Culture-Based Motor Vehicle Exhaust Cover Modification Using Reverse Engineering Methods Combined with Rapid Prototyping

Rahmat Riza(✉), Hendy Junyansyah, and Paryana Puspaputra

Mechanical Engineering Program Study, Universitas Islam Indonesia, KH. Mas Mansyur Building, 2nd Floor, Jl. Kaliurang KM. 14,5 Sleman, Yogyakarta 55584, Indonesia
{rahmatriza,paryana}@uii.ac.id

Abstract. The use of motorbikes is increasing daily, making these products common on the streets. This is for some people to be boredom. It prompted some riders to modify their motorbikes to make it look different. The exhaust cover is one of the most visible parts of the motorbike. This can provide significant changes to the appearance of the motor. The reverse engineering method offers an interesting technique for modifying innovations, especially motorcycle exhaust covers with a touch of Indonesian culture such as batik and armament shields from Kalimantan that had complex geometric. Five reverse engineering steps are applied in this research: scanning, redrawing, modification, zebra analysis, and 3D printing processes. The tools used in this study are available in the market at quite affordable prices for each of these steps, such as 3D scanner brand Sense and Creality 3D printing. However, a few problems required improvisations to obtain acceptable results. The object had been manipulated with bright (white) color and the use of tripod to overcome the problem of low cost handled 3D scanner was used in this work. The optimum setting for 3D printing was obtained after several trials. The results of Creality 6 with the combination of vertical positioning produced the optimum among the others. Furthermore, the overall results obtained showed that this method offers interesting results.

Keywords: Exhaust cover · modification · reverse engineering · 3D printing · zebra analysis

1 Introduction

Motorcycles are the most popular transportation users in Indonesia compared to others. This considerable number of users is due to fuel efficiency, easy to reach the existing routes in cities and villages, and more economical and affordable to the most public in Indonesia. The price of motorcycles that are quite affordable for the public is partly due to this product being produced from mass production. This makes the forms of motorbikes in society tend to be the same and monotonous [1].

T. P. Syawitri et al. (Eds.): MEST 2022, AER 222, pp. 296–306, 2023.
https://doi.org/10.2991/978-94-6463-134-0_29

For some people, these same forms create a desire to change the vehicle's appearance that goes with them daily to make a living. One of the interesting components to make changes is the shape of the exhaust cover. This part is quite visible. This can be seen from the forms made by motorcycle factories which are quite interesting and vary from one type of motorbike to another. The change or modifications to any part of a motorized vehicle must consider the part function, including modification to the exhaust cap. The primary function of the exhaust cap is maintained as a protector between the muffler and the feet of the rider or those around it [2].

This modification of the exhaust cover can be even more interesting and unique by giving it a touch of Indonesian culture which is famous for its beauty, one of which is batik motifs and tribal war shields in Kalimantan. The combination of the shape of the exhaust cover and the cultural elements that will be added makes this modification of the exhaust cover a complex geometric shape. However, the first part of the modification is recreating the product to be modified. It is facilitated by the latest reverse engineering technology that uses 3D scanners and strengthened by the development of rapid prototyping technology, which is currently expected to be applied to products that are used directly by consumers [3, 4]. Rapid prototyping technology, one of which is 3D printing, originally used to make product samples, can now produce 3D objects that do not disappoint, including when creating complex geometric shapes [5].

This discussion brought for researching developing an exhaust cover that are combined with the beauty of Indonesian art and culture. In this case, a combination of the beauty of batik and war shields from the Kalimantan region combined with reverse engineering and rapid prototyping technology was used to evaluate the methods.

2 Methodology

We divided the modification processes into four processes: scanning, redrawing, re-designing, and re-manufacturing.

Scanning. The initial stage carried out in this study was to do the scanning process on the object to be modified. The aim was to get an initial sketch or guide of the object with the basic shape that matches the object. The scanning process is carried out to obtain numerical data converted into a 3D image corresponding to the scanned object. 3D Scanning results are used as a reference in making innovative designs where was done using a 3D scanner.

