DESIGN AND FABRICATION OF A TWIN DISC METALLOGRAPHIC POLISHING MACHINE

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CERTIFICATION

This is to certify that this project**, Design and Fabrication of a Twin Disc Metallographic Polishing Machine** was carried out by **AKHABUE ODION BESTON ENG1604216, SOJA HAPPY ENG1604290,** and **OGBEIFUN ISREAL EKANOSETALE ENG1604348** in the department of Mechanical Engineering, Faculty of Engineering, University of Benin.

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DEDICATION

This project is prayerfully dedicated to God Almighty, who has made everything possible. We also dedicate this project to our parents for their immense guidance, support, and prayers throughout our study.

ACKNOWLEDGEMENT

Our gratitude is to God Almighty for His Grace, Mercy, Wisdom, and Strength throughout this project.

Our heartfelt thanks go to our unique and highly esteemed supervisor, DR. (Mrs) U.G. Unueroh, for her dedication, time, and disciplinary actions, which pushed us to do our best and ensure the success of this project; she is more than a supervisor.

Our heartfelt appreciation goes to our parents for their love and support throughout this undertaking.

ABSTRACT

In this project, a metal polishing machine, an advantageous apparatus in the testing and property investigation of metals, is designed and fabricated. The essence is to produce a simple and affordable piece of apparatus that can be used in research centres, laboratories, and workshops of Nigerian higher institutions and can serve as an alternative to the imported and costly polishing machines currently in use. The design uses motor-powered grinding wheels of appropriate composition to be rotated against a marked-out area of a sample metal piece to be polished and subsequently etched for metallographic purposes. A considerably chemically inactive liquid does the etching in Nita solution comprising nitric acid and ethanol. Mainly dependent on the type of metal being polished, water is used for flushing the polished area to ensure a smooth polished surface that retains the original microstructural composition and arrangement inherent in the original sample as it where before polishing. The polishing wheels are fine-grained and dense structured abrasive materials bonded together with an appropriate bonding agent. Provision is made for wheel insertion and removal from the motor spindle to accommodate different wheel types- either with a soft grinding abrasive material for polishing hard metals or hard grinding abrasive material for soft metals. A tank will also be incorporated into the machine to aid the flow of fluid needed for this experimentation. Thus, with the locally fabricated polishing machine from this project, it is possible to etch different types of metals for proper surface exposure for optical or electron microscopic investigations and analysis.

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CHAPTER ONE

1.0 INTRODUCTION

The study of metals' physical structure and components, generally employing microscopy, is known as metallography. Various processes of grinding, polishing, and etching are used to prepare the surface of a metallographic specimen. Following separation, it is frequently studied using optical or electron microscopy (Vander, 1999).

It can also be described as the study of the internal structure of materials, metals, and alloys and the relationship of structure to composition and physical, chemical, and mechanical characteristics, which is known as metallography. Many methods for determining internal structure have been developed, but microscopically investigations have always been the most significant. Throughout the history of metallography, they have been performed using an optical microscope (Vander, 2012).

In metallography, to obtain a smooth surface the metallographic machine which compose of rotating plates and it forces is used, polishing is the final process of the precipitating part of the test. Polishing is often used to enhance the glossy, smooth workpiece, prevent the contamination of medical equipment, remove oxidation, or prevent pipe corrosion (Erinle et al., 2011).

Polishing is the process of rubbing or chemically removing a smooth and shiny surface to reveal a surface with a high specular reflection. Polishing is a step-by-step process. The first stage starts with rough polishing, and each subsequent level uses finer emery paper of increasing grades to achieve the desired finish. Metal is removed during this stage (Samuels, 2013).

Fine polishing, which includes minimal or minor metal removal, is introduced in the second stage. It is usually used to remove scratches on the surface of the specimen.

In order to make plates free of defects for a microscopic inspection of metal microstructures, polishing is employed in metallography and metallurgy. The usage of automated polisher equipment is advised to achieve adequate graphite retention. This technology enables constant control of the needed weight on the time for each preparation stage and the specimens and in contrast to hand specimen preparation. This equipment also enables homogeneous specimen alignment against the preparation surface, influencing graphite retention (Nur et al., 2020). To avoid the possibility of pulling out of the graphite phase, the number of grinding and polishing stages should be kept to a minimum (Akinlabi et al., 2018).

At increasingly more acceptable levels, abrasive particles remove material from the specimen surface until the required metallographic surface quality is attained. Several metallographic preparation machines for grinding and polishing are available, each satisfying a particular set of preparation quality, capacity, and repeatability requirements (Erinle et al., 2011).

Disc polishing machines are commonly used to polish metallography samples for microscopic investigation of diverse metal structures. Disc Polishing Machines produce a clean, without scratch, reflective surface appearance that allows metallographic perception to be corrected. Polishing is the final stage in achieving a flat, smooth, without scratch, reflective look. A surface of this type is necessary for subsequent correct qualitative and quantitative metallographic interpretation. The machine is powered by the motor spindle, which is attached to the motor shaft through a friction mechanism. Polishing discs are installed and fixed by a nut on the shaft. For smooth operation, the shaft contains two bearings inserted into a bearing holder (Nur et al., 2020).

Finally, etching is the process of selective chemically attacking the surface of a polished object to reveal its micro-structural properties (grain boundary, phases, precipitates, and other micro-structure components). A widespread misconception is that a polished surface has a bright mirror finish, but most bright mirror surfaces are buffed (Akinlabi et al., 2018).

The development of a twin-disc metallographic polishing machine will contribute tremendously to the successful polishing of metallographic materials. This machine overcomes the tediousness, time-consuming, messy, nasty, and discouragement in manual polishing. In addition, this machine improves accuracy high-volume processing and discourages local hand polishing.

