G-Tech : Jurnal Teknologi Terapan
Vol. 9, No. 3, July 2025, p. 1215-1225
E-ISSN: 2623-064X | P-ISSN: 2580-8737

Design and Manufacture of Speedometer Covers using the House of Quality (HOQ) Approach

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Article Information

Article History

Received : May 17, 2025
Revised : June 06, 2025
Published : July 04, 2025

Keywords:

3D Print;
House of Quality;
Design

ABSTRACT

This study aims to design and fabricate a speedometer cover for Yamaha Aerox and N-Max 155 motorcycles using 3D printing technology, guided by the House of Quality (HOQ) framework. The increasing consumer demand for motorcycle accessories motivated this research. A structured design process was implemented, beginning with a consumer needs analysis conducted through questionnaires and surveys to identify user expectations. These needs were systematically translated into technical requirements using the HOQ method. The design stage utilized 3D CAD modeling and 3D scanning to ensure accurate fitting to the speedometer unit, followed by prototyping using fused deposition modeling (FDM) 3D printing. The final prototype exhibited key consumer-desired attributes such as heat resistance, structural durability, and a secure fit. Results indicate that integrating the HOQ approach with digital fabrication methods effectively aligns product design with user expectations. This study demonstrates the potential for further development of customizable motorcycle accessories using a consumer-driven and technology-supported design process.

INTRODUCTION

The speedometer is a vital measuring instrument in motorized vehicles, primarily functioning to display the vehicle's speed. In addition to this primary role, modern speedometers are often integrated with additional indicators such as fuel levels, engine temperature, and various warning lights. Collectively, these features provide essential information that enables drivers to operate their vehicles safely and efficiently.

However, based on interviews with motorcycle users—particularly those using digital speedometers, such as those found on Yamaha N-Max and Aerox models—several common issues have been identified. These include cracking, yellowing, and sunburn damage caused by prolonged exposure to sunlight. These problems not only impair the visibility of the display but also reduce the durability and aesthetic appeal of the speedometer. Recognizing the need for a practical solution, this study proposes the development of a protective speedometer cover.

To ensure that the resulting product aligns with user expectations, the design process was carried out using the House of Quality (HOQ) approach. This method enables a structured translation of consumer needs into measurable design specifications, helping to ensure a user-centered outcome.

Design is a sequential process that is informed by relevant and specific data (Trisna et al., 2013). In evaluating the quality of a design or product, a variety of methods can be applied. Among these, the HOQ method is one of the most frequently used due to its systematic and analytical nature (Putri et al., 2021). This method has the ability to collect the Voice of the Customer (VoC) in the form of user needs and translate them into technical specifications using the HOQ framework (Pratama et al., 2024; ANDRIYONO, 2013). It has proven effective in guiding product development and quality control (Basuki et al., 2020).

In terms of manufacturing strategy, various approaches can be employed to develop products that meet consumer expectations. Among these, the HOQ method has emerged as one of the most relevant and widely adopted tools in design and product development research. Several studies have demonstrated its effectiveness in aligning product features with user needs, making it a preferred method across multiple industries (Oddershede et al., 2019; Jia & Bai, 2011; Roy et al., 2021; Wang et al., 2021; Yang et al., 2020).

To obtain technical response priorities that reflect the ranked service needs of consumers, the HOQ design method was used (Dewi et al., 2011). Fundamentally, HOQ is a structured technique that connects consumer demands—the "what"—with technical responses or design solutions—the "how." These relationships are visually represented in a matrix resembling the shape of a house, hence the term "House of Quality" (Zulkarnain et al., 2023). This matrix serves as a powerful tool to systematically translate the voice of the customer into measurable and actionable technical specifications, ensuring that design decisions are based on actual user priorities.