In this work, the 3D Scan Sense brands were utilized, as shown in Fig. 1. This 3D scanner is a portable 3D scanner classified as low-end. With this 3D Scan Sense tool, the objects can be scanned and saved in the STL file format so that the scanned object can be modeled immediately.

Several things must be prepared in scanning using the 3D scan tool as follows selecting the product's color to be scanned where the effect of light on the scan is being carried out, then choosing the background color when using the 3D scan tool. Lastly, the scanning distance between products and the 3D scan tool will be used.

In the scanning process, the object was placed in a room with sufficient light intensity to make it easier for the 3D scan sensor to target the object (exhaust cover) to be recorded.

Fig. 1. The 3D Scanner Sense

The 3D scanning process was carried out several times until the shape matched the original shape. After the scanning process, the scan results could be seen in the software included with the 3D scan tool, namely 3D system SENSE 2. Light modifications could also be made in this software, such as crop, trim, erase, and color changes, as shown in the picture. After scanning, the file is saved in.obj or.stl file format.

Redrawing. This converted the results of the 3D scanning process into a complete image. It was necessary because the images produced by 3D scanning still point to clouds. Furthermore, the results obtained from the 3D scanning process still had many deficiencies and were not in the form of a complete image ready to be processed. This work was carried out on the Autodesk Fusion 360 software application and was carried out using several processes.

Work at this stage began with modeling and inputting the scanned file in STL format by importing the file. After that, the process of re-creating the 3D image of the object used the Fusion 360 application. Object surfaces were created using a tool called “form”. From these tools, the surface will be generated area by area. The surface created follows the surface of the scanned objects used so that a complete 3D image of the object scanned before was formed.

Modification. At this stage, a new design was made according to the 3-dimensional drawing resulting from previous redrawing processes. In this study, modifications were made by giving a cultural touch to products that had been redrawn from the 3D scan results. This process was simulated by using Inventor to obtain the combination between the object and the cultural touch. The design used in the exhaust cover modification research is a design that is able to add aesthetics and local wisdom, which contains art from the Kalimantan Dayak culture. Batik and Dayak war shields are of interesting forms to be combined in the modification of the motorbike exhaust cover in this study.

Zebra Analysis. Zebra analysis is a simulation that is used to analyze the curvature of the surface and the continuity between the surface of the object [6]. This affects the machining process that is carried out. Zebra analysis was carried out using Fusion360 software. Zebra results were read using Autodesk Fusion software by looking at Zebra’s black and white stripes. If the lines show parallel lines and are not broken on the same surface, or Zebra lines are broken to each other, it can be said that the surface is not continue each other or the surface is not smooth.

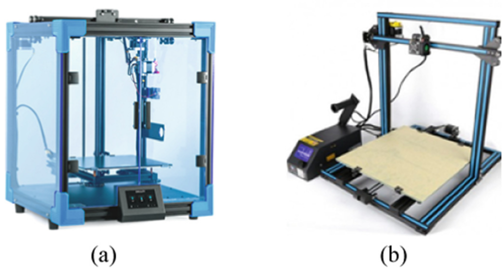


Fig. 2. (a) 3D Print Creality Ender 6; (b) 3D Print Creality R10-S5

Fig. 3. The original exhaust cover

3D Printing Processes. Rapid technology with its additive manufacturing, or 3D printing, has developed into a more reliable product in the manufacturing stage. A 3D printer is a machine capable of making digital files into 3-dimensional objects. This machine has the concept of printing layers until the 3D object is formed. At this moment, this technological development has been able to produce acceptable products with economical cost. One of the 3D printings consumers use is Fused Filament Fabrication (FFF), or Fused Deposition Modeling (FDM). This provides an alternative to the manufacturing process. In this work, two 3D printing brands were utilized, namely 3D Print Creality Ender 6 and 3D Print Creality R10-S5 (Fig. 2).

Materials. Here are materials used in this design.

