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Design and functional optimization of a multi-feature coaster using petg-based additive manufacturing

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ABSTRACT

A coaster is a cup base designed to protect table surfaces from scratches and condensation drops from drinks. However, in their use, various problems are still encountered, such as low capacity to hold condensation drops, the lack of straw holders, and poor stability on slippery surfaces. This research used a product development method comprising three main stages: planning, design, and testing. This research aims to develop a more functional coaster design by adding several innovative features, namely a place to collect condensation drops, a hygienic straw holder, an anti-slip rubber layer, and a magnetic system to keep the handle and straw holder from coming off easily. The design process was carried out in Autodesk Inventor, then produced using FDM type 3D printing with Polyethylene Terephthalate Glycol (PETG) and laser cutting with acrylic. The base model of a coaster was derived from the Forgecore coaster, and the developed coaster was tested through several functional tests, including condensation container tests, glass stability, coaster stability, magnetic strength, and ease of use of additional features. The test results showed that all features functioned as designed and provided a significant performance improvement compared to the coaster made by Forgecore. Thus, this 3D-printed coaster design proves to be effective and feasible as an innovative product that supports daily work and study activities.

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1. INTRODUCTION

Working and studying are daily activities performed by almost everyone worldwide. Both activities generally take up a lot of time and are typically performed while sitting at a desk. One of the most common habits during these activities is drinking coffee. Sipping a cup of coffee is a popular choice for many people because it provides an energy boost and improves focus and concentration (McLellan et al., 2016).

When serving coffee, most people use a coaster to protect the table surface from scratches caused by the bottom of the glass. Coasters are often associated with coffee drinking, making them a relevant product for further development. In addition to protecting the table from scratches, coasters also serve to contain condensation drops from cold beverages that could otherwise wet the table surface. Although synonymous with

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coffee connoisseurs, coaster users are not limited to coffee lovers alone. Anyone who drinks beverages such as water, tea, juice, or milk while working or studying can benefit from using a coaster (Utomo and Wardaya, 2023).

Figure 1. Coaster made by Forgecore (Forgecore, 2025)

An example of a coaster that can be used is shown in Figure 1, which is a coaster made by Forgecore. However, in practice, some problems are still encountered, such as condensation drops from the glass overflowing because the coasters are not able to hold water well. In addition, there is no place to put the straw, so the straw is placed carelessly, making it less hygienic. The glass is easily shifted on the coaster surface, and the coaster is easily shifted on slippery surfaces. This problem encourages the need for innovation in coaster design, so this research is focused on developing coaster design modifications and adding several features, namely the coaster is designed to be carried for walking with the glass still on the coaster, holes for condensation droplets to prevent the table surface from getting wet, straw holders to keep straws hygienic, rubber layers to reduce glass shifting on the coaster, the addition of anti-slip rubber under the coaster to increase stability on slippery surfaces and the addition of magnets in various parts of the coaster which aims to make the straw holder and the handle part on the coaster not easily detached.

The developed coaster will be produced using 3D printing with PETG filament as the primary material, combined with laser-cut acrylic. 3D printing technology, also known as additive manufacturing, is the process of creating three-dimensional objects by adding material layer by layer based on a digital design or model (Prasetyo et al., 2020). The choice of filament type is one of the key factors that affect the quality, mechanical strength, and reliability of printed products (Dey et al., 2021). Filaments used in 3D printing technology come in various types with different characteristics. Parameters such as nozzle temperature, infill density, speed, and others are very important in 3D printing because they can affect the final print result (Muhammad et al., 2022). Laser cutting is one of many thermal-energy-based non-contact machining processes that can be applied to almost all types of materials. The working method of laser cutting involves directing a high-powered laser to cut the material with the assistance of a computer guiding it (Yusuf, 2024). In laser cutting, cutting speed affects the quality of the cut results on acrylic (Ürgün et al., 2024). After the manufacturing process is complete, a series of tests will be conducted to compare the Forgecore-made coaster with the 3D-printed coaster.

2. RESEARCH METHODS

This research used the product development method. The product development process is a sequence of steps or activities to develop a product so it can be used to generate value (Irawan, 2017). In this research, the first step was to identify the problem and what was needed to solve it with the Forgecore coaster. In general, the product design and development process consists of the planning stage, the design stage, and the product testing.

