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Development of a Twin Disk Laboratory Metallography Machine

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ABSTRACT

Polishing is a vital step in metallography, which involves grinding and polishing metallic samples to prepare them for microscopic examination. A metallographic specimen polishing machine is a valuable piece of equipment in this process. The goal of this project is to design and fabricate an affordable and efficient polishing machine suitable for research centers, laboratories, and workshops in Nigerian higher institutions. The proposed machine uses motor-powered grinding wheels of appropriate composition, which rotate against a marked-out area of a metal sample to be polished. A chemically inactive liquid, such as Nita solution comprising nitric acid and ethanol, is used for etching. After polishing, the surface is flushed with water to ensure a smooth, polished surface that retains the original microstructural composition and arrangement inherent in the original sample. The polishing wheels are fine-grained, dense-structured abrasive materials bonded together with an appropriate bonding agent. The machine design incorporates the ability of the twin disk to run at different speeds. This machine can be used to etch various metals for proper surface exposure for optical or electron microscopic investigations and analysis, making it a valuable asset in metallography research.

1. 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 [1]. 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 [2]. Many methods for determining internal structure have been developed, but microscopic investigations have always been the most significant. Throughout the history of metallography, they have been performed using an optical microscope [2].

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 [3]. 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 [4]. To avoid the possibility of pulling out of the graphite phase, the number of grinding and polishing stages should be kept to a minimum [5].

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 [6, 7]. 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 [8]. 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. Several metallographic preparation machines for grinding and polishing are available, each satisfying a particular set of preparation quality, capacity, and repeatability requirements [9].

The origin of polishing machine began from the quest by Leonardo da Vinci who was a scientific and technology pioneer. He envisaged designing an 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 [3,10]. 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 [10, 11]. 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.

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 [9, 11]. 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 [11, 12]. 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. 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 [9, 11].

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 [11, 13].

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 [11].

1.1. Literature Review

More recently a lot of work has been carried at in the design and fabrication of polishing machine. Erinle et al. [8] for instance, studied and developed metallographic polishing machine with the aim of developing a machine that can polish metal in order to get a flat and smooth surface. They concluded that their developed machine has ability to grind and polish metal components. Vijayan et al, 2019 designed and fabricated a polishing machine that could execute polishing operations continuously and used it to polish several types of workpiece. The results showed that the machine can polish stainless-steel flat bars, square tubes and rectangular tubes into 10mm-150mm width products, operate at a high speed of 2,000~3,000 rpm, Barbuto, [14] also developed procedures to automate polishing of ceramics. They studied these procedures considering Struers automatic polishing machine. They concluded that their procedure produces a very high-quality product. Zhong, [15], developed a polishing machine which works based on parallel-kinematic system. They developed a hexapod which was held in the machine frame in order to drive the polishing tool. They concluded that the designed hexapod can polish steel material with good surface roughness. Rathod et al. [16] studied the metal removal rate considering different types of emery paper during polishing. They fabricated a polishing machine and tested its effectiveness. They concluded that these types of machine can be used to polish metal components. Wang. and Wang [17] has developed a special polishing machine. They studied the different process parameters considering surface roughness and polishing efficiency using Taguchi method. They concluded by giving optimal combination of process parameters. Wu et al. [18] studied M300 steel in considering surface quality during polishing. They used a ball-type abrasive tool polishing and then optimized considering surface roughness and material removal rate. They concluded the optimization process using confirmatory tests. Fernadez et al, [19] developed a newer method of abrasive polishing using robotics and concluded that the final surface quality can be predicted using the method they developed. Qu et al. [20] studied the dynamic design process in grinding and polishing. The optimization process was done considering genetic optimization in FEA software. They concluded from their analysis that dynamic properties have been enhanced significantly.

From the above literature review, a lot of work has been conducted in designing a polishing machine and in optimizing parameters to obtain good surface finish. However, none to the best of my knowledge have designed for the twin disk to run at different speed. This research therefore focuses on designing a twin disc polishing machine with the ability of running at different speed.

The design was also 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.