1.1 AIMS AND OBJECTIVES

This project aim is to design and fabricate a laboratory twin disc metallographic polishing machine that can be used for grinding and polishing metallic materials in the metallographic laboratory.

In order to achieve the stated aim, the following objectives shall be met.

i. To design and model the components of the machine

ii. To fabricate a machine using materials that are readily available locally that can polish metals in a lab.

iii. To inputs a lagging material to help reduce heat loss during polishing

iv. To design a machine that may be utilized everywhere.

v. To evaluate the machine's performance with selected relatively cheap materials and whose service areas apply to the design.

1.2 PROBLEM STATEMENT

Due to a lack of laboratory equipment for research and training in the Nigeria, the design and manufacturing of a metallographic polishing machine appropriate for grinding and polishing is required for enhanced training, teaching, and research in materials metallography in University of Benin.

1.3 SCOPE OF PROJECT

The scope of the project is to design and fabricate a laboratory twin disc metallographic polishing machine with the following capacity:

i. A twin disc that can polish metals simultaneously or individually

ii. To develop a polishing machine for use in laboratories utilizing the following parts: angle bars, mild steel plate, electric motors, shaft, bearings, pipes, and polishing disc.

CHAPTER TWO

2.0 LITERATURE REVIEW

One of the most helpful pieces of equipment for grinding and polishing metallic samples so that their physical makeup may be examined under a microscope is the metallographic specimen polishing machine. The goals of the project are to design and construct a machine for polishing metal in order to discover its physical structure using metallography, as well as to design and construct a machine utilizing locally accessible materials to generate a flat, mirror-like surface for any metallic materials.

A metallographic specimen polishing device that can grind and polish any metal, is user-friendly, and needs little upkeep was developed by Erinle et al. Any metallic substance in the material laboratory may be ground and polished using the metallographic specimen polishing equipment. Since the 16th century, polishing machines have gone through various alterations and designs, with several inventors and scientists working on its development using the resources available at the time [Erinle et al., 2011].

Leonardo da Vinci was a scientific and technology pioneer, designing equipment to build optical instruments. In fact, he envisaged equipment between 1513 and 1517 to polish and grind telescope mirrors, which were made of bronze at the time. But unfortunately, it appears that Leonardo da Vinci did not build his idea during his lifetime as he has done with many of his previous projects [Baucon, 2021; Samuel, 2003].

Progress in optics theory and proficiency in the manufacturing of quality glass led to the emergence, particularly in Italy, of artisans specializing in the making of lenses for medical glasses, microscopes, field glasses, refractors, and so on in the early 17th century. During the period, specialized instruments were constructed to aid opticians' jobs, namely machines based on the ideas discovered by Descartes, Huygens, Hooke, Helvelius, Cherubin d'Orleans, and others. The lens polishing devices of Huygens (1683) and Cherubin d'Orleans (1670) were significant examples of this era [Vijayan et al., 2019; Buckley, 1934].

Since Galileo popularized it, the refractor was dominant until the nineteenth century. Leonardo da Vinci's notion of utilizing a mirror to make an astronomical instrument was neglected until Jacques Grégory (1663), who was subsequently followed by Isaac Newton, resurrected it with the reflecting telescopes that retain their names this day. The original telescope mirrors were hand-shaped tiny metal disks. However, as they grew, it became necessary to shape and polish them using machines. The early amateur astronomers were the most prominent in this historical history [Vijayan et al., 2019; Buckley, 1934].

William Herschel (1738-1822) constructed a polishing mechanism in 1788 that allowed him to finish a 50' mirror in 1789. Unfortunately, there is no description of the device that William Herschel maintained a secret up until his passing. He merely asserts that the need for its development was a result of the several workers—up to a dozen men—needed to complete his larger mirrors. Nonetheless, a tiny polishing machine he created may be exhibited at his museum in Bath, England [Vijayan et al., 2019; Buckley, 1934].

Following in the footsteps of William Herschel, Lord Rosse (1800–1867), a wealthy landowner and amateur astronomer, started construction on a 183 cm bronze mirror for his telescope in 1843, which is still visible in Ireland. The Parsonstown Leviathan is still in use today. To do this, he used a polishing device, which he described in 1841 for the benefit of the Royal Society [Vijayan et al., 2019; Friedrich, 1937].

Later, another hobbyist, a wealthy trader named William Lassell (1799-1880), utilized a polishing machine to make large-sized mirrors (notably a 122cm mirror set up in Malta in 1855). However, during the story, we meet experts such as Henry Draper (1837-1882), who was one of the first to cut mirrors using Leon Foucault's theories. For this reason, about 1850, he created the machine based on Lord Rosse's invention from 1840, which served as a model for a long time. Today, this sort of equipment is still recognized by its name [Vijayan et al., 2019; Buckley, 1934].

The same equipment was later improved and used by George Willis Ritchey, first in the United States (particularly for the 2.5-meter mirror for the Mount Wilson Hooker telescope), and then in France at the optics lab of the Dina foundation at the Paris Observatory. He left behind two machines after his time in France, along with the idea for a bigger machine with an 8-meter capacity, which was never realized. The polishing device used by George Willis Ritchey at his American workshop (1890). G.W. Ritchey built a two-meter polishing machine for the Dina laboratory at the Paris Observatory (from 1924). G.W. Ritchey designed the eight-meter machine [Vijayan et al., 2019; Buckley, 1934].