Exhaust Cover. The main component of the research is the exhaust cover. We use the Honda Beat cover with a length of 380mm, a width of 110 mm, and a thickness of 3.5 mm. It is illustrated in Fig. 3. This object was selected because its original offered an exciting form. There is challenging to give a touch of Indonesian culture which also has complex forms. It is hoped that the results of this combination will become a product that provides added value.

PLA +. This material is a better version of PLA filament in the impact resistance. Data sheet of this material showed that it also offers better flexural modulus than PLA material [7]. Both properties concluded that this material is tougher than PLA material. This was the reason to choose this material for this work. The exhaust cover was considered too subjective to receive impact load when the motorcycle fell or got hit by any material or foot.

(a) (b)

Fig. 4. Object scanning; (a) original color; (b) white color

Fig. 5. Process of 3D Scanning

3 Results and Discussion

3D Scanning Process. This work's scanning process is carried out using a 3D scan tool with the 3D Scan Sense brand. From the specifications and experiments of the scan tool, the optimal scanning distance is at 300 mm-400 mm. The scan capabilities of this tool are quite limited. This can be seen in the scanning experiment on the exhaust cover which is the object of this study. The exhaust cover which is black (dark) is very difficult to read with this scan tool. So that the object is given a white color as shown in Fig. 4.

Several scanning attempts have been carried out, showing problems with distance consistency even though this scan tool is included in the portable scan category. This can be accomplished by placing the scan tool on a tripod and the object on the rotary table as shown in Fig. 5.

In the scanning process, objects or exhaust covers are placed on sitting tables and in rooms with sufficient light intensity. The light intensity influenced the scanning process. The scanning process must be carried out in a room with sufficient light intensity.

The sitting table is covered with a dark cloth to make it easier in the scanning process on the 3D Scan sensor tool in aiming at the object (exhaust cover) to be recorded, while the scanning process is running.

After repeating several times, an image that approximates the main shape of the scanned object was obtained as shown in Fig. 6**.** The results obtained in the scanning process can be evaluated using the software included with this scan tool after the scanning process is finished. Furthermore, the image could also be simply modified, such as crop, trim, erase, or change the color in this software as shown in the picture. After scanning processes, the file was saved in.obj or.stl form.

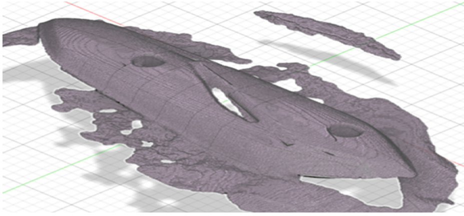


Fig. 6. 3D Scan result image in the form of mesh or STL format

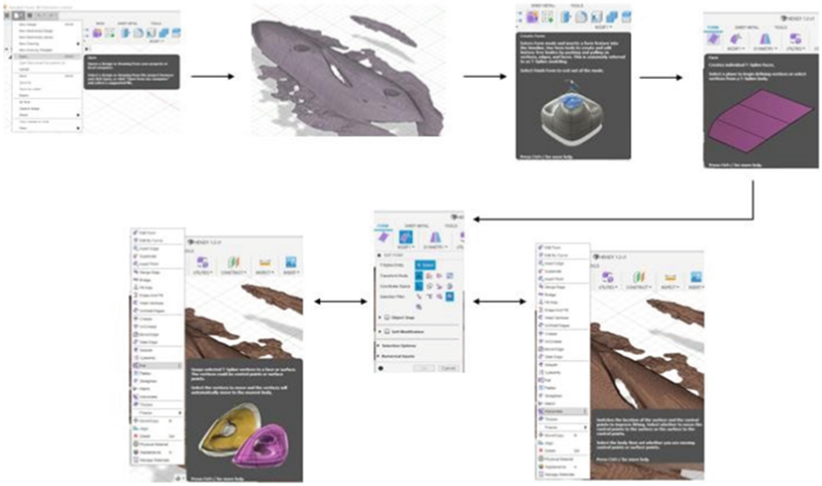


Fig. 7. Autodesk Fusion tool surface for redrawing processes

Figure 6 shows the best results obtained after doing several repetitions. These results indicate that the images obtained from the 3D scan process are still far from perfect. However, this image is sufficient to provide key information regarding the main shape and dimensions of the scanned object.

