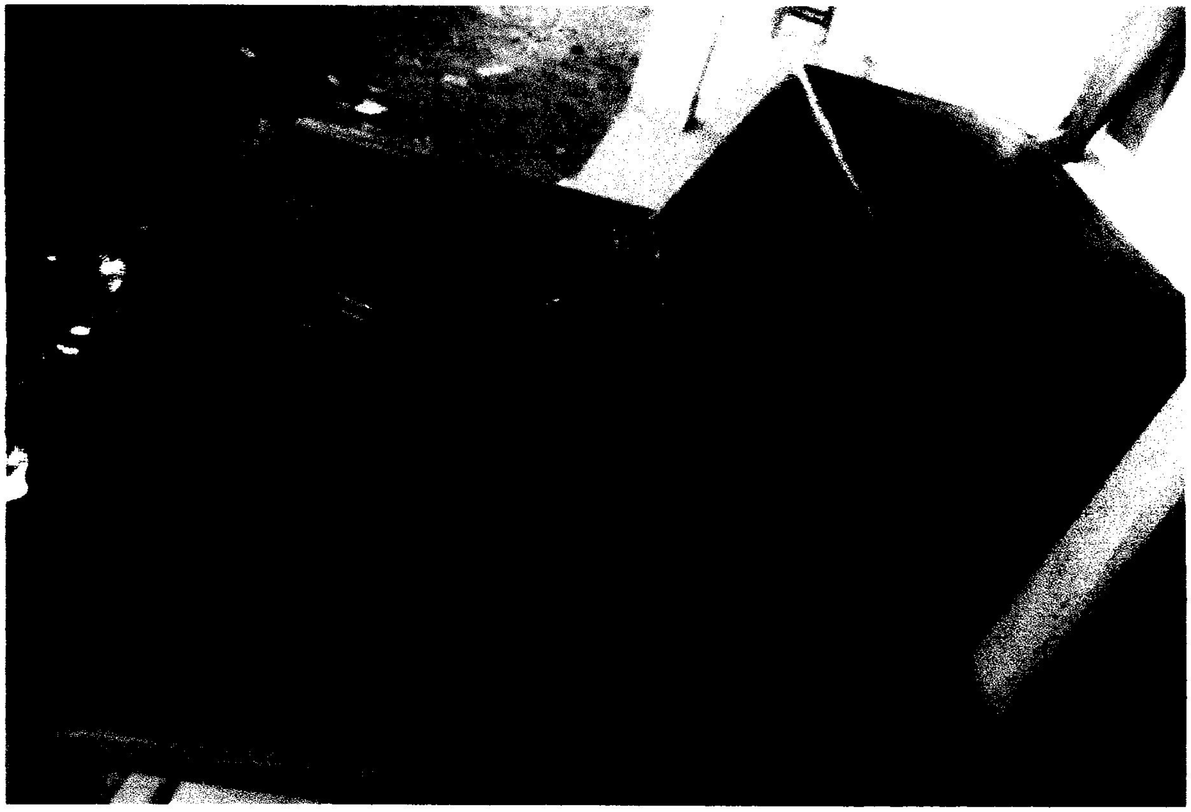

Plate 3.17: The Completed Laboratory Polishing Machine

Having fabricated the polishing machine, it was tested and evaluated in two (2) different ways which involves test running of the machine at different speed rate without placing any metallic specimen on it and after the metallic specimen was introduced for grinding and polishing.

The results obtained are as follows.

1. **No specimen test:**

During the no specimen test, the three speed was tested and the following observation were made.

i. The higher the speed, the higher the number of strokes and vice versa.

2. With specimen test:

When the specimen came in contact with the surface of the rotating disc at different speed interval, the following observation were made.

i. All levels of speed has important role to play in giving good and smooth result for both grinding and polishing. For instance, the higher the speed, the faster it will be in grinding and polishing of the metal and the lower the speed, the more time it will take in grinding and polishing.

ii. The polishing machine proved to be effective for grinding and polishing of metallic materials during testing and evaluation.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the satisfactory performance of the laboratory polishing machine, the aims and objectives of the research was achieved, such as the design and construction of a machine that will prepare metals for physical metallographic determination and also the design and construction of the polishing machine using locally available materials. The following conclusions can also be made:

1. The polishing machine proved to be effective for grinding and polishing of metallic materials during testing and evaluation.

2. Constructing the laboratory polishing machine locally proved to be more economical and time saving during operation.

3. All level of speeds has important roles to play in giving good and smooth results for both grinding and polishing.

4. The machine efficiency increases at each level of speed (i.e. high speed has high number of strokes and low speed has low number of strokes).

5. It can be concluded that the device is suitable for use in material laboratory and metallographic workshop of tertiary institutions for the grinding and polishing of any metallic materials.

This project work has shown that with this simple device, the problem of importing laboratory polishing machine in Nigeria will be solved, as the machine gave good results when compared with imported one, is easy to operate and requires minimum maintenance.

5.2 Recommendations

1. Further research is recommended to ease the operation of the system.

2. The diameter of the rotating disc should be increased so as to make the handling of the specimen more convenient during the grinding and polishing process.

3. An awareness campaign should be launched to encourage the use of locally-made polishing machine.

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