Bernhard Schmidt (1879-1935) employed a different sort of machine. Due to his low financial resources, its motions were actuated with the foot. Despite this, he continued to produce high-quality mirrors. With the development of huge telescopes at professional observatories in the twentieth century, polishing equipment grew in size and sophistication. In that regard, computer science enabled significant breakthroughs by creating novel procedures mastered by specialized corporations (Zeiss, REOSC). For example, mirror cleaning and figuring robots of the same kind employed in the care sector are controlled by computers. The motions and pressures are thereby regulated, as are the deformations of the stand for mirror and lap polishing (these are known as the stressed-mirror or stressed-lap techniques). Furthermore, the deployment of such robots enables modifications to the machine's software based on the data acquired [Vijayan et al., 2019; Pawar and Koli, 2016].

Reference to the use of machines early in modern amateur astronomy is discovered. Indeed, Paul Vincart reports one of them in an edition of the Belgian Astronomical Society's (Société Belge d'Astronomie) periodical "Ciel et Terre" as early as August 1922. In the 1930s, in the United States, Albert Ingalls covered many machines in his foundational work (Amateur Telescope Making). In France, details of similar devices may be found in an issue of the SAF (Société Française d'Astronomie) magazine "Astronomie" dealing with the 108th session of the committee in charge of instruments in February 1958 [Vijayan et al., 2019].

Amateur mirror manufacturers have been researching the benefits of machines for a very long time. Names like Pierre Bourge, Félix Bacchi, and, more recently, Dany Cardoen come to mind. But in our country, these strategies have never enjoyed the same level of acceptance as they have on the other side of the Atlantic. This occurrence may be explained by the fact that these tools were never included in Jean Texereau's "La fabrication du télescope d'amateur," the holy book of French amateur mirror producers. Because of the recent growth of Internet exchanges, one may read numerous testimonies from amateurs who have benefited from the community of amateur creators. Jean Texereau's Draper and Hindle machines were featured in L'Astronomie magazine in 1958 [Vijayan et al., 2019, Pawar and Koli, 2016].

These devices were eventually employed as allies by independent professional mirror producers. For example, one of them was utilized by the late Roger Mosser in France decades ago. The same may be said today of Franck Grière (Mirro-Sphère) and JeanMarc Lecleire (Astrotélescope) [Vijayan et al., 2019].

One such example is Carl Zambuto, a professional who voluntarily imparts his wisdom and strategies to the American amateur community. Romano Zen, an Italian, and Mike Lockwood, another American, should be noted [Vijayan et al., 2019].

2.1 METALLOGRAPHIC ETCHING

Metallographic etching is one of a number of processes that takes place during sample preparation for metallographic examination (Greene et al., 1966; Petzow, 1999). The steps involved in preparing a sample include:

- Sectioning;
- Mounting;
- Identification;
- Grinding;
- Polishing;
- Cleaning;
- Etching. (Greene et al., 1966; Petzow, 1999)

2.1.1 Sample Preparation Techniques

2.1.1.1 Sectioning

Metallographic cutting or sectioning is typically the first step in the metallographic sample preparation process. In most cases, it is required because the part or solid body is too large for the subsequent metallographic grinding and polishing stages to be performed on a laboratory scale (Greene et al., 1966; Petzow, 1999).

2.1.1.2 Mounting

Mounting is often the second step after sectioning in metallography. Mounting encases the tested material in a plastic shell and prepares it for the metallographic grinding and polishing operation that follows. In many circumstances, it leads to easier sample preparation and, as a result, better findings (Greene et al., 1966; Petzow, 1999).

2.1.1.3 Identification

This is the process before grinding. It encapsulates the whole process of finding out which surface is best for grinding and polishing processes (Greene et al., 1966; Petzow, 1999).

2.1.1.4 Grinding

Metallographic grinding is one of the process steps in mechanical sample preparation for microscopic inspection. The approach is based on the employment of progressively finer grain size abrasive particles to remove material from the surface until the desired result is reached. These particles are present in bound and unbounded forms after grinding and polishing (Greene et al., 1966; Petzow, 1999).

2.1.1.5 Polishing

Metallographic polishing, like metallographic grinding, is the final stage in the metal sample preparation process before analysis. Its goal is to correct deformations generated by previous work procedures (during sectioning and cutting). The information that follows gives some general considerations as well as tips for further sample preparation techniques (Greene et al., 1966; Petzow, 1999).

2.1.1.6 Cleaning

Cleaning and drying are two of the most underappreciated steps in specimen preparation. However, incorrect cleaning might produce deceptive results. Cleaning is essential to remove polishing residue as well as surface particles (Greene et al., 1966; Petzow, 1999).

2.1.1.7 Etching

Etching is a step that comes after metallographic grinding and polishing, and it can be chemical or electrolytic. Metallographic etchants are chemicals that can expose microstructural details on a mirror-polished metal sample that would otherwise be invisible. The etchant will etch or discolor microstructural features such as grain boundaries or metal phases selectively. These characteristics can then be examined under a microscope. Etching increases, the contrast on surfaces, allowing you to see the microstructure or macrostructure (Greene et al., 1966; Petzow, 1999).

In metallography, etching exerts control over the surface profile or optical properties at grain boundaries, phases, or grain surfaces, enabling microscopic analysis and the use of optical filters in the microscope.

2.1.2 Metallographic Polishing Machine

There are three main etching processes used in metallographic sample preparation, which are:

1. Chemical etching
2. Electrolytic etching
3. Heat tinting (Samuels, 2003)

2.1.2.1 Chemical Etching

Chemical etching entails immersing a prepared sample, often ground (for macro etching) or finely polished (for micro etching), in an etching fluid (etchant) or simply swabbing the surface with an etchant. Macro etching allows you to examine the sample surface with your eyes or a magnifying glass (magnification up to 25x). Micro etching allows for microscopic inspection at magnifications of 1,000x or higher (light microscopy) (electron microscopy) (Samuels, 2003; Kern and Deckert, 1978).