HOQ helps bridge customer needs with technical solutions (Bolar et al., 2017; Chan & Wu, 2002). By applying the HOQ method, designers and engineers are better equipped to prioritize features that add value from the customer's perspective (Neira-Rodado et al., 2020). This leads to more targeted and effective product development, reducing trial and error during the design phase. As a result, the final product is more likely to satisfy user expectations in terms of functionality, reliability, and overall quality (Irawati & Ezrani, 2018). Ultimately, HOQ bridges the gap between consumer insight and technical design, fostering a more user-centered innovation process.

This study aims to design and develop a speedometer cover by considering consumer needs through the application of the HOQ approach. By systematically translating user requirements into technical specifications, HOQ provides a structured framework to ensure that the final product aligns closely with consumer expectations. This approach not only enhances product functionality and user satisfaction but also supports a more efficient and targeted design process.

RESEARCH METHODS

This study adopts an applied research approach aimed at developing a protective speedometer cover for Yamaha N-Max and Aerox motorcycles, with the design process grounded in real consumer needs. The methodology integrates both qualitative and quantitative methods, utilizing the House of Quality (HOQ) within the Quality Function Deployment (QFD) framework to systematically convert user input into technical product specifications (Temponi et al., 1999; Mistarihi et al., 2020).

The research process began with the selection of participants through purposive sampling, targeting individuals who actively use Yamaha N-Max and Aerox motorcycles. A total of 50 respondents, aged between 20 and 45, were chosen based on their experience with the motorcycles' digital speedometers. Data were collected using structured interviews and questionnaires designed to identify common user concerns and preferences. Respondents were asked to rate the importance of various speedometer cover attributes—such as heat resistance, ease of installation, durability, and visual appeal—using a 5-point Likert scale.

After collecting the data, the results were analyzed to prioritize user needs. This was accomplished using the Relative Importance Index (RII), which quantified the significance of each requirement based on user ratings. The prioritized needs were then translated into measurable technical characteristics using the HOQ matrix. In this matrix, the relationships between customer needs (the "Whats") and technical responses (the "Hows") were scored based on the strength of correlation, using a standardized scale: strong (9), medium (3), weak (1), or no relationship (0) (Wu & Wang, 2012; Ji et al., 2014). These values were used to calculate weighted scores, enabling the identification of the most critical design specifications.

The next phase involved the application of digital manufacturing tools to translate these specifications into a working prototype. A 3D scanner (EinScan-SP, accuracy ±0.05 mm) was employed to capture the precise geometry of the speedometer unit, ensuring a perfect fit for the new cover. The digital model was then created using Autodesk Fusion 360, a CAD software platform well-suited for parametric and feature-based modeling.

To fabricate the prototype, 3D printing technology was used, specifically a Creality Ender 5 Pro printer equipped with PLA+ filament, chosen for its enhanced strength and resistance to environmental stress. Additional measurement tools, including digital calipers and thickness gauges, were used throughout the process to verify dimensional accuracy.

Finally, the prototype underwent a series of evaluations to ensure it met the expectations identified during the consumer research phase. Field testing involved a small group of experienced users who assessed the product based on fit, durability, heat resistance, and aesthetic compatibility. Their feedback, combined with the technical priorities determined through the HOQ analysis, guided the final design decisions.

Through this structured and iterative process, the study was able to produce a speedometer cover that not only aligns with technical standards but also meets real-world consumer demands, demonstrating the practical value of integrating HOQ with modern digital fabrication techniques.

RESULTS AND DISCUSSION

Classification of needs

The first step in this research involved identifying user needs through qualitative data collection. A total of 25 Yamaha N-Max and Aerox motorcycle users were selected using purposive sampling. Participants were interviewed using open-ended questions to allow the expression of detailed feedback regarding their experiences and expectations for a speedometer cover.

The responses were then analyzed and grouped into a hierarchical structure of primary and secondary needs. Primary needs include *functional*, *aesthetic*, *ergonomic*, and *durability*-related factors, while secondary needs—specific user concerns—were nested under these broader categories. The classification is shown in table 1.

