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Low Cost Semi-Automatic Acrylic Cutter and Bending Machine

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Abstract*: In the current market, the acrylic cutter and bending machine is mostly available in big size and equipped with advanced system processes for large industrial application. This is undesirable since the cost of the machine can be quite expensive for a small industry. This paper proposed the development of a low-cost semi-automatic acrylic cutter and bending machine to cater to the small industry requirement. The design methodology has been accomplished using engineering design method to propose a suitable design semi-automatic acrylic cutter and bending machine based on commercially available design. A 3D representation of the machine was generated with the help of Autodesk Inventor 2019 to visualize all the details concerning the semi-automatic acrylic cutter and bending machine. The semi-automatic acrylic cutter and bending machine are designed for cutting, bending, and finishing acrylic sheet in simple manual operation. The machine was fabricated using industrial material specifications such as plywood and hollow steel to ensure the effectiveness of semi-automatic acrylic cutter and bending machine. This semi-automatic acrylic cutter and the bending machine was also equipped with a table that can be adjusted to different heights. The performance of the machine was tested by cutting and bending different thicknesses of the acrylic sheet and polishing of the acrylic sheet. The results found that the semi-automatic acrylic cutter and bending machine is capable of handling the thickness of the acrylic sheet up until 5 mm in a single operation. The developed machine was able to cut the acrylic sheet up to 5 mm thickness and bend from 0 to 180 degrees. Thus, this machine could provide a highly ergonomic solution that responds to the needs of small industrial applications.

***Keywords*: Acrylic, Bending, Cutter, Machine, Semi-automatic.**

I. INTRODUCTION

Poly (metyl methacrylate) (PPMA) is a type of polymer that is categorized under methacrylate glass which contain one or more derivative acrylic acid. PMMA is also knows with several commercial names including Acrylic, Plexiglas, Lucite, Perspex, and Crystallite [1]. Acrylic has a density value of 1.171.20 g/cm^3, which is a half less than the glass density. The impact strength can exceed than that of glass and polystyrene. With a thickness of only 3 mm, acrylic can transmit up to 92% of visible light. It can reflect up to 4% light from its surface with a refractive index of 14905 at 589.3 nm. It is also considered as the best options for most outdoor applications in the plastics industry due to the environmental stability of acrylic compared to polystyrene and polyethylene [2]. It is a transparent material with a glass-like appearance and exhibit a good optical property [3]. Hence it is mostly used as a substitute to glass for numerous applications such as automotive, healthcare and medical, building and construction, and optical industries [4].

A cutter machine is an essential item in dealing with shaping and cutting the acrylic sheet to any design. Based on the available products on the market, it shows that most manual tools consume more time to cut the sheet of acrylics. High energy is also needed to cut the acrylics based on a repeated motion such as using a scoring knife. The use of automatic cutter machine to cut the acrylic sheet is advantageous since it can easily cut the intricate shapes and designs with high accuracy and faster time. Computer numerical control (CNC) is one of the automatic cutter machines that is available in the market. This machine features with a laser cutting which is highly efficient in cutting all type of acrylic plastic. However, this laser cutting machine is extremely expensive [5]. Apart from that, it is mostly designed for industrial application which explained their large and bulky size material.

Previously, a semi-automatic acrylic cutter machine has been proposed by Sohaimi [6]. However, the design is mostly focused on one feature only which is cutting. On top of that, there are some weakness can be found such as less rigid, wobbly and not compatible with working space. Besides, the chrome wire is too thin, whenever the acrylic sheet in the state of half of the melting point where both sides have attention to become joint back together when the sheets are cooled.

Therefore, as a solution to this problem, a low-cost semi-automatic acrylic cutter and bending machine was designed. The semi-automatic acrylic cutter and bending machine is capable of cutting, bending and polishing acrylic sheet in simple manual operation. By using this machine, the production time, human workforce and the labour cost can be reduced. In addition, the optimization of cutting parameters in this developed cutting machine could meet the requirement of engineering specifications as suggested by Mohamed and co-workers [7].

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The developed acrylic cutter and bending machine can also be used for cutting of other types of thermoset material including epoxy and polymer composite [8, 9]. The objective of this study is to design and fabricate a low-cost semi-automatic acrylic cutter and bending machine for small industry application. The design of the semi-automatic acrylic cutter and bending machine was conducted based on the available design on the market. The performance of the prototype was tested and evaluated to determine the effectiveness of the developed design in cutting and bending different thickness of the acrylic sheet.