The etchant corrodes microstructural characteristics selectively. Immersion or etching time is greatly dependant on the technology and, in most circumstances, experience is required. The selection of the best etchant is also critical in sample creation. For low magnification inspections, deeper etches are favored, while shallower etches are preferred for higher magnification examinations (Samuels, 2003; Kern and Deckert, 1978).

2.1.2.2 Electrolytic Etching

Chemical etching entails immersing a prepared sample, often ground (for macro etching) or finely polished (for micro etching), in an etching fluid (etchant) or simply swabbing the surface with an etchant. Macro etching allows you to examine the sample surface with your eyes or a magnifying glass (magnification up to 25x). Micro etching allows for microscopic inspection at magnifications of 1,000x or higher (light microscopy) (electron microscopy) (Samuels, 2003; Petzow, 1999).

The etchant corrodes microstructural characteristics selectively. Immersion or etching time is greatly dependant on the technology and, in most circumstances, experience is required. The selection of the best etchant is also critical in sample creation. For low magnification inspections, deeper etches are favored, while shallower etches are preferred for higher magnification examinations under polarized light (Barker-etching) (Samuels, 2003; Petzow, 1999).

2.1.2.3 Heat Tinting

Oxidizing a sample in a furnace is the process of heat tinting, also known as thermal etching. As a result, different surface characteristics oxidize at different rates, revealing distinct features. This method is not popularly used (Samuels, 2003; Vander Voort, 2004).

2.2.3 How to do etching

2.2.3.1 Method Selection Steps

- The sample must have a smooth surface free of defects or imperfections before being polished.
- From the list of literature, the appropriate etching fluid for the material is chosen.
- In some instances, light microscope filters can be used in addition to chemical etching to improve contrast. Optical etching is the term used to describe this.
- In the case of electrolytic etching, a suitable electrolyte, voltage, and sample exposure time should be selected (Petzow, 1999; Samuels, 2003; Vander Voort, 2004).

2.3 COMPONENTS OF THE MACHINE

The machine is made up of the parts of following components, which include:

- **Shaft:** The shaft is a rotating machine component that distributes power within a machine from one part to another. A tangential force is used to apply power to the shaft, and the torque (or twisting moment) that is formed is placed inside the shaft, enabling power to be transferred to various machines linked to the shaft. The shaft spinning causes the polishing disc to revolve, transmuting power from one shaft to another. The shaft is composed of robust and wobble-free carbon steel. (Shugley, 1980; Khurmi and Gupta, 2005).

Figure 2.3.1 Shaft

- **Frame:** All of the machine's subassemblies are housed in the frame. The frame structure is comprised of angle bars that are soldered together.
- **Bearing and Housing:** The bearing and housing are used to support the shaft, and roller bearings and ball bearings will be used for this project's load [Shugley, 1980; Khurmi and Gupta, 2005].

Figure 2.3.2 Bearing and housing

- **Electric Motor:** An electrical machine turns electrical energy into mechanical energy. Electrical motors provide a linear or rotational force (torque), which causes the shaft to revolve. An electric motor controls the polishing disc's movement [Shugley, 1980; Khurmi and Gupta, 2005].

Figure 2.3.3 Electric Motor

- **Pipes:** pipes are used to connect the flow of water from the reservoir to the tap.
- **Bots and Nuts:** They are used to hold various parts while assembling the Machines components [Shugley, 1980; Khurmi and Gupta, 2005].
- **Polishing Disc:** A polishing wheel's function gives metal a soft, smooth surface [Shugley, 1980; Khurmi and Gupta, 2005].

Figure 2.3.4 Polishing Disc

- **Electric Motor Controller:** Motor controllers are devices that regulate the operation of an electric motor.

Figure 2.3.5 Electric Motor Controller

CHAPTER THREE

3.0 DESIGN METHODOLOGY AND MATERIAL SELECTION

3.1 Materials and Methods

The design was aimed at fulfilling the following goals: manufacturing a decent and quality dual-component machine with a high probability of efficiency, raw material availability, and machine cost.

3.2 Design Methodology

3.2.1 Technical Parameters

1. Polishing Pad: diameter 228.6 mm (Two Discs)
2. Rotation Rate of motor: 2800 rev/min
3. Motor: AC motor; 1119W, 220/240 V, 50 HZ
4. Motor Dimension: Ø 150 × 16 ×12.7 mm

3.2.2. Speed of the polishing discs

According to Khurmi, the Speed of the polishing disc can be calculated by:

$$N_1/N_2 = D_2 / D_1 \qquad \text{(Khurmi R.S, 2006)}$$

Where:

N_1= Speed of the pinion in revolution per minute (rpm)

N_2= Speed of the gear in revolution per minute (rpm)

D_1= diameter of the pinion in millimeter (mm)

D_2= diameter of the gear in millimeter (mm)

Data:

N_1=2800 rpm

D_1=50 mm

N_2 = x rpm

D_2= 60 mm

$$N_1/N_2 = D_2/D_1$$

$$2800/N_2=60/50$$

$$N_2=2333.33 \text{ rpm}$$

Therefore, the maximum calculated speed of the electric motor through the shaft to the polishing disc will be 2333.33 rpm

3.2.3 Design Considerations of the Shafts

The structure screwed shaft can be designed for strength, rigidity, and stiffness as considered for most shaft members. If these are to be regarded necessary in our job, one or more of the following must be considered:

a. When the Shaft is solely subjected to a twisting moment or torque.
b. If it is solely exposed to bending moment.
c. If it is subjected to varying loads.
d. If it is exposed to twisting and bending moments simultaneously.
e. If it is subjected to axial loads and torsion and bending stresses combined.

In designing a shaft based on strength, shaft subjected to axial loads in addition to combine torsion and bending loads were taken into consideration (Khurmi R.S et al, 2006). Consideration was given to the axial load (F) which comprises the disc that was being attached to the shaft, likewise the weight of the surface to be polished.