Tabel 1. Interview Results Identification of needs

Number	Secondary Needs	Primary Needs
1	Withstand Heat	Functional
2	Withstands Impacts	
3	Easy to disassemble and reassemble	
4	Shiny	Aesthetic
5	Smooth	
6	Safe	Ergonomic
7	Easy to maintain	
8	Not easy to come off	
9	Long-lasting	Durability
10	cheap	

Relative level and Voice of Customer

To quantify and prioritize these needs, a second questionnaire was distributed to the same group of 25 respondents. This phase used **closed-ended** questions and a **5-point Likert scale**, where:

1 = Very Unimportant, 2 = Unimportant, 3 = Quite Important, 4 = Important, 5 = Very Important.

Each item was scored, and the **Relative Importance Index (RII)** was calculated to assess priority. The formula used is:

RII = (Σ w) / (A × N)

Where:

w is the weight given to each factor by the respondent (1–5),

A is the highest possible score (5),

N is the total number of respondents (25).

Tabel 2. Interview Results Identification of needs

No	Secondary Needs	1	2	3	4	5	RII	Rank
1	Withstand Heat			4	9	12	8.64	3
2	Withstands Impacts			6	9	10	8.32	5
3	Easy to disassemble and reassemble			5	10	10	8.4	4
4	Shiny			3	11	11	8.64	3
5	Smooth			4	4	17	9.04	1
6	Safe			8	9	8	8	7
7	Easy to maintain			3	8	14	8.88	2
8	Not easy to come off			7	6	12	8.4	4
9	Long-lasting			8	7	10	8.16	6
10	cheap		2	8	6	9	7.76	8

Table description: 1 Very Unimportant; 2 Unimportant; 3 Quite Important; 4 Important; 5 Very Important

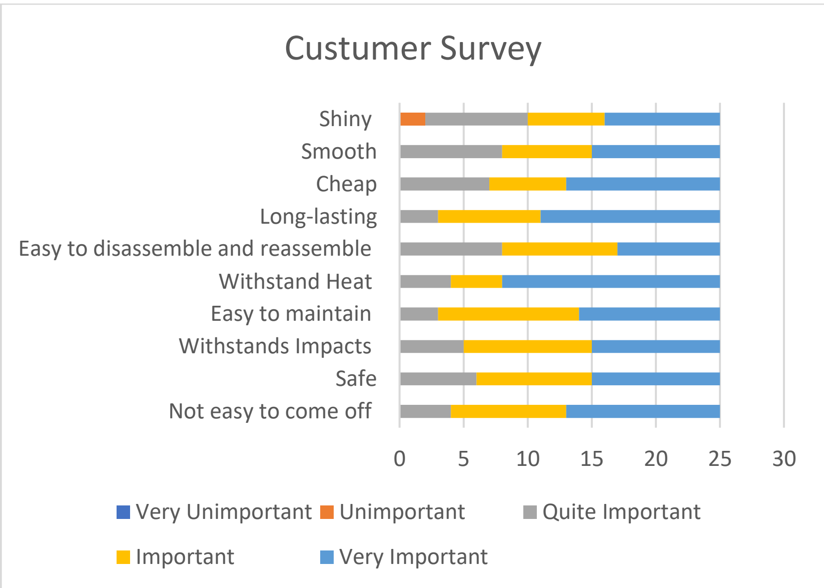


Figure 1. Customer Survei

The top three most critical needs from the RII calculation were:

1. Smooth finish (9.04),
2. Easy to maintain (8.88),
3. Withstand heat (8.64).

These were placed in the Customer Needs section of the HOQ matrix.