II. DEVELOPMENT OF DESIGN CONCEPT

The basic concept of the designation of semi-automatic machine is the hot wire foam cutting machine. This design has been chosen because it provides a highly ergonomic solution that responds to the needs of users today. This invention comes with additional features which are related to bending and finishing the sheet. Other than that, the working table can be adjusted to different heights according to the user's need. Besides, the machine also features a portable function where the working table is equipped with wheels. This will allow the user to easily move the machine around and store it after usage. The main components of the semi-automatic acrylic cutter and bending machine can be divided into five main parts consisting of the table top, leg, handle arm, heater strip and motor as illustrated in Fig. 1. The function of each components is summarized in Table 1.

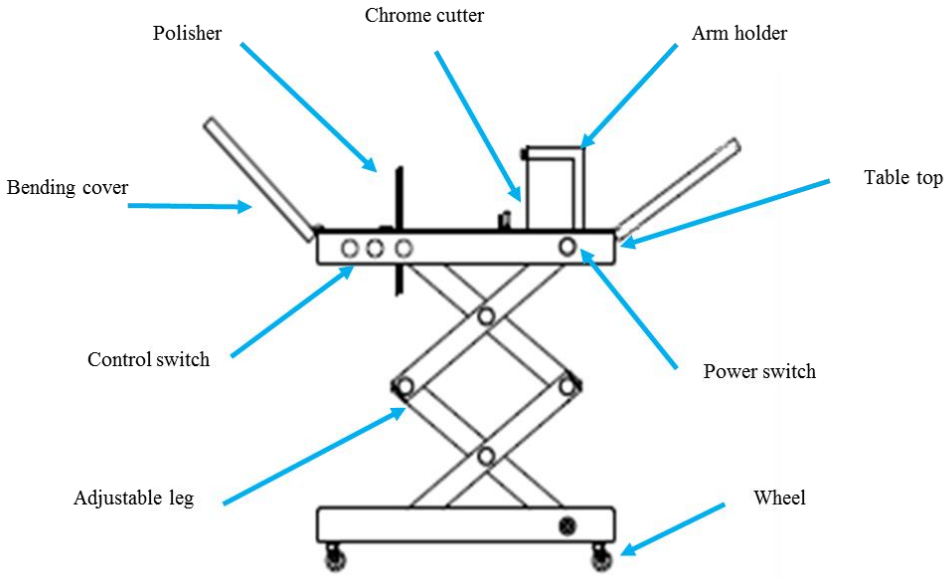

Fig. 1. Conceptual design sketch of semi-automatic acrylic cutter and bending machine

Table-I: Main components of semi-automatic acrylic cutter and bending machine.

Component	Material	Function
Table top	Plywood	• As the main part for the machine to place the handle, arm cover, bending cover and motor cover
Adjustable leg	Mild steel	• To provide support to the machine components • To adjust height of the machine according to the user
Portable handle arm	Hollow steel	• To hold the chrome wire
Cutting wire	Chrome	• To cut the acrylic sheet
Bending cover	Plywood	• To bend the acrylic sheet
Strip heater	Chrome	• To soften the acrylic sheet for bending
Sander disc	Non-woven pad (4")	• To sand and polish the acrylic sheet
Motor	12-24 V DC Motor	• To supply voltage and changing the strength of current • To provide rotation to the sanders
Motor cover	Plywood	• To cover the electronic parts
Power switch	Plastic	• To switch ON/OFF the machine
Control switch	Plastic	• To control the heating temperature of chrome wire for cutting and bending • To control the sander rotation
Wheel	Steel and rubber	• For mobility

III. DESIGN AND FABRICATION OF SEMI-AUTOMATIC MACHINE

The 3D model for semi-automatic acrylic cutter and bending machine have been done using Autodesk Inventor 2019 software. This is to ensure that all the main parts of the machine are fabricated with an accurate dimension as illustrated in Fig. 2. The basic shape of the machine is rectangular with 660 mm in length, 508 mm in width and 730 mm in height.

Fig. 2. 3D design model for semi-automatic acrylic cutter and bending machine

The development process of acrylic cutter and bending machine was conducted as illustrated in Fig. 3. Each part was built using different methods and types of materials. The process began with the design of the adjustable leg. The purpose of the adjustable leg is to provide support to the machine components. In addition, the machine can be moved up or down to cater the special needs by the user with maximum height up to 900 mm. During the welding process, mild steel was used in the table design and fabrication at an early stage. The grinding process takes place before painting to remove all the rust that had accumulated on the surface. The next process involved them manufacturing of the main frame of the semi-automatic acrylic cutter and bending machine which is the table top which placed the handle arm cover, bending cover and motor cover. All the components of the main body were constructed using plywood and aluminium angle bar. Plywood was chosen since it is low price and lightweight material.