Redrawing Process. In Fig. 7, a smart surface is performed where the model is regenerated by following the results of a 3D scan. In the redrawing process, steps must be considered, especially in drawing a new surface to follow the pattern resulting from the 3D scan. The problem that occurs during the surface drawing process is the high sensitivity of the surface to the x, y, and z axes. Therefore, the surface pulling process must be perpendicular to or in accordance with the surface's direction. If this is not taking a noticed, then the new surface created will be wavy or the curve not smooth.

The processes involved in creating the new surface of the scanning image result is given in Fig. 8.

Redrawing results require a checking process to determine whether it is smooth enough for the drawing. This can be done using the zebra analysis method which will be discussed in the following section (Fig. 9).

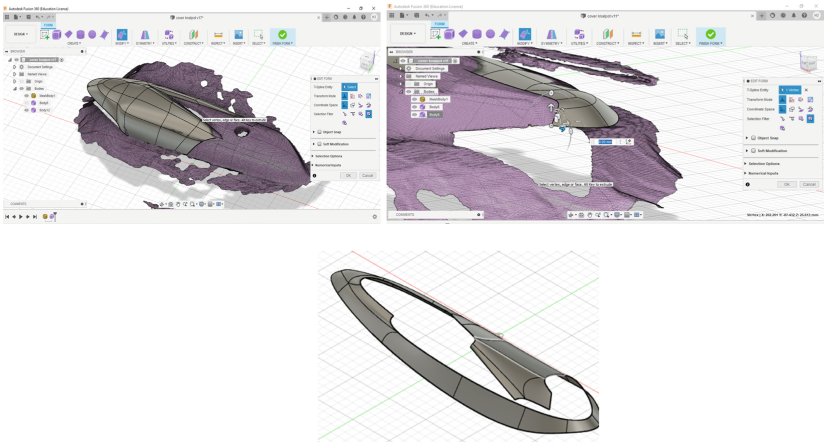


Fig. 8. Surface forming in redrawing processes

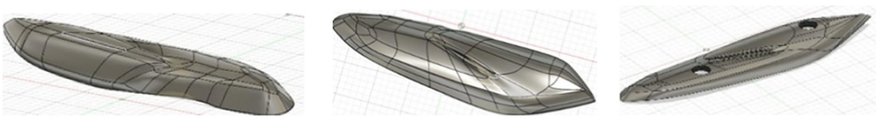


Fig. 9. Surface forming in redrawing processes

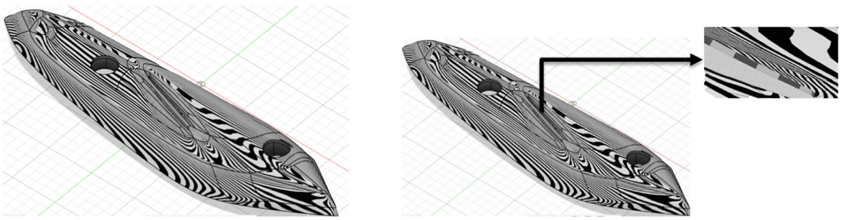


Fig. 10. Zebra analysis results

Zebra Analysis. A Zebra analysis was carried out to determine the smoothness of the object surface. Preliminary results in the surface manufacturing process show that there are many discontinuous areas of the object, as shown in Fig. 10. There are lines that have unequal distances in some areas compared to other areas.

Areas with a line distribution like this have curves or non-smooth surfaces. Therefore, the curve or surface must be corrected by adjusting the position of drawing curve lines forming the surface. This must be done slowly, being careful because any bend in the curve will affect the surface directly. The modified curve line must be selected correctly because a wrong selection will impact surface conditions, which could be worse or more discontinuous.