3.2.4 Torque Required to Rotate the Disc

$$T=\frac{P \times 60}{2\pi Np} \text{ N-m} \quad \text{(Khurmi R.S, 2006)}$$

Where, P = Power transmitted in watts, and

N_p = Speed of the pinion in rev/min.

P = 1119 W, N_p = 2800 rev/min

Π =3.142

$$T = \frac{1119 \times 60}{2 \times 3.142 \times 2800}$$

$$T = \frac{67140}{17595.2}$$

T = 3.816 N-m

3.2.5 DESIGN ANALYSIS FOR BEARING

Using a bearing is to decrease machine part wear and heating. A shaft journal rotates or oscillates within a sleeve/bearing in a sleeve bearing, and the relative motion is sliding. The principal relative motion in anti-friction bearings is rolling.

Because anti-friction bearings are frequently subjected to radial, and axial stresses combined, choose journal bearings and pluming bearing to build these projects.

In many instances, the following characteristics make a ball bearing more desirable:

1. Less sensitivity to lubrication interruptions
2. Absence of self-excited instabilities
3. Low temperatures during start-up are ideal.
4. Capability to sustain both radial and thrust loads
5. Low starting friction and good operating friction

A good bearing must have a low melting point, a low modulus of elasticity, and sufficient compressive and fatigue strength to withstand imposed stresses. The most crucial need is that it be corrosion resistant (Arvid, 1945).

3.2.5.1 Bearing design calculations

Because of its significant load-carrying capacity and adaptability for high running speed, the single-row deep groove ball bearing was chosen. Given the shaft's diameter of 25mm, a bearing with a bore of 25mm was employed for this computation. The specific static load rating or capacity C_o (Arvid, 1945)

$$Co = \frac{1}{5} \times ko \times i \times z \cos \alpha Dw^2 \qquad \text{(Arvid, 1945)}$$

Where:

C_o = Specific Static Load rating or Capacity = 10kN

K_o = Factor depending on the type of bearing. = 12.3

D_w = Diameter of the ball

α = Nominal angle of contact = 0

i = Number of rows of the ball in any one bearing = 1

z = Number of balls per row in the groove = 6

$$Ko = \frac{Q\max}{\mathrm{Dw}^2} \qquad \text{(Arvid, 1945)}$$

Qmax = Maximum bearing load.

And the above data (Budynas et al, 2008) the ball diameter can be calculated

$$Dw = \sqrt{\left(\frac{Co \times 5}{Ko \times i \times z\cos\alpha}\right)} \qquad \text{(Budynas et al, 2008)}$$

$$= \sqrt{\left(\frac{10 \times 10^3 \times 5}{12.3 \times 1 \times 6\cos 0}\right)}$$

$$= \sqrt{677.5067751}$$

= 26.02896mm

Then the maximum bearing load Q_{max} becomes:

$$Ko = \frac{Q\max}{\mathrm{Dw}^2}$$

$Q_{max} = K_o \times D_w^2$

= 12.3 × 677.5067751

= **8333.333N**

The bearing 6206, with an inner diameter of 25mm and an exterior diameter of 55mm, was then selected. The bearing number 200 denotes a light bearing of the bore with an inner diameter of 5 5 = 25mm. Also considered in the bearing selection was the radial load that the bearing can withstand. However, when the temperature is less than 20oC, grease is used at low and medium speeds, while oil is utilized at higher speeds. As a result, grease is regarded as the most suitable lubricant for this design.

3.2.6 Electrical System

The electrical system comprises of a wiring of the machine and its components parts, the electric motor, circuit breaker, speed regulator, battery, and their interconnections with each other.

3.3 CONCEPTUAL DESIGN

3.3.1 CONCEPTUAL DESIGN ONE

This conceptual design comprises of a single electrical motor control system. A single electrical motor control system is a system whereby both discs are controlled by one electrical input system; either is the speed variable of the disc or in the switch system in turning off the power.

This system encompasses gears' use in the disc for polishing, and this concept has been the most fabricated system over the years.

The design diagram below depicts an isometric perspective of the polishing machine.

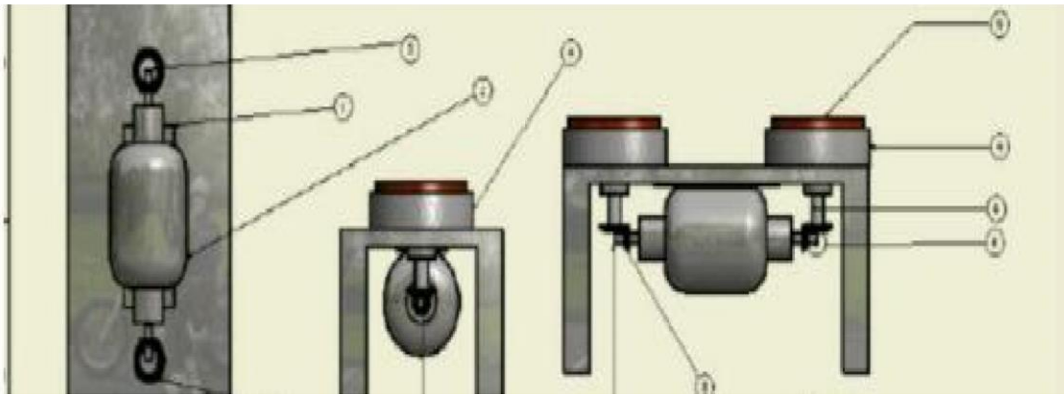

Fig 3.3.1.1 Isometric View of the Machine

Advantages of this concept

1. Single electric motor is needed to run the both disc through the use of gears.

Disadvantage

1. If the gear is not well sited in line with the electric motor, there will be wearing away, in order words, friction will be induced.
2. The gears system periodically needs lubrications for effective and smooth motion

3.3.2 CONCEPTUAL DESIGN TWO

In this design, different motor operating system is used. Each polishing disc is outrun by the individual electric motor, placed beneath a firmly enclosed metal pan welded to the machine frame, helping turn the discs independently without a central control regulator. It is different from the first concept and is considered an improvement of the well-known polishing machine of the first concept, which has been used over the years. The concept two was chosen due to functionality regarding the regulation system, power consumption and elimination of the gear system.