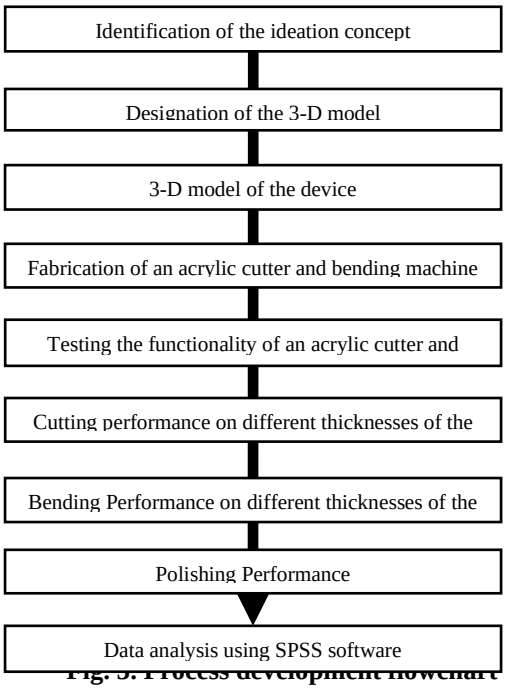

Fig. 3. Process development flowchart

For the cutter and bending part, it was developed using chrome wire material because it has high tensile strength and can reach the temperature of a few hundred Celsius degrees in a few seconds. It will help the user to cut up until 4 mm thickness of the acrylic sheet and bend from 0 to 180 degrees. The handle arm was designed to hold the chrome wire that connected with the electric circuit located through the bottom of the table. The motor is also one of the parts in semi-automatic acrylic cutter and bending machine where it contributes to the rotation of the sander. The selection of the motor used was considered few aspects such as the speed of a DC motor is controlled using a variable supply voltage or by changing the strength of the current within its field windings. A 12-24V DC motor is used because it is small and inexpensive, yet powerful enough to be used for many applications and work perfectly with machine.

For the assembly process of the main body and table, wooden glue, nail, and hammer are used as a fastener. The combination of the main body and the motor must be in parallel way in order to ensure that the motor is capable to functionalize the rotating sander. The blade is not capable to well functioned if the rotating sander and motor are not placed in parallel position.

IV. RESULTS AND DISCUSSION

The functional prototype was fabricated based on the design model and presented in Fig. 4. The specification of the product is listed in Table II. The machine was further evaluated to determine the working performance in terms of acrylic cutting, bending and polishing.

Fig. 4. Fabricated semi-automatic acrylic cutter and bending machine

Table-II: Specification of semi-automatic acrylic cutter and bending machine.

Item	Specification
Dimension (L x W x H)	660 x 508 x 730 mm
Weight	20 kg
Material	Plywood, hollow steel and chrome
Colour	Woody colour
Performance	Portable and user-friendly
Maintenance	Easy maintenance

A. Cutting Performance

The cutting performance of semi-automatic acrylic cutter and bending machine tested out using four different thicknesses of the acrylic sheet from 2 mm to 5 mm. The performance was evaluated in terms of time taken to cut the given acrylic sheet up to 100 mm. The cutting performance of the semi-automatic cutter and bending machine is presented in Table III and Fig. 5.

Table-III: Time taken to cut acrylic sheet using manual and semi-automatic cutter and bending machine

Thickness of acrylic sheet (mm)	Time taken for acrylic sheet cut for 100 mm (manual)	Time taken for acrylic sheet cut for 100 mm (machine)
2	195 s	141 s
3	261 s	198 s
4	780 s	480 s
5	1800 s	900 s

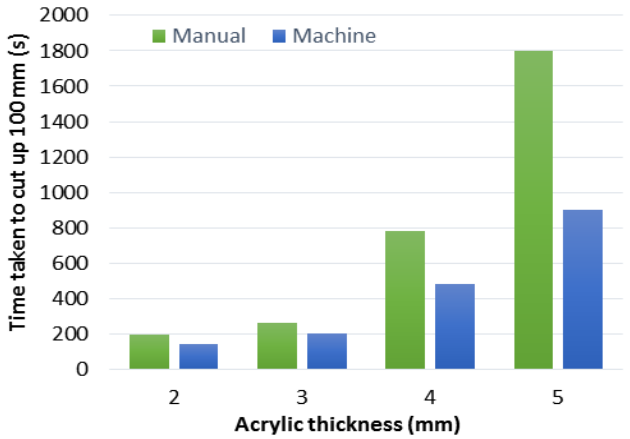

Fig. 5. Time taken to cut acrylic sheet using manual and semi-automatic cutter and bending machine

The results found that the semi-automatic acrylic cutter and bending machine is capable to cut the thickness of the acrylic sheet up until 5 mm in a single operation. The cutting performance of the developed machine was compared to the manual method. The results revealed that acrylic cutting using manual operation took longer time to complete as compared to machine operated. Almost 50% of working time can be reduced by using this machine to cut the acrylic sheet.