This stage begins by identifying the coaster's needs and problems. From the identification carried out, several problems were found, such as condensation drops from the glass often overflowing because the coasters are not able to hold water well. In addition, there is no place to put the straw, so the straw is placed carelessly, making it less hygienic. The glass is easily shifted on the coaster surface, and the coaster is easily shifted on slippery surfaces. Based on this identification, target product specifications are established, including able to contain condensation drops from the glass, has a place to support the straw, can reduce the glass's slippage on the coaster, the coaster's handle is not easily detached, has good stability and is not easily dislodged on slippery surfaces, made of heat-resistant and strong material as needed, and can be manufactured using Fused Deposition Modeling (FDM) technology and laser cutting technology.

Based on the established specifications, several design concepts were generated through brainstorming. Each concept was evaluated based on suitability to requirements, ease of manufacture, and aesthetics. The selected concept was a circular coaster with several features, namely a hole and a place to catch condensation drips to prevent the table surface from getting wet, a straw holder to clamp and maintain hygiene, a rubber layer to reduce the glass's slippage on the coaster, a non-slip rubber bottom to increase stability on slippery surfaces, and a neodymium magnet N50 to prevent the handle from slipping off.

The design stage is the process of translating the initial concept into a detailed technical product design, so that the product is ready for testing and production (Naiju, 2021). The selected concept is detailed in Autodesk Inventor Computer-Aided Design (CAD) software. Figure 2 shows that the coaster dimensions are adjusted to fit standard-sized glasses, which generally have a diameter of 80 mm. The condensation drip tray is designed with a depth of 8 mm. The straw holder grips standard-sized straws with an 8 mm diameter and is easy to remove. The coaster's top, which serves as a cover for the condensation drip tray, is designed to be easily removed and reinstalled, simplifying cleaning. The water drainage hole is located in the center of the coaster. The magnet hole is 8 mm in diameter for easy magnet installation. The magnet is attached to the coaster using glue. The hole at the bottom of the coaster for the anti-slip rubber is 2 mm in diameter for easy installation. In addition, there is a hole for hanging the coaster when not in use.

