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MINI SANDER MACHINE FOR SMALL-VOLUME PRODUCTION

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Abstract— Machines are tools that simplify tasks by enhancing human effort. However, they are often costly and not readily available in compact sizes for small-volume production works. Therefore, this project was carried out to design and construct a mini electric belt sander. The design process utilized SOLIDWORKS, and the machine was built through drilling, cutting, and grinding techniques. The belt sander operates effectively when activated, making it ideal for tasks such as shaping knives and regrinding drill bits. Ultimately, this mini machine is expected to be highly useful for small-scale projects and affordable for most users.

I. Introduction

Sanders plays a crucial role in various industrial sectors such as woodworking, metalworking, and automotive, facilitating the attainment of refined and polished surfaces. The belt sander machine has emerged as a widely recognized tool [1-2]. Using, continuous abrasive belts, belt sanders are adept at quickly and effectively removing material from the workpiece, thereby enhancing productivity and surface quality [1, 3].

The belt sander machine comprises a motorized drive unit responsible for driving the abrasive belt, a working table, and a tensioning mechanism to maintain the belt's tension. This setup enables the continuous movement of the abrasive belt across the surface, facilitating user manipulation of the workpiece against the abrasive surface [4]. Furthermore, the belt's dimensions and grit can be tailored to accommodate material removal specifications and user needs.

The primary objective of using a belt sander is to achieve rapid material removal while maintaining a smooth and uniform surface finish [5]. These machines are widely used for tasks such as levelling surfaces, removing paint or varnish, and shaping and refining wood and metal substrates.

Over the years, advancements in belt sander technology have developed powerful and efficient machines. Innovations include features like variable speed control, dust collection systems, and ergonomic designs to improve user comfort and productivity [6]. Furthermore, the availability of different abrasive materials, such as aluminium oxide, silicon carbide, and zirconia, has expanded the capabilities of belt sanders [7-8]. Although belt sander machines offer significant benefits in material removal and surface finishing, they also present specific challenges that must be addressed.

The following problem statement identifies critical areas of concern regarding using belt sander machines. One common issue with belt sanders is the tendency to produce uneven or inconsistent surface finishes.

This problem can occur due to improper belt tension, inadequate pressure distribution, or variations in the workpiece material. Inconsistent surface finishes can lead to additional time and effort spent on manual touch-ups, reducing overall productivity and increasing costs. Belt sanders generate a significant amount of dust and debris during operation. Inadequate dust collection systems or improper dust containment can result in poor air quality in the work environment and health hazards for operators [9-10]. Besides, dust accumulation can affect the sander's performance and durability, leading to frequent maintenance and downtime.

The durability and performance of the abrasive belts used in belt sanders are crucial factors affecting the efficiency and cost-effectiveness of the machine. Issues such as premature belt wear, clogging, or reduced cutting ability can impact material removal rates and productivity. Understanding the factors that affect belt durability and finding ways to optimize belt performance is essential for improving the reliability and effectiveness of belt sanders.

Prolonged use of belt sanders can lead to operator fatigue and discomfort due to the vibration and weight of the machine. Ergonomic design considerations, such as handle grip, weight distribution, and vibration damping, must be addressed to enhance operator comfort and reduce the risk of musculoskeletal disorders. Addressing these problems will contribute to developing more efficient and reliable belt sander machines, ultimately improving productivity, surface quality, and operator well-being in industries that rely on this equipment.

To produce a mini sander machine that copes with the current interest, this study was carried out to design and construct a mini electric belt sander. Based on the information gathered from the previous study, an improved belt sander machine for small-volume production was proposed. This enhanced design represents an improvement over the previous models, offering improved efficiency and precision in sanding operations.

Product Benchmarking

Several key factors must be considered when evaluating and comparing available belt sander machines, including power, speed, belt size, construction quality, and price. In this benchmarking and comparison study, three popular belt sander models, Model 1, Model 2, and Model 3, were evaluated based on these criteria.

Model 1, invented by Herman S Newton (US2416493A), boasts a robust motor with high power output, enabling it to handle demanding sanding tasks easily [11]. Its variable speed control allows users to adjust the belt speed according to the sanded material, ensuring precise results. The durable construction and large belt size of Model 1 make it suitable for heavy-duty applications in industrial settings.

Model 2, invented by Georg Weber (US20050136813A1), offers a compact and lightweight design, making it highly portable for on-the-go sanding tasks [12]. It features a slightly lower power rating but compensates with a wide range of belt speeds, allowing users to achieve different finishes. This model is favored by DIY enthusiasts and hobbyists for its 14 versatility and affordability.