Fig 3.3.2.1 Exploded view of the Machine

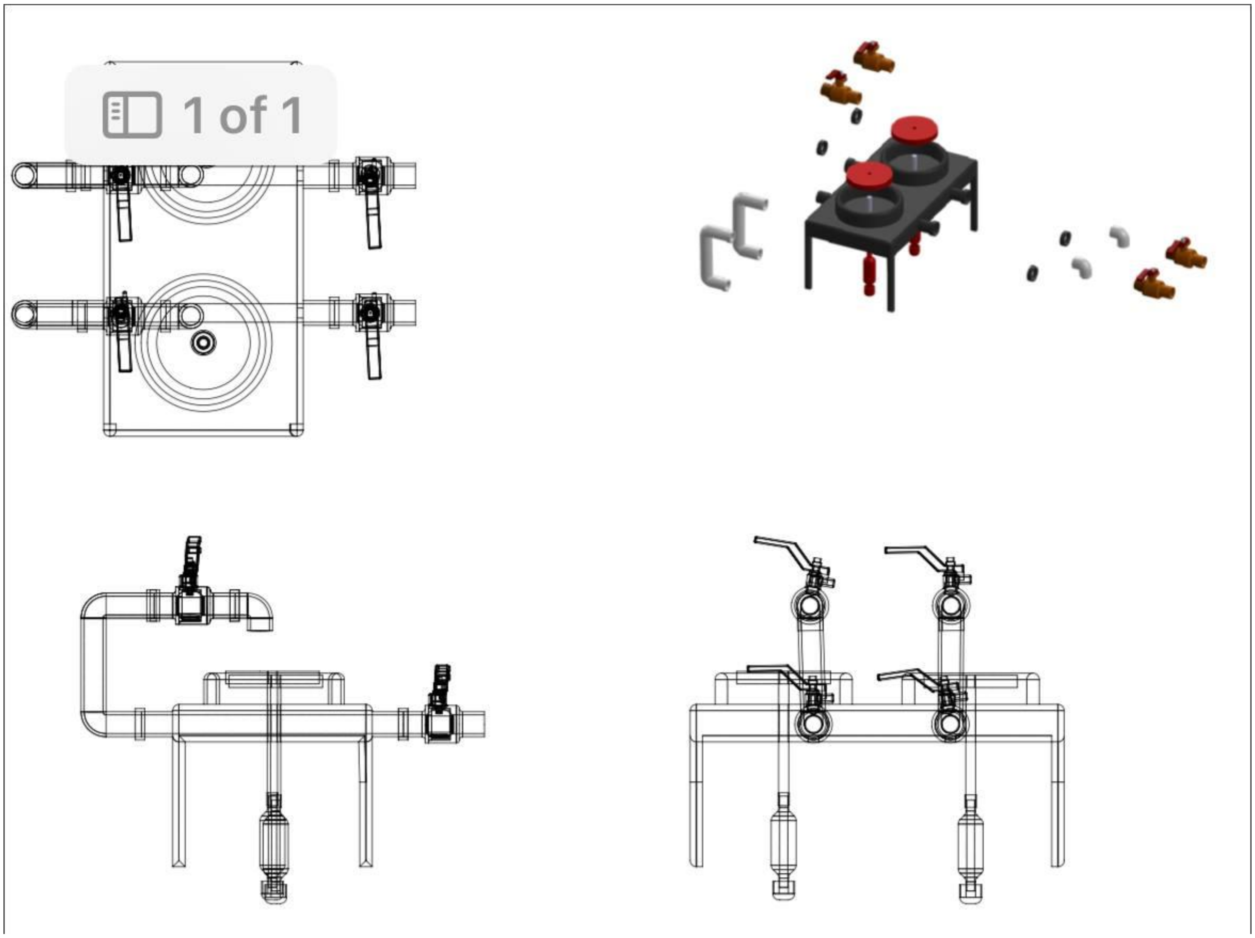

Fig 3.3.2.2 Orthographic View of the Machine

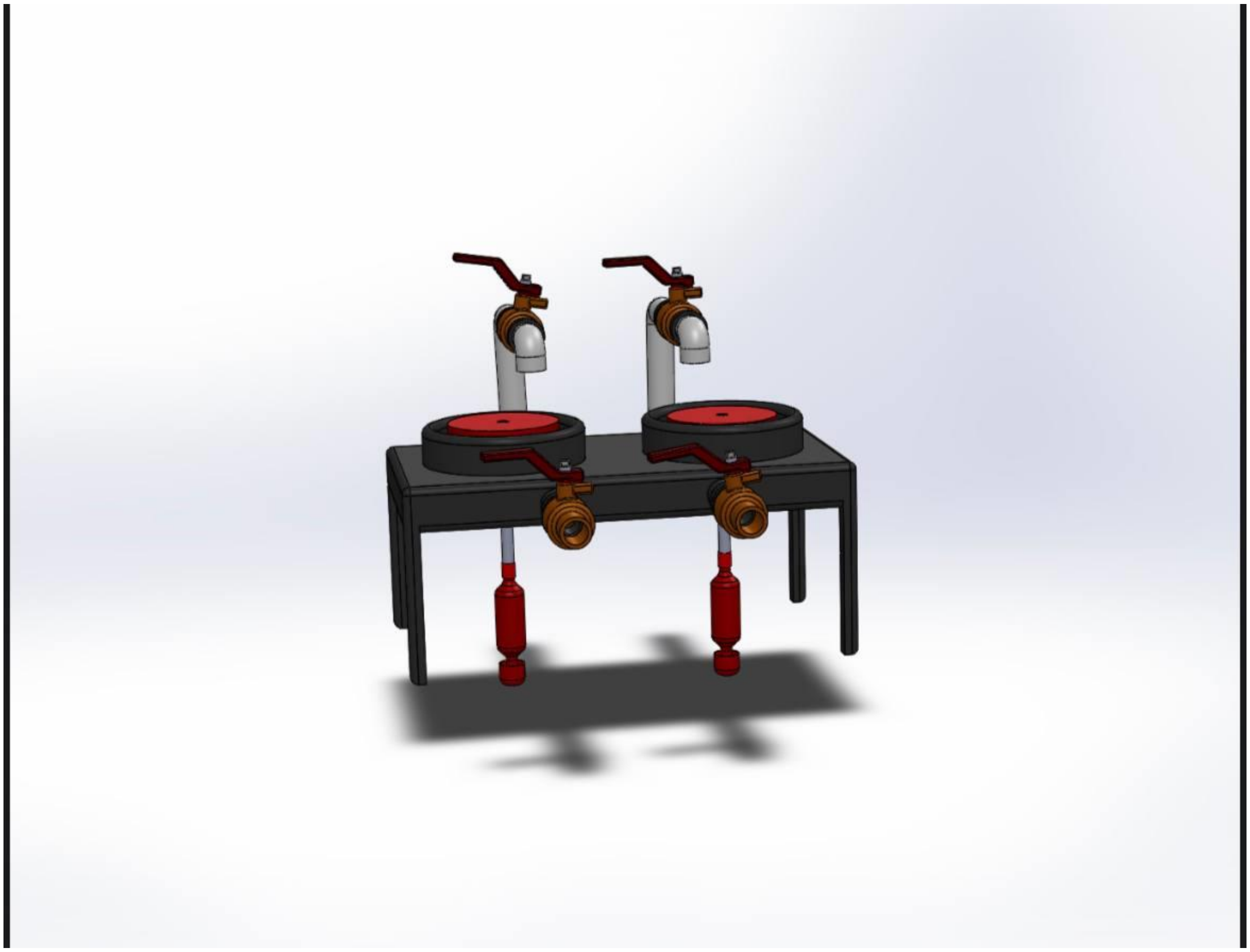

Fig 3.3.2.3 Isometric View of the Machine

Advantage of concept two

1. Each disc can be regulated individual
2. It doesn't require gear system and so lubrication is not needed

Disadvantage of concept two

1. The cost of production is high due to different regulatory systems such as use of more than one electric motor.

3.4 MATERIALS SELECTION

A thorough understanding of materials and their properties is critical in machine design. The qualities of a chosen material should be adequate to fulfil the requirements and service conditions of operation at the lowest possible cost.

The following are the primary variables to consider when selecting a material for design:

i. Material cost

ii. Material quality
iii. Resistance to compressive and repetitive loadings
iv. Resistance to corrosion
v. Material Availability

Several material qualities are sufficiently examined about their functions in the project. This project includes the following components: a frame (metal casing), shafts, a bevel gear, a pillow bearing, a wooden plate disc, a metal clip, a bush bearing, a cover plate, a tap, and a pipe.

Table 3.4.1 Materials Selection

S/N	MACHINE COMPONENTS	CRITERIA FOR MATERIAL SELECTION	MATERIAL SELECTED	REASONS FOR SELECTION
1.	FRAME (METAL CASING)	Should be able to endure the machine's eccentric motion while in operation.	Square bar Mild steel	It is not prone to twisting, can tolerate vibration, and maintains strong stability.
2.	SHAFTS	It should be able to withstand the force and weight of the other components that are linked to it.	Cylindrical bar Stainless steel	Capability to tolerate twisting caused by a torque moment and compressive force caused by the weight of other components linked to it.