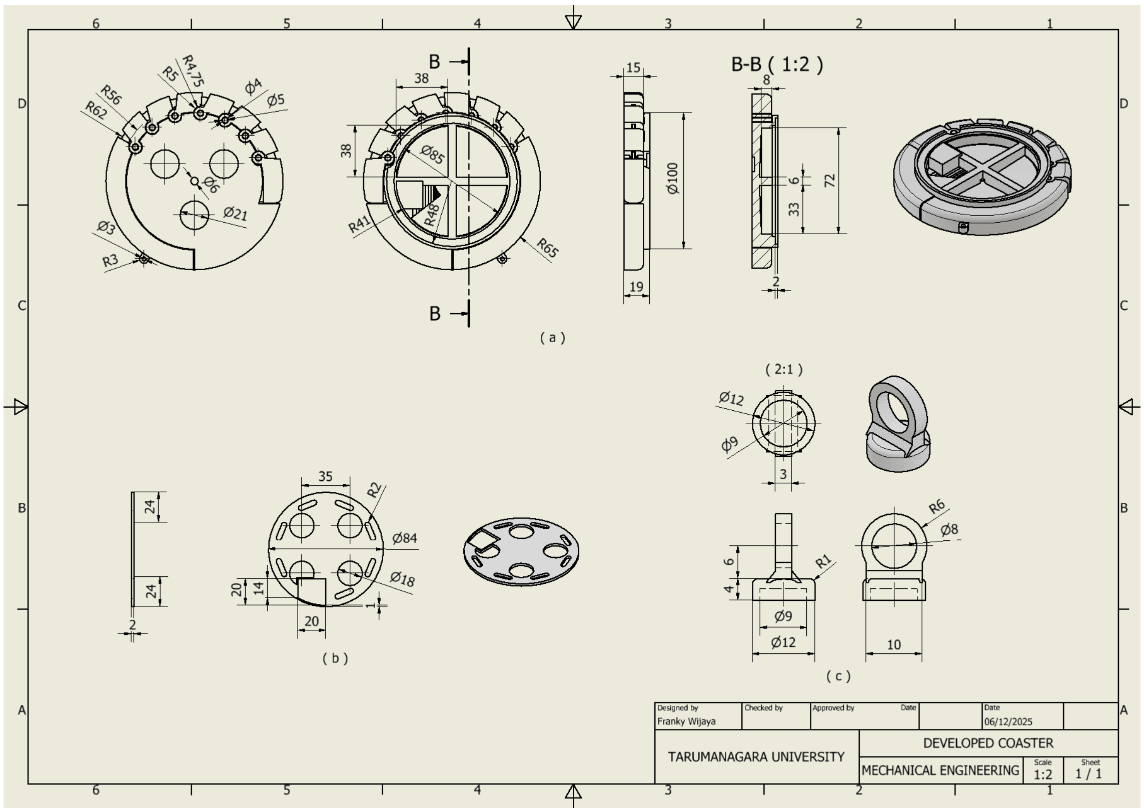

Figure 2. Engineering drawings for (a) developed coaster, (b) top of the coaster and (c) straw holder

All parts of the coaster are produced using 3D printing with PETG filament. However, for the cover (top of the coaster) of the condensation drip tray, the manufacturing process uses laser-cutting technology with 2 mm-thick acrylic.

The material used is Polyethylene Terephthalate Glycol (PETG) filament. The selection of PETG filament is based on its advantages of heat resistance, good mechanical strength, impact resistance, and moisture resistance compared to PLA, and on the specific needs (Sri et al., 2024). The advantages of PETG material also include ease of printing (printability) and environmental durability. PETG is relatively less susceptible to warping than ABS. From a sustainability perspective, PETG is also recyclable, supporting efforts to reduce plastic waste and to implement environmentally friendly principles in the manufacturing process (Flores et al., 2024).

The 3D printing process was carried out using a Bambu Lab A1 printer with the following parameters:

Table 1. The value of 3D printing parameters

Parameter	Value
Nozzle temperature	255°C
Bed temperature	80°C

Layer height	0.2 mm
Infill density	20%
Wall loops	2
Infill pattern	Gyroid

The laser cutting process is carried out using a laser cutting machine with an area size of 1300 mm x 1000 mm 100 watt with the following parameters:

Table 2. The value of laser cutting parameters

Parameter	Value
Speed	15 mm/s
Minpower	40%
Maxpower	40%

The coaster made by Forgecore and the developed coasters will be produced using 3D printing technology with the same parameters. However, laser cutting is used only for the developed coasters because Forgecore's coasters do not have features that require it.

The testing phase aims to determine the performance and effectiveness of the product that has been created. This process is carried out to ensure the product functions properly and meets the needs and objectives set in the planning and design stages (Martoatmodjo et al., 2024). The printed coaster is tested to evaluate the performance of the added features. Testing is carried out by comparing the Forgecore coaster with the developed coaster. The Forgecore-developed coaster is shown in the figure 3.

Figure 3. Coaster made by Forgecore holding a cup in the folded position (left) and developed coaster (right)

The tests conducted between the Forgecore coaster and the developed coaster included several functional evaluations. First, a condensation drop tray test was performed by placing a glass filled with cold water on a coaster for 30 minutes at room temperature. The straw holder was then assessed by clamping and releasing a standard 8 mm straw five times to evaluate grip strength and ease of removal. Glass stability was tested by placing a glass on a coaster equipped with a rubber layer to reduce slippage. Next, a regular oscillatory motion is performed along the x-, y-, and z-axes with an amplitude of 0.3 m and a frequency of 1 Hz to observe whether the glass shifts excessively during the stability test. Coaster stability test (anti-slip) was examined by placing a glass filled with water on a coaster, then the coaster is placed on a smooth surface, such as glass. Next, a regular translational motion along the x- and y-axes with an amplitude of 0.1 m and a frequency of 0.5 Hz is performed to assess whether excessive slippage occurs during the stability test. The magnetic strength test on the coaster was performed by performing a regular translational motion about the x- and y-axes with an amplitude of 0.1 m and a frequency of 1 Hz to observe whether the handle on the coaster is easily detached. Additionally, a condensation drop drainage test was performed by filling the condensation drop drain on the coaster with water while closed. The drain cover is then opened to observe whether water or condensation drains properly. Finally, the condensation drop cover was installed and removed five times to observe whether it functions properly and remains in place after several uses.

