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Mould Making for Vacuum Thermoforming Machine Using Rapid Prototyping Method

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Abstract: Thermoforming consists of warming a plastic sheet and forming it into a cavity or over a tool using vacuum, air pressure, and mechanical means. The process begins by heating a thermoplastic sheet slightly above the glass transition temperature, for amorphous polymers, or slightly below the melting point, for semi-crystalline materials. As the final thickness distribution of the part is drastically controlled by the initial temperature distribution inside the sheet, it is essential to optimise the heating stage. In most thermoforming machines, this step is performed using an infrared oven consisting of waves infrared emitters. The need for workshop tools such as thermoform machine machines is significant in the Plastic Workshop Practice course offered to students of Mechanical Engineering (Plastic) Diploma in Politeknik Sultan Abdul Halim Mu'adzam Shah (POLIMAS). Existing thermoform machines require high-performance operators and require high maintenance for a process. Long maintenance times and inefficient handling result in machine malfunctions and disrupt the teaching and learning process. This innovation is to make the teaching and learning process better through complete and proper tools.

Keywords: *Thermoforming, Mould, Rapid Prototyping,*

1.0 Introduction

As a practitioner of plastic engineering, plastics studies are the most important to learn and the proper string knowledge on plastic must be attained. Therefore, the learning process must be complete from physical teaching to the usage of proper knowledge in different aspects and to proper hands-on teaching and learning in plastics fundamentals and the basics of it. When having various processes and methods of plastic production, it is vital to understand every process no matter the background and importance (I.Gajdoš, I *et.al*., 2018).

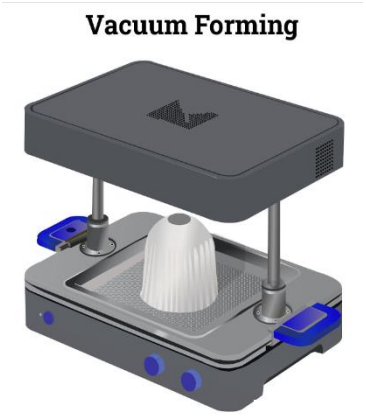


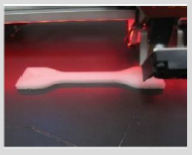
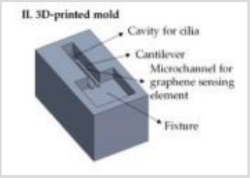
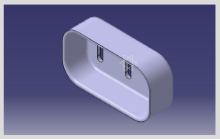
Figure 1: Vacuum forming

Plastic idea innovation is the most important to educate as research of plastic engineering and string knowledge on plastic is vital. Figure 1 displays a thermoforming apparatus that uses heat, pressure, plus vacuum to transform a plastic into a three-dimensional model.

2.0 Literature Review

The mould design was intended and decided to be done based on one of the five ideas recorded in the table above. The designs were studied carefully and suited as well as possible to the objective of the experiment and method of data analysis. Table 1 shows a criteria comparison according to previous research findings. From the above, the tray design came most suitable. Using 3D printing, filament is used to design a soap case. The size was decided based on the ability to maximize its usage as if it were in real use. So, the most adequate size that was decided on the tray design is (150mm) (He *et al.*, 2020). The 3D printing technology developing rapidly throughout the recent years allows for high-precision, personalized elements' printing, made of thermoplastic materials. In design terms, a parameter however, it is significant to develop and print stuff exhibiting mechanical properties comparable to the mechanical properties of stuff produced.

Table 1: Criteria Comparison Table

Criteria	(1)	(2)	(3)	(4)	(5)
Mold Design					
Parameter	Time	Time	Temperature	-	Time Temperature
Method of production	3D printing	3D printing	3D printing	3D printing	3D printing
Author	(Shrestha et al., 2019)	(Ferretti et al., 2021)	(Mrówka et al., 2019)	(He et al., 2020)	-

The benefits of utilizing shell containers for hacking are well-known, simple to obtain, and a straightforward procedure of fabrication. The reason for the low use of shell containers is that their plastic composition causes the plates or the input portion's surface to be fatty, which results in numerous undesired folds on the printed. Sustainability has to do with maintaining and preserving originality. There is a wide variety of vacuum molding patterns that can be used. The most popular vacuum molding mold is made of wood, mostly due to its low cost and ability to accommodate design modifications (Günther, D. *et.al.*, 2021).

3.0 Methodology

The methodology is the study of research strategies, or, more technically, "a clear and consistent scheme based on ideology, convictions, and values that guide the choices researchers make." It involves a theoretical analysis of a branch of knowledge's set of standards and practices, with methodologies from multiple disciplines depending on their historical development. This leads to a series of methodologies that transcend competing perspectives on how information and actuality should be perceived. This places methodologies in the framework of global philosophies and approaches. The methodology may be viewed as a spectrum ranging from a primarily quantitative to a generally qualitative approach. A methodology is identical to a methodology in that it attempts to provide solutions (Wei, H., 2021). A methodology, on the other hand, offers a framework for evaluating which method, combination of methodologies, or practice guidelines can be used to define the research aforementioned challenges.

i. Designing

The CATIA software is used as a design medium to sketch and design out the mould that was intended to be made as the final product. Here, the exact measurements were put in as to how we wanted the final product to look. The measurements included were the length, breadth, and thickness of the material.

ii. Simulation

For the simulation process, it is important as we need to apply it in different environments. This is however done through software again. This time it is CATIA shown in Figure 2.