Technical Response

The next step in compiling the House of Quality (HoQ) is to fill the functional parameters room with technical responses or characteristics of the product being developed. Technical responses are the results of the translation of the questionnaire that has been filled out by the respondents. Used to facilitate the development of the design of the tool desired and needed by the respondents or consumers. The results of the technical response are as follows: 1. Aerodynamics 2. Strength 3. Material 4. Manufacturing process 5. Selling price 6. Size/Dimension 7. Design

The functional parameters room contains the technical response or characteristics of the product to be developed. For the direction of importance column, it contains the analysis of the objectives of each characteristic, the symbol (▼) means the aim is to minimize, the symbol (▲) means the aim is to maximize and the symbol (X) means the aim is to achieve the target. Then each statement is connected with several symbols.

Tabel 3. Statement connected symbols

Desciption	Symbol
Strong positive	++
Moderate positive	+
No relationship	-

To build the House of Quality (HoQ) matrix, a symbolic scoring system was used to show the strength of the relationship between customer needs and technical responses:

- Strong Positive (++) Indicates a strong, direct influence, critical for meeting customer needs.
- Moderate Positive (+) Shows a moderate influence, relevant but not dominant.
- No Relationship (-) Suggests no meaningful connection, changes in the technical aspect do not impact the related need.

This system helps prioritize design elements based on their actual contribution to user satisfaction.

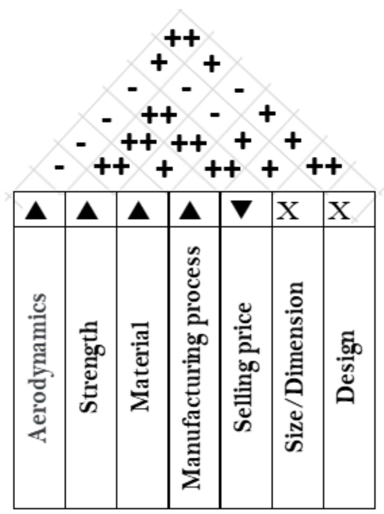


Figure 2. Technical Response

As seen in the image above, the relationship between technical responses can be described, the relationship between aerodynamics with strength, material, manufacturing process and selling price is not related, aerodynamics with size/dimension is Moderate positive, while aerodynamics with design is Strong positive. The relationship between strength with material, manufacturing process, and selling price is Strong positive, strength with size/dimension and design is Moderate positive. The relationship between material with manufacturing process is Moderate positive, material with selling price is Strong positive, and the relationship between material with size/dimension and design is not related. The manufacturing process with selling price is Strong positive, the manufacturing process with size and design is Moderate positive. Selling price with size and design is Moderate positive. While size and design are Strong positive.

Relationship Matrix

The relationship that shows the relationship between technical parameters and customer needs modeled in HOQ. The relationship value can be seen in the following table:

Tabel 4. Relationship Matrix symbols

Symbol	Value	Desciption
●	9	Strong
○	3	Moderate
▽	1	Weak

In the House of Quality (HoQ) matrix, symbols are used to quantify the strength of the relationship between customer needs and technical responses. Each symbol is assigned a numerical value to support weighted analysis:

● (Value: 9 – Strong Relationship) Indicates a strong and direct correlation where the technical feature plays a crucial role in fulfilling the customer need.

○ (Value: 3 – Moderate Relationship) Represents a moderate connection, the technical aspect contributes to the need but is not the key factor.

▽ (Value: 1 – Weak Relationship) Denotes a weak link, the technical feature has minimal influence on the customer requirement.

This scoring allows for a systematic assessment of design priorities and helps identify which technical attributes should be emphasized during product development.