2.0. Materials and Method

The materials used for this experiment include the frame, shaft, tap and pipe, steel plate, motors, polishing disk casing, metal clip. etc. 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 cost. Some of the major components include:

1. Frame and Table stand: The rectangular frame was made of mild steel. It had an overall dimension of 30 inches by 20 inches providing a sturdy base for the various components. The table stand, measuring 21 inches by 18 inches, was designed to provide optimal support for the electric motor, shaft, bearings, tap, and polishing discs.
2. Polishing plate: The polishing plate used was made with mild steel material. It was selected based on its ability to endure eccentric movement. The polishing plates were attached to the base of the frame and joined to the shaft end via a hexagonal bolt.
3. Shaft: The shaft was made of steel. It was selected to withstand the force and weight of the other components linked to it. The shaft, with a diameter of 25mm and a length of 15mm, was erected at the center of the mainframe, supported by two bearings, and securely attached at the top and bottom of the frame through brazing.
4. Tap and Pipe: The taps and pipes were made from polymers. It was selected because of the its significant strength and corrosion resistance.
5. Motors: Two high-capacity 1119W electric motors with a rotation speed of 2800 rpm were integrated to ensure the appropriate level of performance. The motors were securely fastened to the frame using hex head bolts and nuts.

2.1. Machine Fabrication for the Plucking Component

The sequence of fabrication for the machine is outlined as follows: assembly of the frame structure, fabrication of the table support, integration of electric drive motors, installation of bearings on the rotational shaft, attachment of the polishing disc, addition of the required tapping mechanisms, connection of the water supply hose, finalization of the construction process, application of a protective paint coating.

2.2. Principle of Operation

Additionally, during operation, the material to be polished is placed on the rotating polishing disc in a secure manner. The tap is activated to regulate the temperature and maintain optimal conditions during the polishing process. The rotational motion of the polishing disc is driven by the shaft, which rotates against the stationary frame. The speed of rotation can be precisely controlled to accommodate the unique requirements of each individual polishing cycle, providing versatility and flexibility in the polishing process.