B. Bending Performance

The bending capacity of semi-automatic acrylic cutter and bending machine was determined by using different thickness of acrylic sheet (2 – 5 mm). The time required for bending the acrylic sheet up for 100 mm was measured and the results are presented in Table IV and Fig. 6.

Table-IV: Time taken to bend acrylic sheet using semi-automatic acrylic cutter and bending machine

Thickness of acrylic sheet (mm)	Time taken for acrylic sheet bend for 100 mm
2	180 s
3	240 s
4	360 s
5	480 s

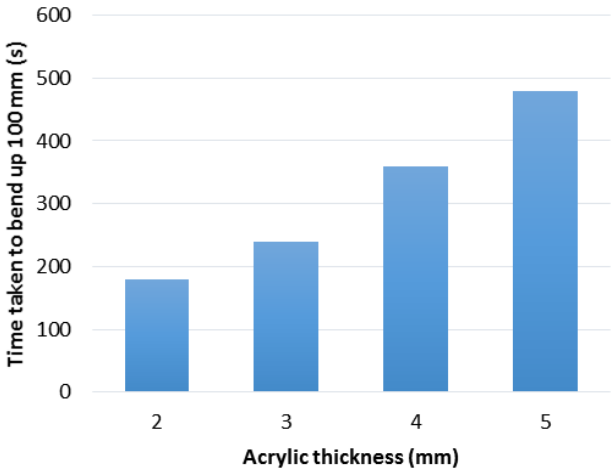

Fig. 6. Time taken to bend acrylic sheet using semi-automatic acrylic cutter and bending machine

From the result, it can be observed that the machine was able to bend the acrylic sheet ideally up to 5 mm of thickness. The time taken to bend the acrylic sheet increase with the increment in the thickness of the acrylic sheet. Nevertheless, the required bending time are shorter than cutting time for each thickness.

C. Polishing Performance

The polishing performance of the machine was evaluated using 5mm acrylic sheet. The comparison between unpolished and polished acrylic sheet is presented in Fig. 7. From the figure, the difference between the unpolished and polished acrylic sheet can clearly be seen using visual observation. The polisher showed a good performance by eliminating any remaining marks or imperfections on the acrylic cut edges. As a result, smooth edges of acrylic sheet was obtained.

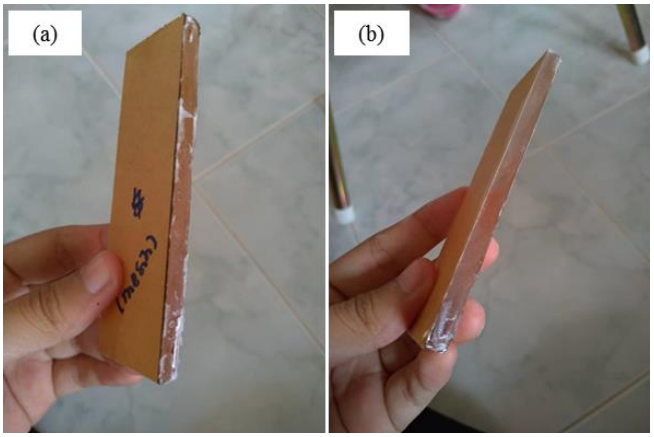

Fig. 7. (a) Unpolished acrylic sheet and (b) Polished acrylic sheet polishing using semi-automatic cutter and bending machine

V. CONCLUSIONS

A semi-automatic acrylic cutter and bending machine has been successfully designed and fabricated in this study. The machine featured a combination of cutting, bending, and polishing functions.

Semi-automatic acrylic cutter and bending machine features user-friendly design with adjustable height and multiple usage for cutting, bending and polishing. The machine was designed in smaller size and user friendly which is suitable for small scale application and educational purposes. Moreover, the portable feature on the machine is advantageous for easier storage and usage. The ergonomic design with adjustable height can cater variety of users which also give additional value to this machine.

Performance test that has been done showed that the semi-automatic acrylic cutter and bending machine is able to efficiently cut and bend up to 5mm thickness and polished acrylic sheet after being cut in a single operation. On top of that the operating time to cut the acrylic sheet can be reduced to 50% compared to manual operation. Hence, it improves the processing time compared to manual operation. Thus it can be concluded that, the semi-automatic cutter and bending machine is highly suitable and feasible for acrylic sheet processing.

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