The results of calculating the total value of the relationship between technical responses and importance attributes (voice of customer) can be seen in the following image

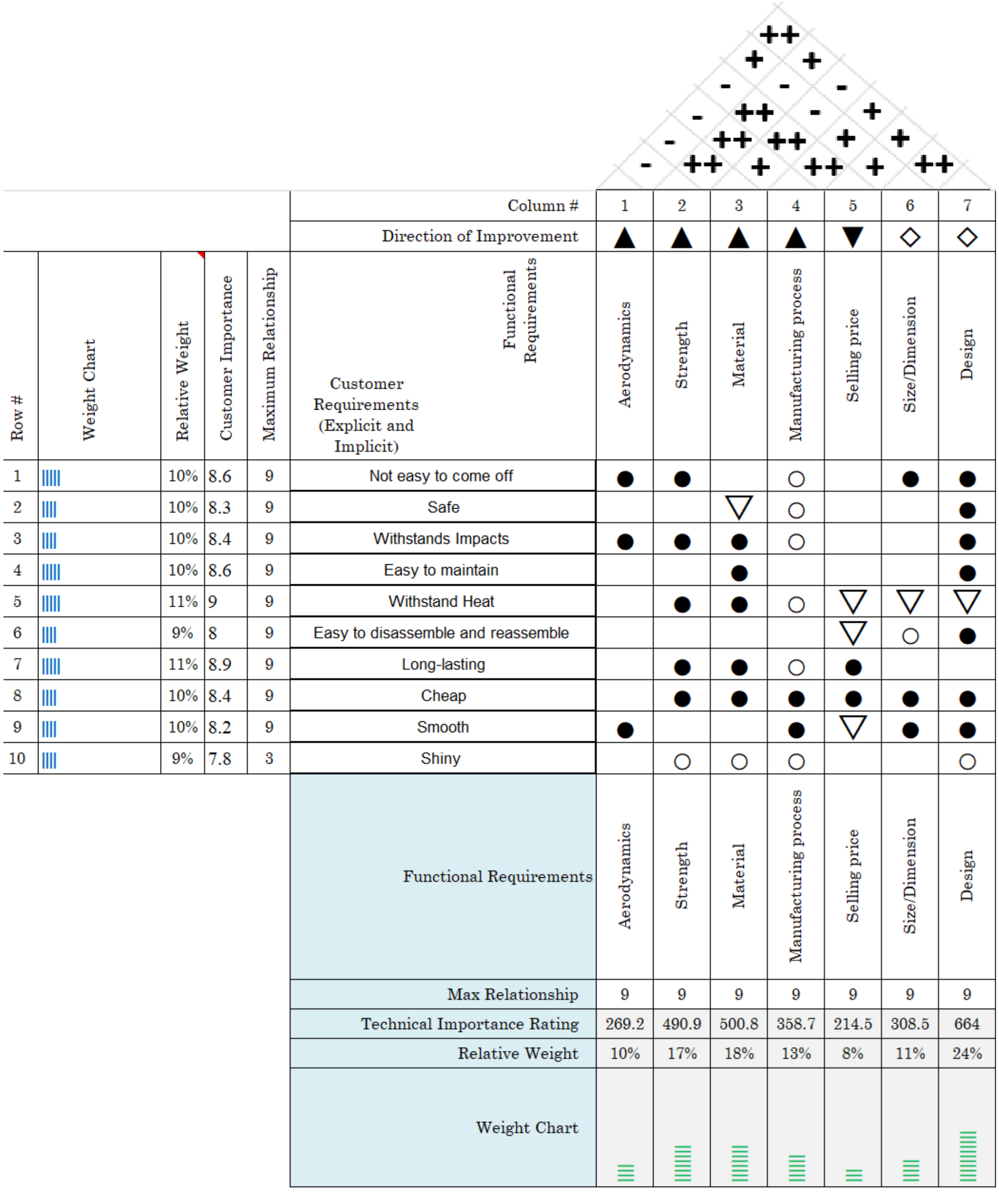
Tabel 5. Relationship Matrix

Customer Requirements (Explicit and Implicit)	Technical Response	Aerodynamics	Strength	Material	Manufacturing process	Selling price	Size/Dimension	Design
Not easy to come off		●	●		○		●	●
Safe				▽	○			●
Withstands Impacts		●	●	●	○			●