3.	PILLOW BEARING	Should be able to withstand machine and motor torque.	Mild Steel	Adjustment is simple, and appropriate alignment is achieved.
4.	WOODEN DISC	Should be able to withstand machine and motor torque.	Softwood	Ability to rotate quicker, lightweight, corrosion resistance, easy to make, and easily accessible
5.	METAL CLIP	Should be able to withstand machine and motor torque.	Galvanized steel	Simple to grasp
6.	BUSH BEARING	Should be able to withstand machine and motor torque.	Mild steel	Easy to adjust and good alignment
7.	COVER PLATE	Should be able to endure the machine's eccentric motion while in operation.	Galvanized steel	Significant strength, ductility, and toughness
8.	TAP AND PIPE	Should be capable of assisting in	Stainless steel	Significant strength and

		transferring water from the polishing disc during the polishing process.		corrosion resistance.
9.	POLISHING DISC CASING	Should be able to endure the eccentric movement of the polisher disc and shield the machine body from splashing water.	Mild steel	Considerable strength and corrosion resistance

3.5 Design Factor

It refers to various aspects that impact or influence the machine's design or some of its components. However, just one or a few of the countless aspects that influenced the design will be identified as significant factors, with the minors discarded since they will have little or no effect on the design. These aspects or features are;

i. the material's thermal conductivity.
ii. The durability of the materials employed.
iii. The machine's total weight to accomplish portability and machine size.
iv. Maintainability.
v. Vibration and noise.
vi. Corrosion resistance.
vii. Finishing.

