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Development of Cylindrical Silk Screen Printing Device

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Abstract: Traditional silk screen printing struggles with efficiently printing on cylindrical surfaces like bottles and mugs. This study addresses the gap by developing a Cylindrical Silk Screen Printing Device specifically designed for rigid cylindrical material. This study focuses on evaluating its operating performance in terms of paint consumed in the number of pieces printed per minute, energy cost, and assessing the print quality and acceptability in terms of design, technical features, composition, operating performance, and safety of the device motor.

The device uses a motor-driven system with a threaded rod and limit switch to control the printing process onto a cylindrical object. This innovative approach improves ink application and reduces setup time compared to flat-bed methods. A rigorous evaluation, involving 50 experts and end-users, assessed the device's performance using a five-point Likert scale. These evaluators were selected through purposive sampling based on their expertise. The testing and evaluation took place at Capiz State University-Main Campus, while the development work was done at the researcher's residence.

Testing revealed an average paint consumption of 266 mL across 133 prints, with a total energy cost of only Php 0.80. The approximate printing speed ranged from 94 to 180 pieces per hour. The device's robust, industrial-grade design prioritizes both user-friendliness and safety. Overall, the device received a "Very Acceptable" rating, demonstrating its effectiveness and suitability for high-volume cylindrical printing. Its adjustable design allows for precise printing on various cylindrical sizes, making it a significant improvement over existing method.

Keywords: Cylindrical, Printing, Device and Silk Screen

I. INTRODUCTION

Background of the Study

Silk screen printing, commonly referred to as serigraphy, is a highly versatile printing technique employed for centuries to produce intricate designs on a variety of surfaces. Its rich history spans multiple cultures, and its application to cylindrical materials, such as drinkware, introduces distinct challenges and advancements (Kathleen Kuiper, 1965) [1]. This study relates to a silk screen printing device, particularly to a silk screen printer into a cylindrical material. This innovation is an improvement over the silk screen printing device capable of printing using of pigment or color into the fine mesh with pattern of letters or design assembled into stencil frame which is intended to move using motor controller (threaded shaft/rod) that controls the speed travel of 12V DC motor connects into power converter that directly connected into the supply and activates the mechanism.

A 12V DC motor is connected to a relay that operates within a cycle controlled by the limit switch. When the limit switch is activated (through an object reaching a certain point), it closes the circuit, energizing the relay. The energized relay then closes its contacts, completing the circuit to the wiper motor reaches its end point and the limit switch is deactivated (through an object moves past the sensor), the circuit opens, de-energizing the relay, and stopping the motor. This creates a simple on/off control mechanism for the motor's movement, preventing over-travel. The squeegee is arranged or set for pressing the stencil against the print material. The pigment is being transferred into a cylindrical product which is located above the roller bearing bolt into the roller bracket. Printed material will revolve once the stencil frame is pull which is mounted into the frame carriage by the help of a threaded rod that connect into the 12V DC motor where its function is to push and pull back the frame carriage, while the another wiper motors' function is to lift up and down the frame carriage with threaded rod that controls the speed travel and come up with an output.

Significance of the Study

This device is particularly useful for businesses involved in custom printing, promotional items, branding, and artistic design. It is beneficial for small businesses, artisans, and large-scale manufacturers alike due to its versatility and cost-effectiveness.

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Scope and Limitation of the Study

The device was limited only on printing on rigid cylindrical products with the maximum measurement of design to 4" x 4" which consume approximately 2ml of paint. One printing cycle lasts 20 to 38 seconds and can produce approximate of 94 to 180 pieces in one hour. However, loading and unloading of cylindrical material and placing of ink into the framed silk screen are manual.

II. METHODOLOGY

This study relates to a silk screen printing device, particularly to a silk screen printer into a cylindrical product. This innovation is an improvement over the silk screen printing device that specialized piece of equipment designed for applying ink to cylindrical objects, particularly drinkware like bottles, mugs, and tumblers. The device is capable of printing utilizing a silk screen, a mesh fabric stretched over a 1" X 1" thick and 8" X 13" dimensions of wooden frame, with a stencil pattern that defines the design to be printed using of pigment or color which is intended to move using motor controller (threaded shaft/rod) that controls the speed travel of 12V DC motor connects into power converter that directly connected into the supply and activates the mechanism. The drinkware is precisely rotated and indexed within the device, ensuring accurate alignment of the pattern as it passes under the screen. Once the stencil frame is pull which is mounted into the frame carriage by the help of a threaded rod that connect into the 12V DC motor where its function is to push and pull back the frame carriage, while the another wiper motors' function is to lift up and down the frame carriage with threaded rod that controls the speed travel and come up with an output.