Easy to maintain			●				●
Withstand Heat		●	●	○	▽	▽	▽
Easy to disassemble and reassemble					▽	○	●
Long-lasting		●	●	○	●		
Cheap		●	●	●	●	●	●
Smooth	●			●	▽	●	●
Shiny		○	○	○			○

House Of Quality (HOQ)

After knowing the strength of the relationship between customer needs and technical statements, the final result of the preparation of the HoQ matrix is a technical statement target that will be used as a reference in making the speedometer cover. From the final results above, it can be concluded that there needs to be a speedometer cover design process according to customer requests Preparation of the House of Quality In accordance with the calculations that have been described, the House of Quality (HOQ) can be prepared. HOQ can be seen in the following picture



Row #	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit)	Aerodynamics	Strength	Material	Manufacturing process	Selling price	Size/Dimension	Design
				Column #	1	2	3	4	5	6	7
				Direction of Improvement	▲	▲	▲	▲	▼	◇	◇
1	10%	8.6	9	Not easy to come off	●	●		○		●	●
2	10%	8.3	9	Safe			▽	○			●
3	10%	8.4	9	Withstands Impacts	●	●	●	○			●
4	10%	8.6	9	Easy to maintain			●				●
5	11%	9	9	Withstand Heat		●	●	○	▽	▽	▽
6	9%	8	9	Easy to disassemble and reassemble					▽	○	●
7	11%	8.9	9	Long-lasting		●	●	○	●		
8	10%	8.4	9	Cheap		●	●	●	●	●	●
9	10%	8.2	9	Smooth	●			●	▽	●	●
10	9%	7.8	3	Shiny		○	○	○			○
				Max Relationship	9	9	9	9	9	9	9
				Technical Importance Rating	269.2	490.9	500.8	358.7	214.5	308.5	664
				Relative Weight	10%	17%	18%	13%	8%	11%	24%

Figure 3. House Of Quality

 DOI : https://doi.org/10.70609/g-tech.v9i3.7119

From the HOQ Figure 3, it is known that the highest weight is the design with a weight percentage of 24%. Design is the answer to meet consumer needs, one of which is heat retention.

Material Selection of Polylactic Acid (PLA)

In this study, Polylactic Acid (PLA) was selected as the material for manufacturing the speedometer cover due to its suitability for rapid prototyping and 3D printing applications. PLA is a biodegradable thermoplastic derived from renewable resources such as corn starch or sugarcane, making it an environmentally friendly option compared to petroleum-based plastics.

PLA is a popular choice for prototype development, particularly in early-stage design validation, due to its ease of use, affordability, and excellent printability, consistent mechanical properties suitable for prototype parts in engineering applications (Attolico et al., 2020). PLA's biodegradability and biocompatibility make it a sustainable choice for temporary or replaceable components.

Given that the speedometer cover is a non-structural part and is not subject to continuous mechanical stress, PLA offers an optimal balance between printability, visual quality, and stiffness making it well-suited for this specific application.

3D Scanning and design

The purpose of this stage is as a technical communication tool in carrying out the manufacturing or creation process in the next stage. The dimension design is made using help of 3D scanning. Then design is made using design software.