Modification Process. This modification process considers several things to evaluate the reverse engineering method used which one of them was the complexity of the

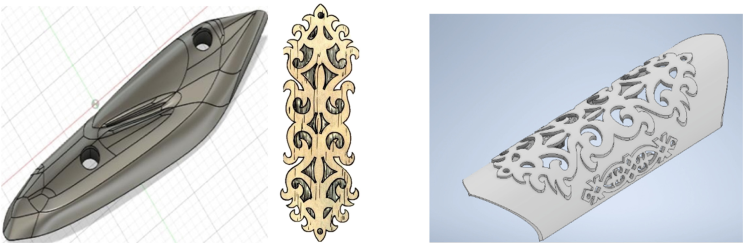


Fig. 11. Proposed design

Fig. 12. Zebra analysis for modification design

object's shape. In addition to the beauty offered by Indonesian culture, one of which is batik and shield war equipment from the Kalimantan region, the complexity of the shape of this motif is quite a challenge. The modification process is carried out at this stage using Autodesk Inventor combined with Fusion 360. It has different processing steps from the redrawing process. The modified drawing is made based on the same basic size as the drawing from the redrawing results. Some areas and dimensions of the original drawing are adapted to adopt a combination of batik and war shields from Kalimantan. This is shown in Fig. 11.

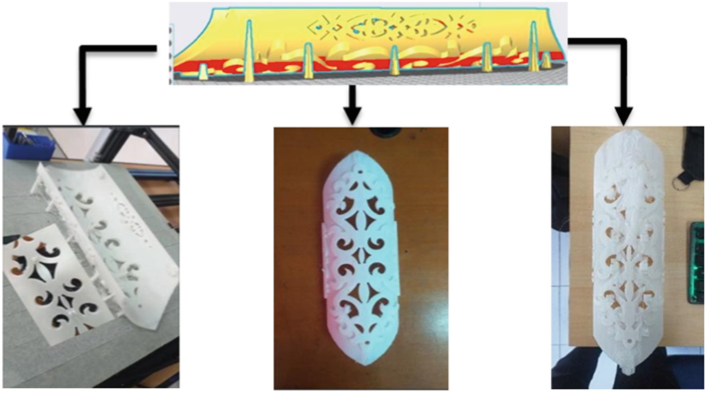
The next step is to perform a zebra analysis to ensure that the modified drawing has a smooth and unbroken curve. The result of zebra analysis for the modified drawing were illustrated in (Fig. 12).

In this figure, dark lines of zebra analysis were distributed uniformly. This could conclude that the drawing had no problem with the continuity of the surface of curve.

3D Printing Process. The dimensions of the original and modified exhaust covers are within the size limits for 3D printing on several 3D printers on the market, namely the CR10S5 and Creality Ender 6. However, the sizes of these two ready-made objects are within the maximum manufacturing limits on both 3D printers. This meant the manufacturing process for that size must be done precisely to get satisfactory results.

For the CR10-S5 3D printer, the object was made in a horizontal position. It is done because the width of this 3D printer could still accommodate the length of the exhaust cover, both the original and the modified one. The settings of 3D printing for this work were infill: 50%, time estimate: 2 – 3 days, bed temperature: 50 °C, nozzle temperature: 220 °C, thickness of the layer: 0.2 mm.

In this work, the object was carried out in three trials on the 3D printer CR10-S5 with a horizontal position, as shown in Fig. 13**.** The results obtained indicated several failures on the support and on several surface forms with unsatisfactory shapes.



(a) (b) (c)

Fig. 13. Results of Horizontal printing object with 3D printer CR10-S5; (a) 1st trial; (b)2nd trial; (c)3rd trial

This was caused by its complex geometrics requiring many supports. In the design that had been proposed, many small edge areas need support if they are made in a horizontal position. Support for the objects to be 3D printed had a function as a foundation or foothold when doing 3D printing, because if there is no support, the results will be less than optimal and can even be damage to the 3D printed object. 3D printing with too many supports would cause requiring more material which meant the processes were expensive.

This was considered to manufacture the object with vertical positioning in 3D printing. Furthermore, this was reinforced by the printing results from CR10-S53 3D printers were not so optimal to create the proposed motif for the modification. Therefore, 3D Print Creality Ender 6 was utilized to manufacture this object in the vertical position compared to the horizontal positioning object manufacturing. This 3D printer was selected because the maximum depth of this 3D printer is more than the long dimensions of the two objects.