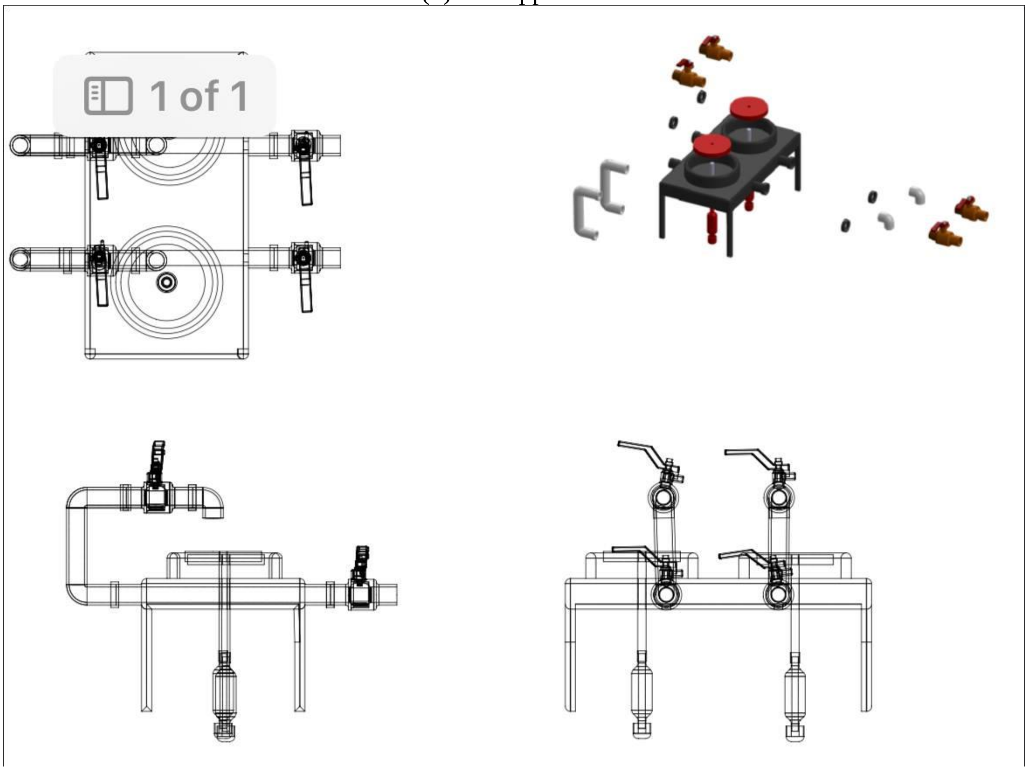

Figure 1: The orthographic view of the polishing machine

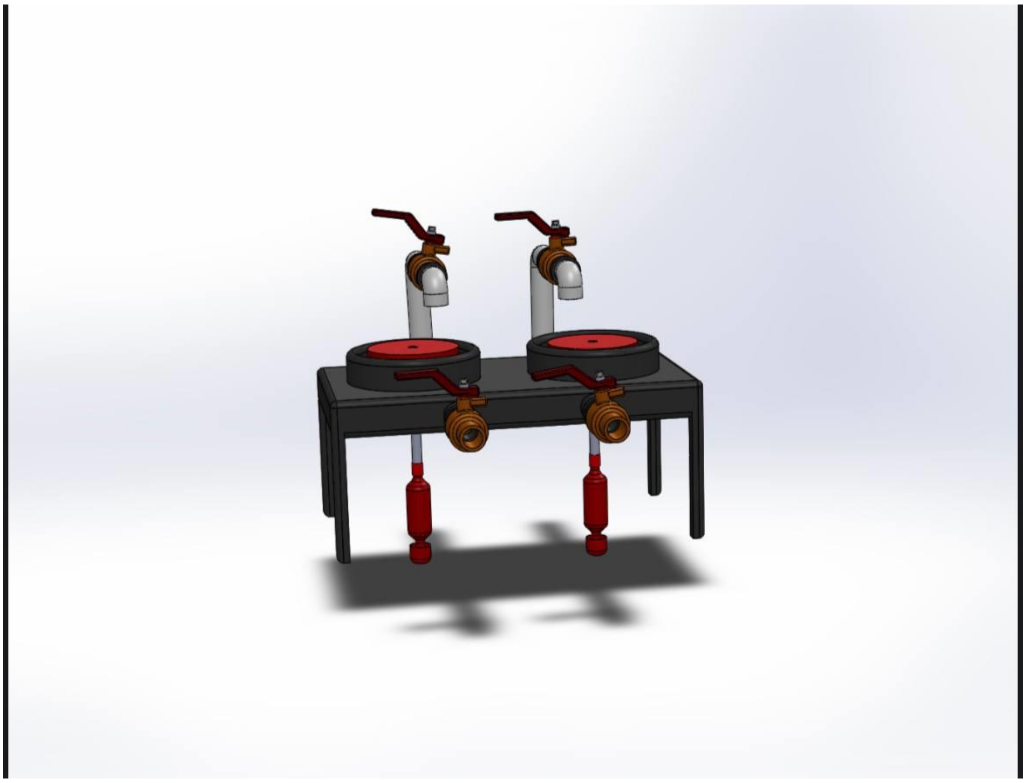

Figure 2: The isometric view of the polishing machine

3.0 Results and Discussions

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. A shiny, smooth surface of the mild steel metal sample was obtained with no presence of scratches. 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 as a result of the mirror-like finish imparted on the polished surface. No observable change occurred after the application of an etchant to an unpolished surface 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.

3.1 Base Frame Fabrication
The I-beams is one of the three integral parts of the base frame assembly. These beams are made of mild steel metal. The I beam were cut using handsaw to the desired length in sets of two and fabrication work has been performed which serves as a bed frame on which all the components will be mounted.

3.2. Supporting Legs
The supporting legs have been fabricated and the I beam are mounted on these support legs. These supporting legs are made of 21inch x 18 inch hollow square tubes for support and better load distribution and stability.

3.3. Flat Plate
The side plate is the final addition to the base frame assembly. The fabrication process of side plate comprised of both welding and drilling procedures. The side plate was first cut to the required dimension using handsaw cutting process and then four holes were drilled in pairs opposite to each other.
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4.0 Conclusion and Recommendation
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.

Recommendations worthy of note are;
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. 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.
4. Because of its light weight and low water reactivity, composite polymer material could be used as the polishing disc.
5. A VARIAC Transformer should be used to reduce and increase the speed.

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