Model 3, invented by John Schnell and Daniel Wall (US20060264161A1), balances power and price [13]. It is suitable for sanding applications and has a moderate power rating and adjustable belt speed. Its sturdy construction ensures stability during operation, and the competitive price makes it an attractive option for budget-conscious users.

This benchmarking and comparison study is based on product specifications, manufacturer information, and user reviews from reputable websites and industry publications. It aims to provide a comprehensive analysis of the strengths and weaknesses of each model, assisting users in making an informed decision.

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II. Methodology

The design of the sander machine is shown in Figure 1. Any related design activities were based on this preliminary design and expressly, along with the preparations of final construction plans. The figure includes detailed specifications for the performance of construction work. This project's overall design was produced using the SOLIDWORKS software, a 3D CAD software tool to create 3D parts and draw and assembly models. A few steps are required in designing this project: to make every part of the product with the correct dimension and assemble the created parts through a mating system. The details of the machine are shown in a different view: the front, top, side, and isometric views.

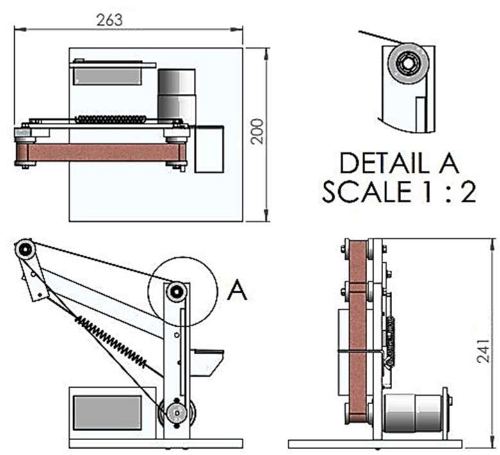

Figure 1: Detail design of the mini sander

Figure 2 shows the project flow chart required to complete the machine. It started with a research background study and underwent several processes before completion. From the literature review, the design was configured to meet requirements, especially the mini size and capability of fabricating various materials such as metal, plastic, and wood [14], and it was based on the design analysis of the machine's assembly. Several parts, such as the body frame, are selected to be fixed to satisfy

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the design requirements and be stable during the work. Besides the fabrication of the designed parts, some components were purchased, as listed in Table 1.

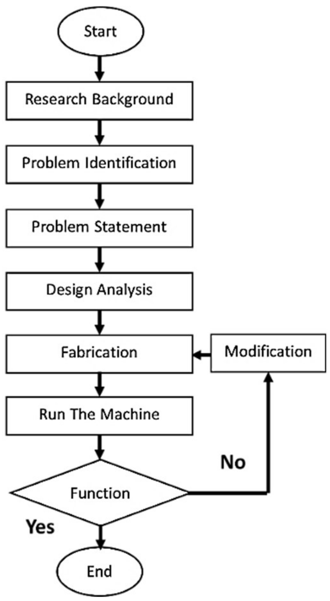

Figure 2: Project flow chart

Table 1: Lists of purchases and custom material

Purchase	Fabricated
Voltage	Voltage
Regulator	Regulator
Bearing Holder	Bearing Holder
DC Motor	DC Motor
Motor Holder	Motor Holder
Ball Bearing	Ball Bearing
Body Frame	Body Frame
Sanding Belt	Sanding Belt

III. Engineering Analysis

Engineering analysis serves as the foundational framework of a project, involving analysing an object, system, problem, or issue into its fundamental components to understand their core characteristics and interrelationships, as well as their interactions with external factors [15]. In the context of this project, finite element analysis (FEA) was employed to simulate and analyse the stress distribution in a mini sander belt machine. This approach allowed for a detailed examination of how the machine's components respond under various loading conditions, providing crucial insights into its performance and structural integrity.

Figure 3 shows the boundary condition of the part made from aluminium alloys, 1060. Aluminium 1060 refers to a specific alloy within the aluminium series. It is a commercially aluminium with high thermal and electrical conductivity, excellent corrosion resistance, and good formability. The designation "1060" indicates the composition of the alloy, with 99.6% minimum aluminium content. This alloy is commonly

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used in various applications and has advantageous properties, such as electrical conductors, heat exchangers, chemical equipment, and architectural components.