In this 3D printing manufacturing processes for vertical positioning were carried out in two trials. The parameters setting of this Creality Ender 6 3D printer were infill: 100%, time estimate: 1 – 2 days, bed temperature: 50 °C, nozzle temperature: 220 °C, layer thickness: 0.2 mm. However, the first trial used the default setting for the support shown in Fig. 14 (a). The object showed better results compared to the horizontal position results. Unfortunately, the support looked too thick and required a lot of material.

The second trial was developed to optimize the supports required to anticipate the complexity of the design. The method used in this optimization process is to reduce the foundation support and create new support in several areas that really need it more, especially the hanging corners. Based on this consideration, the proposed supported were illustrated in Fig. 14. (b). The final product for the optimization was given in Fig. 14. (b), in the right figure.

The application of exhaust cover modification to the motorcycle was illustrated in Fig. 15.

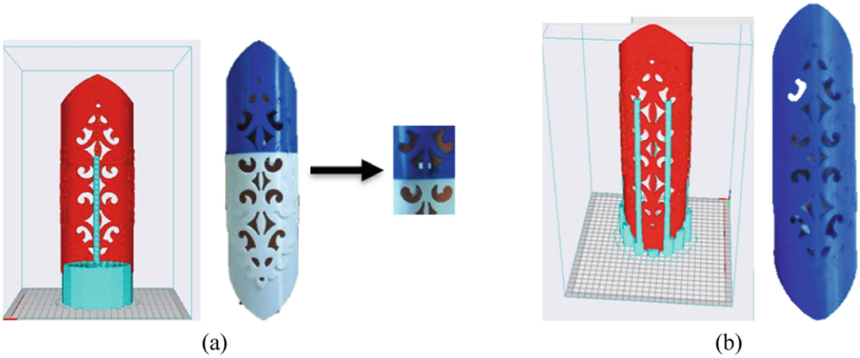


Fig. 14. Results of Horizontal printing object with 3D printer Creality Ender 6; (a) The 1st trial; (b) the 2nd trial

Fig. 15. Application of the design to motorcycle

4 Conclusions

Technological developments in 3D scanners and 3D printing have made the modification process more accessible and more specific. Combining the beauty of Indonesian culture, which has complicated geometric shapes, can be done using more economical equipment. This is also supported by developing software for engineering drawing processing with better interface and features. The design of the exhaust cover product modification was successful with the reverse engineering method. The exhaust cover modification based on a Batik and shield war Kalimantan Dayak carving motif. This enriches the exhaust value by adding artistic variety. Several manipulations need to be applied to overcome some deficiencies in the equipment. However, that does not obstruct modification processes. These deficiencies become a challenge to get a more satisfying product. Combining existing equipment and application developments can support specific and complex creativity.

References

1. Information on https://otomotif.kompas.com/read/2013/01/23/6298/6.alasan.lebih.enak.naik.sepeda.motor

2. Information on https://www.cnnindonesia.com/otomotif/20190819211101-579-422854/bukan-sekadar-gaya-motor-modifikasi-wajib-ikut-peraturan.
3. P. Wang, J. Yang, Y. Hu, J. Huo and X. Feng, Innovative design of a helmet based on reverse
4. engineering and 3D printing, Alexandria Engineering Journal 60 (2021), 3445–3453
5. N. Anwer and L. Mathieu, From reverse engineering to shape engineering in mechanical design, CIRP Annals, 65 (1), (2016), Pages 165-168
6. S.S. Alghamdi, S. John, N.R. Choudhury and N.K. Dutta, Additive Manufacturing of Polymer Materials: Progress, Promise and Challenges. Polymers, 13, 753 (2021)
7. Information on https://help.autodesk.com/view/fusion360/ENU/?guid=GUID-650F81AF-3744-460B-87DE-F2082E86FE5C.
8. Information on www.esun3d.net (Product Manual 3D Printing Material)