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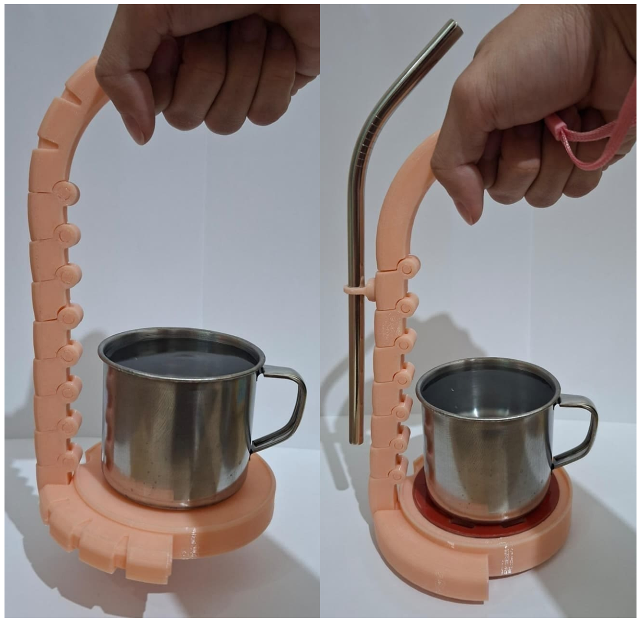

Figure 4. Coaster made by Forgecore in an open handle position (left) and developed coaster (right)

3. RESULTS AND DISCUSSION

After the design process was completed in Autodesk Inventor Computer-Aided Design (CAD) software, the next stage was the coaster printing using a 3D printer. The printing process used PETG filament, while the condensation drip container cover was made by laser-cutting 2 mm-thick transparent acrylic. The final design of the 3D-printed coaster is shown in Figure 5.

Figure 5. The final result of the developed coaster

Printing on the Bambu Lab A1 printer with predefined parameters yielded a smooth print surface and accurate dimensions. The actual dimensional measurements showed relatively minor deviations from the CAD design. This indicates that the process parameter settings, such as a nozzle temperature of 255°C and a bed temperature of 80°C, are appropriate for PETG material (Dey et al., 2021). The laser cutting process was carried out at a speed of 15 mm/s, with a minimum power of 40% and a maximum power of 40%, resulting in a clean cut without excessive melting of the acrylic edge (Ürgün et al., 2024). The combination of PETG and acrylic prints showed good dimensional compatibility and could be attached and removed easily.

Based on Figure 2, the coaster has a basic circular shape with an outer diameter of 130 mm and an inner diameter of 100 mm, which fits a standard glass with a diameter of 80 mm. In the middle of the coaster, there is a hole and a place to collect condensation drops, about 8 mm deep, which collects condensation from glasses containing cold drinks. At the bottom of the coaster, 3 pieces of anti-slip rubber with a diameter of 2 mm are installed to increase stability on slippery surfaces. Based on Figure 3, the condensation drip tray cover is made of 2 mm-thick acrylic and can be easily removed and reattached for easy cleaning and maintenance. The cover also features a rubber layer to prevent the glass from sliding on the coaster. Based on Figure 4, the straw holder grips standard 8 mm straws well, and the straw remains easily detachable from the holder when needed. Furthermore, the holder is detachable from the coaster via its magnet, making attachment and removal easy. Based on Figure 6, it can be seen that there is an addition of magnets to the coaster, and the handle part on the coaster aims to ensure that the handle part sticks firmly and does not come off easily when the coaster is used.

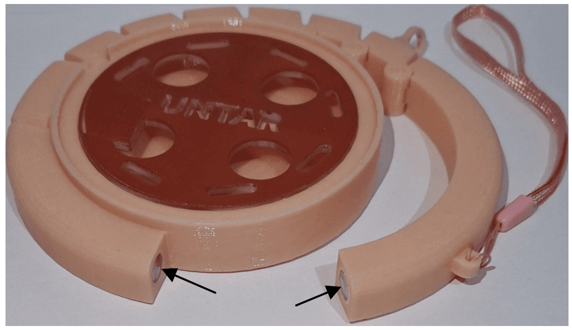

Figure 6. The addition of magnets to the coaster and the handle part

In addition, several features complement the coaster section, as shown in Figure 2. The first is a condensation drop drain hole located in the center of the coaster, which facilitates the drainage of condensation. This hole, with a diameter of 5.5 mm, allows water or condensation to drain properly through the bottom of the coaster. The hole can also be sealed with a rubber plug to prevent water from leaking out of the container when the coaster is in use. The second feature is a hanging hole on the outside of the coaster that serves as a place to hook the hanging rope, so the coaster can be hung when not in use. This hole is 3 mm in diameter, so the hanging rope can be easily attached and removed.