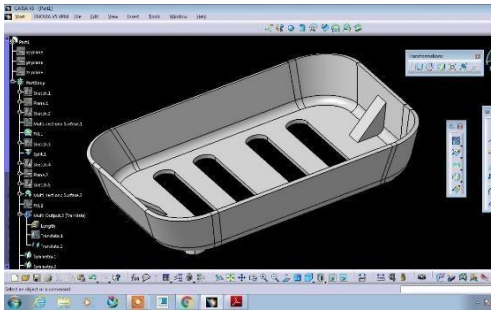


Figure 2: Drawing using CATIA software

The method of experimental is used to test run this mold in the thermoforming machine. Experimental is a concept that will be used as per the objective of this project. However, through this method, the raw data will be collected and tabulated systematically.

4.0 Data Analysis and Findings

Data analysis plays an important role stands almost all investigators from small-scale to big-scale. It is found that it is important because of the after-effects it contributes to. Data analysis aids in creating a more accurate set of data about the research being studied. Conversely, it helps manage the discussion, conclusion, and the main purpose of research. Moreover, with the accuracy of data being the closest to most people's understanding, data analysis gets researchers to understand obtained data much easier through the simplest way forward (Jamil, M. S., 2018).

The vacuum forming activity can be done following the results obtained show that simple equipment can produce a product that is useful to produce various types of packaging according to the form of creativity these results also show that using this tool can produce not only the packaging that is the specific purpose of this research activity however it also has the potential to produce a wide range of other creative products (Mohd Hairol Mizzam *et.al.*, 2022). Although a methodology may typically fit into certain approaches, researchers may merge methodologies to fulfill their research objectives, culminating in multimethod and/or interdisciplinary methods as referred to in Table 2.

Table 2: Data Analysis

Comparative Criteria	Before Project	After Project
Presence of mold	None	Present
Number of mold/s	0	2
Project Quality Assurance	Low	Higher
Teaching and Learning Quality	Low / Uncertain	Higher / Improved significantly

Additionally, recycled materials can be used as molds to ensure sustainability. Aluminum molds are useful for shallow draw pieces and can expedite the fabrication process, despite their high cost.

5.0 Discussion

Modern thermoforming is a manufacturing operation that processes polymeric materials into parts used in everyday life. The process consists of numerous steps including heating a polymer, forming it with a vacuum, then cooling and trimming it. However, it is not perfected and defects still occur during this manufacturing process. Due to their low cost and weight, and relatively easy formability, plastics are becoming increasingly more used in the automotive field (Marmillo, 2008). The vacuum Forming process uses heat and pressure to shape plastic sheets over a mould. A vacuum pushes it into its final shape. The vacuum method ensures an exact shape that is dimensionally stable with an attractive finish. Some

disadvantages include a greater chance of bubbles forming in the plastic, weakening it. To help get around this, the plastic is dried for a lot longer before the thermoforming process starts. Other risks include webs, which can form if the plastic is overheated or the sections that make up the mould are too close together. The temperature of the plastic is typically too low when there is inadequate product detail. Fortunately, it's also the most straightforward to fix. The sheets are heated until they are malleable, then they are placed around the mould to thermoform plastic. When the vacuum is switched on, the plastic sheet won't be flexible enough to draw firmly against the design and obtain the necessary detail if the plastic is too cold or isn't constantly at the proper temperature.

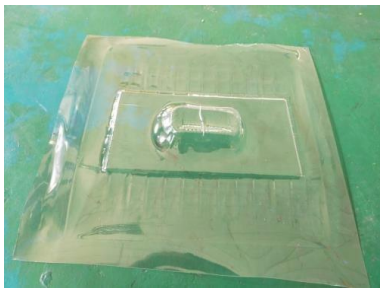


Figure 3: Poor Detail 1

Figure 4: Poor Detail 2

Both images show that has a quality issue which is poor detail. It happens when the heating and cooling are not equal to the plastic material. As you can see, in Figure 3 the adjustment was set at 7 for right, middle, and left. The heating time and vacuum time were set at 35 seconds. For figure 4 the parameter was set at the adjustment of 8 for right, middle, and right. The heating time is 25 seconds and the vacuum time is at 30 seconds.

Figure 5: Part Thickness Inconsistencies 1

Figure 6: Part Thickness Inconsistencies 2

Both images show that has a quality issue which is part thickness inconsistencies. It happens when the vacuum time is not set at the proper time. As you can see, in Figure 5. the adjustment was set at 8 for the right, middle, and left. The heating time was set at 35 seconds and the vacuum time was set at 25 seconds. For figure 6, the parameter was set at the adjustment of 8 for right, middle, and right. The heating time is 30 seconds and the vacuum time is 30 seconds.

Figure 7: Shrinkage 1

Figure 8: Shrinkage 2

Both images show that has a quality issue which is shrinkage. It happens when the temperature is too high and the vacuum time is too short. As you can see, in Figure 7 the adjustment was set at 12 for right, middle, and left. The heating time was set at 25 seconds and the vacuum time was set at 35 seconds. For Figure 8 the parameter was set at the adjustment of 12 for the right,11 for the middle, and 12 right. The heating time is 30 seconds and the vacuum time is 30 seconds.

6.0 Conclusions

This study highlights the importance of standardizing the thermoforming process, as this has a significant effect on the quality and material distribution of the resultant product. Greater model inclination is advised as this optimizes the thickness of the anterior sulcus of the mouthguard which may be more prominently at risk from sport-related impact.

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