CHAPTER FOUR

4.0 COST ANALYSIS, TEST AND RESULT

4.1. COST ANALYSIS OF MATERIALS

The following variables were addressed in the design of the metallographic grinding and polishing machine:

1. Materials accessibility
2. Motor selection
3. Mechanical characteristics of the chosen materials
4. Surface finish needed for polished materials
5. Material costs (Economic Implications)

The essential materials were carefully picked after carefully evaluating the elements required for machine manufacturing, and the machine was manufactured. Machine production costs are highly essential in the industry. The sole goal of every industry is to maximize profit by making the best use of available resources. The cost analysis provides an estimated cost for materials, fabrication, overall cost, and total cost.

The entire cost is split into three (3) parts:

1. Material cost;
2. Labour cost;
3. Overhead cost.

4.1.1 Material cost (Bill of Engineering Materials)

The material cost for the design is presented in the table below. It shows the cost for all purchased parts and equipment as well as the necessary items needed to actualize the fabrication of the design concept.

Table 4.1.1.1 Bill of Materials

S/N	Component	Qty	Unit Cost (Naira)	Total Cost (Naira)
1	Electric motor	2	15000	30000
2	Bearing	2	3500	7000
3	Electric motor regulator	2	3000	6000

4	Polishing disc	2	4000	8000
5	Polishing machine stand	1	10000	10000
6	Tap	2	3500	7000
7	Rubber Tank	1	3500	3500
8	Tank stand	1	4000	4000
9	Hose for piping	1.5m	2000	2000
10	Wire	1m	1000	1000
11	Metallography polishing machine case	1	25000	25000
12	Painting of machine		15000	15000
	Total			**118,500**

4.1.1.1 Labour Cost

This is the cost of manpower that was employed to produce the machine. Labour cost is approximately 25% of the material cost.

Material Cost = N 118,500

Labour cost = 25% of 118,500

= 25/100 x 118,500

=N 29,625

4.1.1.2 Overhead cost

It is the cost of utilities and other indirect expenditures incurred during the manufacturing of the machine. Transportation costs, and equipment rental, are examples. The overhead cost is estimated to be 15% of the material cost.

Material Cost = N 118,500

Overhead cost = 15% of 118,500

= 15/100 x 118,500

=N 17, 775

4.1.1.3 Total Cost

This is the cost incurred in the production of a metallographic grinding and polishing machine. Thus it is a function of cost of materials, cost of fabrication/labour cost and overhead cost.

Total cost= Material cost + Labour cost + Overhead cost

Total cost = 118,500 + 29,625 + 17,775

Total cost = N 166,000

4.2 TEST

1. The machine was tested by using the two polishing discs simultaneously and also by disengaging one of the polishing disc while the second one works.
2. The machine was also tested by polishing different types of mild steel metal samples at varying speeds to ascertain the surface required for microscopic testing.
3. The polished sample was then etched for 90 - 150 seconds with a reagent called Nital solution, comprising of 100mL of Ethanol and 5mL-10mL of Nitric acid which was used to make the polished sample more visible for inspection under the microscope.
4. The same mild steel metal which was unpolished was also tested with the Nital
5. solution
6. A stainless steel pipe was also polished. The stainless steel sample was polished
7. To evaluate the colour change when the Nital solution is used instead of the proper etchant for stainless steel.

4.3 RESULT

1. The polishing discs could work simultaneously. The load to be carried by the motor was already calculated in the design stage. Two separate motors were used for each polishing disc.
2. A shiny, smooth surface of the mild steel metal sample was obtained with no presence of scratches.
3. After cleaning the etchant, a darker surface was observed which made observation under the microscope easier by revealing microstructural details that were not evident to the naked eyes. This was aas a result of the mirror-like finish imparted on the polished surface

4. No observable change occurred after the application of an etchant to an unpolished surface
5. Stainless steel surface which was polished and etched with the nital solution was cloudy, which signified that the wrong etchant was used on the sample

4.4 MAINTENANCE

- Grease the bearing internal for weeks depending on the duration of usage
- Depending on its usage, the polishing disc should be removed to take off to clean beneath it to avoid a reduction in the efficiency of the shaft movement
- Switch off the machine after use

4.5 LIMITATION OF PROJECT.

- Some materials are not readily available
- Time was one of the limitation face during the design and fabrication of this work

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This project report has successfully showed the design of a locally fabricated metallographic grinding and polishing machine. The machine can be used for efficient grinding and polishing of samples for metallographic testing. The objectives of this project which is to design and fabricate an affordable laboratory metallographic polishing machine that can be used for grinding and polishing of metallic materials in the metallographic laboratory saves one the cost and inconvenience of purchasing an imported machine. It doesn't require any highly priced part for its maintenance.

Also, another objective was to produce a machine that is easy to operate and requires minimum maintenance. The overall procurement cost technically eliminates expenses that will arise from inflated prices of imported goods and also import duties and clearing fees. The machine weighs approximately 32 kg, and the polishing disc has a speed of 2333.3 rev/min.

5.2 RECOMMENDATIONS

1. Water flow must be properly controlled so as to ensure that the abrasive particles from the sample while polishing would not damage area for inspection and also to avoid unnecessary splash.
2. The voltage used to operate the machine should not be less than 220 volts in order for the machine to perform efficiently.
3. The shaft adjuster should be used to ensure that the gear and pinion are properly aligned.
4. A sample holder could be integrated into the machine for ease of use. Instead of manual sample holding, which is hazardous to the machine operator's safety.
5. Because of its light weight and low water reactivity, composite polymer material could be used as the polishing disc.
6. A VARIAC Transformer should be used to reduce and increase the speed

5.3 CONTRIBUTION TO KNOWLEDGE

The project developed a technique for locally producing a laboratory metallographic polishing machine with twin polishing discs using locally produced materials.

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