A 12V DC motor is connected to a relay that operates within a cycle controlled by the limit switch. When the limit switch is activated (through an object reaching a certain point), it closes the circuit, energizing the relay. The energized relay then closes its contacts, completing the circuit to the wiper motor reaches its end point and the limit switch is deactivated (through an object moves past the sensor), the circuit opens, de-energizing the relay, and stopping the motor. This creates a simple on/off control mechanism for the motor's movement, preventing over-travel. A squeegee blade, controlled by adjustable pressure and speed settings, is then passed across the screen, forcing ink through the open areas of the stencil onto the surface of the drinkware. The pigment is being transferred into a cylindrical product which is located above the roller bearing bolt into the roller bracket.

This process creates a permanent, quality print that adheres to the cylindrical surface. The device is typically equipped with features for handling varying diameters of drinkware, ensuring consistent ink application, and minimizing ink waste. It also incorporates safety features for operator protection and is designed for efficient production, capable of printing a large volume of drinkware per hour.

These devices are essential for commercial printing on drinkware, allowing for the creation of customized designs and brand logos that enhance the appearance and value of the products.

III. RESULTS AND DISCUSSIONS

Operating performance of cylindrical silk screen printing device in printing glass bottles, mugs and drinking glasses in terms of paint consumed in number of pieces printed per minute, and energy cost.

Table I below shows the operating performance of cylindrical silk screen printing device in printing bottles, mugs and drinking glasses in terms of paint consumed in number of pieces printed per minute, and energy cost. Data further showed the sampling under 1 cycle or pieces printed consumed 2 ml of paint with the power consumption of .00045 kilowatt-hour with energy cost of .006 pesos; in 66 cycle or pieces printed consumed 132 ml of paint with the power consumption of .03 kilowatt-hour with energy cost of .40 pesos and in 133 cycle or pieces printed consumed 266 ml of paint with the power consumption of .06 kilowatt-hour with energy cost of .80 pesos. However, if the price per kilowatt-hour (kWh) increases, the overall energy cost will also increase proportionally. Further, the wiper motor used in the device had a constant voltage of 12V and amperage of 5A.

Furthermore, the result is consistent with the study of Zhou and Li (2020) [2]. in "Optimizing throughput in cylindrical screen printing for mass production" wherein they examined throughput improvements in cylindrical screen-printing machines by adjusting motor speeds and automation levels, highlighting how optimizing parameters like screen movement speed and squeegee pressure can enhance the number of pieces printed per minute without sacrificing print quality.

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Table I. Operating performance of cylindrical silk screen printing device in printing glass bottles, mugs and drinking glasses in terms of paint consumed in number of pieces printed per minute, and energy cost

Number of Cycle or Pieces Printed	Paint consumed	Power Consumption Volts	Amps	Power (Watts)	Time	Power Consumption	Energy Cost 13.36/KWh
1	2 ml	12	5	60W	27 sec.	.00045 kWh	PhP .006
66	132 ml	12	5	60W	30 min	.03 kWh	PhP .40
133	266 ml	12	5	60W	1 hour	.06 kWh	PhP .80

Output of the Device in Terms of Quality of Print

Table II below shows the overall mean of output of the device in terms of quality of print.

The production resulted in 20-27 seconds resulting an overall mean of 4.63 evaluated by experts and an overall mean of 4.77 evaluated by users with the verbal interpretation of "Excellent". The process demonstrated high efficiency and very acceptable output quality.

The production resulted in 28-35 seconds resulting an overall mean of 3.90 evaluated by experts and an overall mean of 3.77 evaluated by users with the verbal interpretation of "Very Good". Print quality assessment indicated an acceptable level. However, moderate ink smearing was noted. Analysis on the smearing issue is required to improve process efficiency and output quality.

The production resulted in 36-38 seconds resulting an overall mean of 2.90 evaluated by experts and an overall mean of 3.16 evaluated by users with the verbal interpretation of "Good". More ink smearing observed resulting in less quality of print. Moreover, process adjustments are needed to address this issue.

The results above corroborate the work of Zhang and Liu (2020) [3]. "High-efficiency silk screen printing system for cylindrical substrates with waste minimization" focuses on optimizing a printing system to reduce material waste while maintaining high-quality prints on cylindrical products. The system uses variable speed adjustments and automated monitoring to ensure minimal ink wastage.

Table II. Output of the device in terms of quality of print.

Time duration	Overall Mean		Verbal Interpretation
	Experts	Users	
20-27 seconds	4.63	4.77	Excellent
28-35 seconds	3.90	3.77	Very Good
36-38 seconds	2.90	3.16	Good

Results Cylindrical Silk Screen Printing Device in Terms of Design, Technical Features, Composition, Operating Performance and Safety

Shown in Table III was the results evaluated by forty (40) experts of cylindrical silk screen printing device in terms of design, technical features, composition, operating performance and safety. The table revealed that the device was "Very Acceptable". Likewise, its specification has an overall mean of 4.76 interpreted also as "Very Acceptable" this means that the device was ideal for mass production in printing cylindrical products like bottle, mug and drinking glasses.