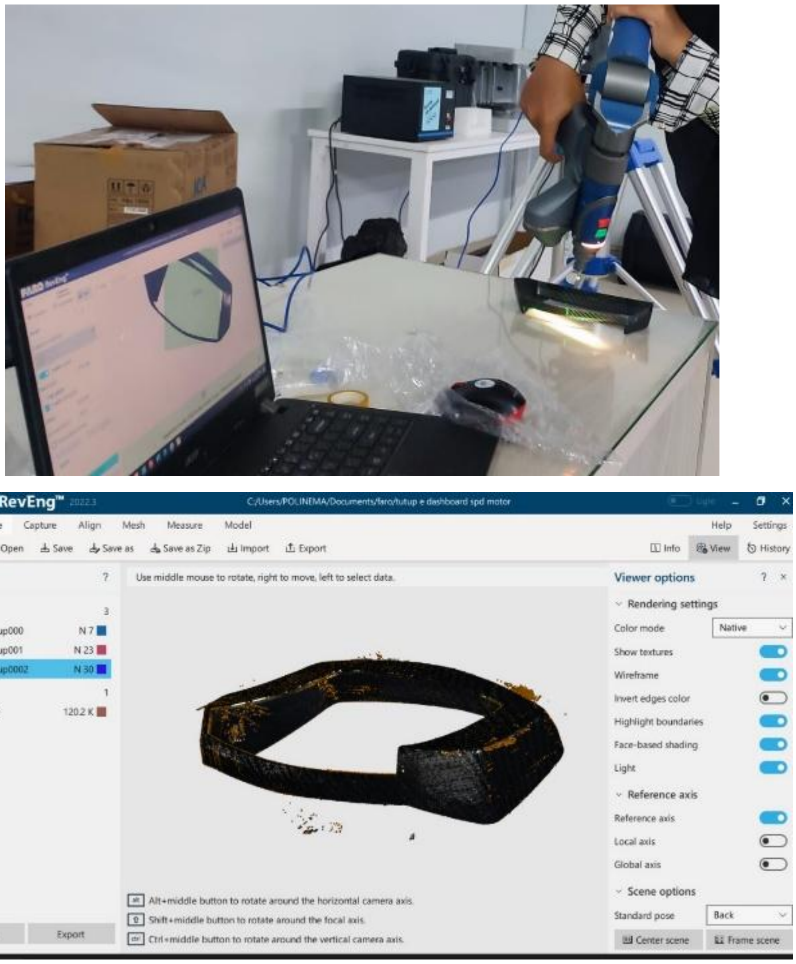


Figure 4. (a) 3D Scan Processing (b) Scanning Result

Design & Manufacturing

Overall, the results of this study explain that product design and development must consider aspects of consumer needs that demand safe and comfortable products. The realization of this from this study is the creation of a speedometer cover design that is heat resistant, durable, and not easily removed when used. Based on customer desires, a speedometer cover design was made with openings/fins to retain heat, the material used is PLA material because of its easy-to-use nature as a 3D print material and has a high stiffness value from other plastics so it is expected to be more durable. the manufacturing process uses 3D scanning and 3D printing so that it is precise (the results are expected to not be easily removed when used and easy to maintain). The design is shown in the Fig 5(a) and manufacturing result in figure 5(b)

Figure 5. (a) Design of speedometer cover (b) Result of 3D Printing

CONCLUSION

The objective of this research was to develop a speedometer cover that meets the specific needs and preferences of Yamaha N-Max and Aerox motorcycle users. By identifying, classifying, and prioritizing customer requirements through qualitative and quantitative methods, the study successfully translated user expectations into concrete technical specifications using the House of Quality (HoQ) approach. The classification of needs revealed that the most critical user requirements were a smooth finish, ease of maintenance, and heat resistance. These needs were addressed by emphasizing the importance of product design, which was identified as the most significant technical factor in fulfilling user satisfaction, with the highest weight of 24% in the HoQ matrix.

Material selection was also aligned with user expectations and technical feasibility. Polylactic Acid (PLA) was chosen due to its suitability for 3D printing, environmental benefits, and adequate mechanical properties for a non-structural component. The use of 3D scanning and 3D printing technology allowed for precise dimensioning and efficient manufacturing, ensuring the final product is easy to install, durable, and visually appealing. Ultimately, the study successfully achieved its goal of creating a user-centered speedometer cover design that is functional, ergonomic, aesthetically pleasing, and manufacturable with accessible technologies. The developed product not only meets the prioritized needs of users but also demonstrates a replicable design process grounded in systematic customer-driven engineering.

ACKNOWLEDGEMENTS

This work was supported by a grant from Politeknik Negeri Malang. The authors would like to acknowledge the institution for their valuable contribution.

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