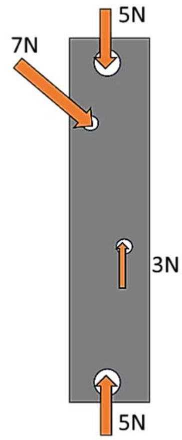

Figure 3: Boundary condition for finite element analysis

Although aluminium does not have a high tensile strength, adding alloying elements like manganese, silicon, copper, and magnesium can increase the strength of aluminium properties and produce an alloy with properties tailored to applications. Part in Figure 3 was selected for the analysis as it holds most of the load applied to the machine. This part is specific to the vertical plate and attached to the base plate. 5N force acted on the top of the pillar plate, and then 5N of reaction force acted from the bottom part. 7N comes from the tension spring and weight of the support structure that worked from the side. The other 3N force was based on spring location. The finite element was then examined to determine the maximum stress and safety factor versus the thickness of the aluminium plate.

IV. Schematic Diagram

Figure 4 shows a schematic diagram of the belt sander machine. Starting from the power supply to the voltage regulator used to control the voltage output to manipulate the speed of the motor and ends with the sander belt machine being operated.

The sender machine's schematic diagram simplified the electrical system of the machine. Starting with the power supply, the voltage regulator ensures consistent voltage output, which is vital for the machine's smooth operation. The regulated power feeds into the motor, the central component that drives the sander belt. Control mechanisms, such as switches or motor controllers, allow operators to initiate and stop the machine's operation as needed, enhancing safety and convenience. The sander belt, rotated by the motor's rotational force, efficiently grinds the interested surfaces, making it a versatile tool for various applications. In addition, the sanding element forms a solid system that enables precise and reliable sanding operations, which is essential in woodworking and other surface modification industries.

The schematic diagram of a sender machine serves several crucial functions. Firstly, it provides a clear visual representation of the electrical circuitry, illustrating how different components are connected and interact. This aids in understanding the machine's operational principles and troubleshooting any issues that may arise during the operation.

Additionally, the schematic diagram facilitates the design and construction of the machine by guiding engineers and technicians in assembling the components correctly. It is also a reference document for maintenance and repair tasks, helping technicians identify and repair faults efficiently. Overall, the schematic diagram is pivotal in ensuring the sender machine's functionality, safety, and reliability throughout its lifecycle.

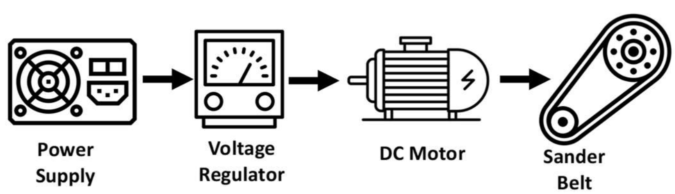

Figure 4: Schematic diagram of the sander machine

V. Fabrication process

Fabrication is the action or process of manufacturing or producing something, combining typically standardized parts using one or more individual processes [16].

In addition, it is publicly acknowledged that cutting and drilling are standard fabrication techniques used to shape, cut, or drill raw materials into a final product [17]. Table 1 and Figure 5 show the important parts of the machine that undergo the fabrication to ensure the mini sander belt machine follows the expected design as in Figure 1.

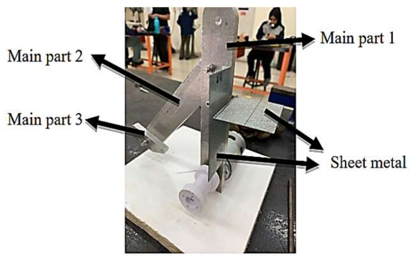

Figure 5: Part component of the sander machine

The machine was made from aluminum plates and sheet metal, as shown in Figure 5. The process started with ten mm-thick aluminum plates based on FEA consideration. The plate was measured, and cut using a band saw machine and angle grinder. Several holes are drilled on the plates. The sheet metals are being measured and cut using the sheering machine. Several holes are drilled on the sheet metal. The sheet metal was then bent 90 degrees using a bending machine. The bending sheet metal is then attached to the aluminium plates using bolts and nuts. The bearing holder contains a ball bearing and is made from PLA plastic. The bearing holder was fabricated using a 3D printing machine, as shown in Figure 6, and it took almost 14 hours to complete the printing process of these three bearing holders. The bearing was inserted into the bearing holder to make sure the part worked properly. The part then was attached to the main part of the mini sander belt machine using bolts and nuts.