However, the summary of the results evaluated by ten (10) end users of cylindrical silk screen printing device in terms of design, technical features, composition, operating performance and safety revealed that the device was "Very Acceptable". Likewise, its specification has an overall mean of 4.78 interpreted also as "Very Acceptable" this means that the device was ideal for mass production in printing cylindrical products like bottle, mug and drinking glasses.

Further, the device facilitated with smooth ink transfer, resulting in a consistent visually appealing print quality. The device ability to maintain consistent ink flow and pressure across the entire print area contributed significantly to this successful outcome. The evaluation conformed the device's ability to produce good prints with aesthetically pleasing composition.

The data is largely comparable to that of Lee and Park (2017) [4], slight variation were noted in design of cylindrical screen-printing machines, with particular focus on the integration of automation, motorized controls, and precision squeegee adjustments for consistent print quality on curved surfaces.

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Table III. Results of cylindrical silk screen printing device in terms of design, technical features, composition, operating performance and safety.

FACTORS AND PARAMETERS	MEAN EXPERTS	MEAN USERS	VERBAL INTERPRETATION
1. Design.	4.77	4.84	Very Acceptable
2. Technical Features	4.80	4.75	Very Acceptable
3. Composition	4.78	4.74	Very Acceptable
4. Operating Performance	4.71	4.77	Very Acceptable
5. Safety	4.76	4.78	Very Acceptable
Overall Mean	**4.76**	**4.78**	**Very Acceptable**

IV. SUMMARY OF FINDINGS

The researcher conducted this study to develop a Cylindrical Silk Screen Printing Device. Specifically, this study aimed to: determine the operating performance of cylindrical silk screen printing device in printing glass bottles, mugs and drinking glasses in terms of paint consumed in number of pieces printed per minute, and energy cost; evaluate the output of the device in terms of quality of print; and evaluate the acceptability of the device in terms of design, technical features, composition, operating performance and safety.

For the operating performance of cylindrical silk screen printing device in printing glass bottles, mugs and drinking glasses in terms of paint consumed in number of pieces printed per minute and energy cost, data further showed the sampling under 133 cycles or pieces printed consumed 266 ml of paint with the power consumption of 60 kilowatt-hour with energy cost of Php .80 per hour.

Furthermore, the output of the device in terms of quality of print, the production resulted in 20-27 seconds resulting in an overall mean of 4.63 evaluated by experts and an ovelall mean of 4.77 evaluated by end users with the verbal interpretation of “Excellent”. The process demonstrated high efficiency and quality output. It means that the faster the time adjustment of the limit switch, the better the quality of the output regardless of the cylindrical materials used for printing.

Moreover, the device was rated as “Very Acceptable” in terms of design, technical features, composition, operating performance and safety precautions. This indicated that the device is both aesthetically pleasing and professionally constructed. Its performance and safety standards suggest that it is well-suited for mass production, particularly in printing on cylindrical products such as glass bottles, mugs and drinking glasses. This invention implies that the device meets the evaluators’ expectations for quality and functionality, making it a viable option for commercialization.

V. CONCLUSION

Based on the findings, the following conclusions are formulated:
The cylindrical silk screen printing device addresses the efficiency of design and technical features in printing curved surfaces, overcoming the limitations of traditional flat-bed methods. Its durable, industrial-grade construction ensures long-term durability while being user-friendly simplifying operation and reducing setup time. The design accommodates varying cylindrical material diameters, ensuring consistent ink application and minimizing waste. Safety features protect the operator, and the device is optimized for high-volume production, capable of printing a large number of beverageware items per hour. A combination of mechanical and electrical components ensures accuracy, consistency, and high-volume printing with less energy consumption. Thus, this device is a highly effective tool for industries engaged in the production of personalized or mass-produced cylindrical products, including cylindrical material manufacturers, promotional companies, and customized gift retailers.

Furthermore, the performance evaluation of the cylindrical silk screen printing device confirms its efficiency in terms of both productivity and energy consumption. The device demonstrates a medium- to high-volume production capacity, supporting output demands across various industrial applications.

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Each printing cycle reflects economical energy usage, contributing to overall operational cost-effectiveness. These findings validate the device's suitability as a reliable, adaptable solution for consistent and cost-efficient printing on cylindrical surfaces.

The evaluation of the cylindrical silk screen printing device in terms of print quality and production efficiency indicates highly satisfactory performance rated as "Excellent" by expert evaluators. These findings confirm that the device consistently produces high-quality prints with operational efficiency, making it a reliable and effective solution for applications requiring precision and productivity on curved surfaces.

Based on the evaluators' overall assessment, the cylindrical silk screen printing device is deemed *"Very Acceptable"*. Thus, it is highly effective and suitable for the mass production of beverageware, meeting standards in design, technical features, and safety. The evaluation indicates that the device uses appropriate materials and components that ensure durability, operational efficiency, and user safety. Its design promotes accurate, consistent printing, proper alignment, and stable operation, making it a reliable tool for industrial printing purposes.

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