To ensure the functionality and performance of the developed features, a series of functional tests was conducted on each coaster feature. The test results are shown in Table 3 below.

Table 3. The results of the comparative test of the coaster made by Forgecore with the developed coaster

Test type	Test results	
	Coaster made by Forgecore	Developed coaster
Condensation drops tray test.	Only a small amount of condensation water is collected, and most drips onto the table surface.	Condensation water is well collected and does not drip onto the table surface.
Straw holder test	There is no straw holder.	The 8 mm-diameter straw can be clamped firmly and easily removed from the straw holder.
Glass stability test (rubber layer)	The glass always moves on the coaster when regular oscillatory movements are carried out on the x-axis, y-axis, and z-axis.	Coasters can withstand glass shifting during regular oscillatory movements along the x-, y-, and z-axes.
Coaster stability test (anti-slip)	The coaster easily slid on the glass surface during testing	The coaster does not shift excessively on the glass surface when subjected to regular translational motion along the x- and y-axes.
Magnetic strength test on the coaster	The handle part of the coaster is not firmly attached and easily comes off when moved, because there is no additional magnet.	The coaster's handle stays firmly attached and doesn't come loose easily when moved. The straw holder can also be easily attached and detached from the coaster.
Condensation drops drainage test.	Water immediately flows out of the coaster, wetting the table.	Water can flow out smoothly when the manhole cover is opened.
Condensation drops cover test.	There is no cover for the condensation drop catchment area.	The cover can be installed and removed repeatedly (5 times) easily.
The hanger holes test	No hanging hole	The lanyard can be installed and removed easily.

During testing, several photos were documented as supporting evidence. The results of the condensation drop tray test and the glass stability test (rubber layer) are shown in Table 4.

Table 4. Condensation drops tray test and glass stability test (rubber layer) results for coaster made by Forgecore and developed coaster

Test type	Test results	
	Coaster made by Forgecore	Developed coaster
Condensation drops tray test.		
Glass stability test (rubber layer)		

Test results showed that all developed features functioned as designed. The condensation drip tray proved effective in collecting water or condensation drops from the surface of a glass containing a cold drink, keeping the table dry. The straw holder gripped and maintained the cleanliness of the straw, and it can be easily attached and removed from the coaster. Testing the stability of the glass and coaster also showed promising results. The rubber layer on the lid of the container increased friction between the glass and the coaster, and the anti-slip rubber on the bottom of the coaster successfully prevented shifting on slippery surfaces like glass (Martoatmodjo et al., 2024). This shows that adding rubber significantly improves stability in use. Furthermore, the use of magnets on the handle proved effective in keeping the handle part firmly attached. Testing the lid of the condensation drip tray showed that the acrylic mounting system did not deform or loosen after several uses, demonstrating good laser-cutting precision.

4. CONCLUSION

Based on the results of the design, manufacture, and testing that have been carried out, it can be concluded that this research has succeeded in developing innovative designs and features on 3D printed coasters using PETG filament as the primary material, which is processed using 3D printing technology and equipped with an acrylic cover using laser cutting technology. The final coaster design has a variety of functional features that work well, including effective condensation drops tray that keeps table surfaces dry, the straw holder is equipped with a magnet that holds the straw clean and makes it easy to install and remove, rubber layer and anti-slip rubber that increases the stability of the glass or coaster on slippery surfaces, and condensation drain holes.

Hanging holes add functional value and ease of use. The use of PETG filament has been proven to produce prints with smooth surface quality and accurate dimensions. Printing parameter settings (nozzle temperature 255°C, bed temperature 80°C, layer height 0.2 mm, infill density 20%) produce optimal print results without deformation or warping. The test results show that all features on the coaster function as intended, in accordance with the research design and objectives.

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