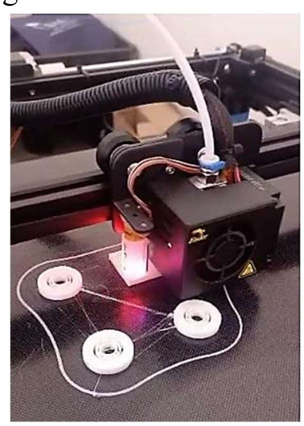
Figure 6: 3D printing of bearing holder

VI. Result

Stress distribution data from simulation work were incorporated into the early

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stages of product design to minimize the number of prototypes required. Additionally, integrating simulations into the design workflow prevents time wastage on creating parts that cannot endure stress. The outcome is illustrated in Figure 7. This analysis step accelerates results and reduces design costs. For structural analysis, key information includes von Mises stress, displacement, and safety factors.

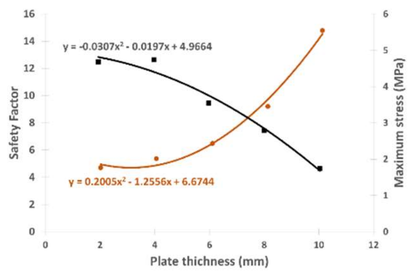

Figure 7: Maximum stress and Safety factor versus plate thinness from FEA study

Figure 1 shows the mini sander belt machine that was analyzed. Figure 3 then shows the critical part made from Aluminium 1060 alloy. This part was chosen because it holds the most significant load among other parts. The different thicknesses show a variety of options to go with. The total load applied to the part is 20N, which comes from 4 sources.

As in Figure 7, thin aluminium plates experienced higher maximum stress and lower safety factor. As thickness was increased, the maximum stress reduced exponentially, increasing the safety factor. A plate thickness of 10mm was the biggest thickness tested, based on the result, it can withstand more stress and has higher safety factors. The polynomial line can be obtained from the equation below. Under the load, the maximum stress is 1.66MPa.

On the other hand, the factor of safety is close to 16. This concludes that the structure with 10mm thickness can withstand the applied load without any failure or fracture. To cope with cost and design considerations. 5 mm aluminium thickness was selected for the final design.

Figure 8 shows the completed mini sander machine, typically used in woodworking or small-scale projects, which serves the purpose of sanding and smoothing surfaces efficiently. Its primary function is removing imperfections, roughness, or old finishes from wood, plastic, or metal surfaces. This is achieved through the abrasive action of sandpaper or sanding discs attached to the machine's sanding pad. Mini sander machines come in various types, including orbital sanders, detail sanders, and belt sanders, each suited to different tasks and surface types.

Figure 8: Completed mini sander machine

One of the most important features is the material removal and smoothing. The primary function of a mini sander belt machine is to remove material from a workpiece and smooth its surface. It utilizes a continuous loop of sandpaper or abrasive belts that rotate over the bearing holder to achieve the sanding action.

Manual operation requires the use of the mini sander belt machine, which is provided in this section. It is important to follow the steps so that any accident can be prevented and to make sure the machine can last longer.

1) Loop the sander belt around the bearing holder and attach the spring to give it tension.
2) Loosen up the wing to adjust the angle of the part to the desired angle.
3) Plug in the power supply.
4) Adjust the voltage clockwise following the LED indicator until the sander belt starts to rotate. Ensure the voltage regulator is off before plugging it into the power supply.

Product advantages are what a product offers to satisfy a customer's needs, desires, and wants. Hence, the advantage of this mini sander belt machine is that it has a low production cost. Since making a mini sander belt machine is roughly RM90, it can be considered a low-cost machine. The price and machine

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will make the machine attractive for small businesses, hobbyists, or individuals on a budget who still require efficient sanding capabilities. It is also a wise choice for the sanding process.

VII.Conclusion

In this project, a mini belt sander machine was designed using SolidWorks software. The mini belt sander machine was successfully fabricated after several design modifications, with the entire process taking approximately ten weeks to complete. The mini belt sander machine has proven effective in sanding and smoothing materials such as wood. It has been tested at three different speeds and operates reliably.

Several recommendations are suggested for future works to enhance the machine's potential further. First is, to install a barrier around the machine to contain dust and debris. The second suggestion utilizes a higher-voltage motor and a belt with a higher grit for improved sanding and smoothing of various materials. The final suggestion is to construct the mini belt sander machine using more stable materials to enable the sanding of metals.

VIII. Acknowledgement

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