International Journal of Pioneering Technology and Engineering

Research Article

Creation And Comparison of Three-Dimensional Models of a Mechanical Part In Agriculture Field by Forward and Reverse Engineering

Özgür Verim[a*], **Ahmet Mete Sabah**[*]

[a] Department of Mechanical Engineering , Faculty of Technology , Afyon Kocatepe University, Afyonkarahisar , Turkey

Article Info

Article history
Received: 12.08.2022
Revised: 27.09.2022
Accepted: 12.10.2022

Keywords:
Reverse Engineering,
Forward Engineering,
Combine Harvester,
Three-Dimensional Scanning

ABSTRACT

In the last 30 years, we often hear about the computer aided design method with the help of the developments in adapting the innovations in the field of computer to the field of design. This method is divided into two sub-methods as forward and reverse. In this study, two methods were applied and compared for a combine harvester part used in the agriculture field. In the reverse engineering method, part was scanned with the laser scanner and the resulting point clouds were made into a mesh structure. These network structures have been improved and optimized with the necessary steps. Then the solid model was created with optimized mesh. In the forward engineering method, a 1/1 scale solid model of the part was created with the help of a caliper. The accuracy analysis of the solid model created with the network model was performed and the deviations from the real values were calculated and interpreted. At the end of the study, the three-dimensional models created by both methods were compared morphologically and the results were evaluated. The average accuracy value between the two models was calculated as 98.24%.

1. Introduction

In recent years, product designs in almost all engineering fields are carried out in virtual environments with the help of computer-aided programs. The biggest reason why designers prefer computer-aided design (CAD) programs is that products can be easily modeled in a three-dimensional (3D) environment. It is possible to examine computer-aided designs under two main headings: Forward and reverse engineering. Forward engineering can be defined as making the designs of parts, machines, and plants using classical engineering activities. Digitizing the product for situations such as when a part has not been produced for a long time and is wanted to be reproduced, the original design has insufficient documentation, the original manufacturer of a product no longer exists but customers need this product, the original documentation of the part is lost or never existed, some bad features have been redesigned and turning it into a CAD model is defined as reverse engineering [1-3].

In Zang research [4], successfully created and digitized a 3D CAD model of the core mold at the inlet of a diesel engine and described the reverse engineering process up to rapid prototyping using this model. The researcher then used rapid prototyping for mold removal with the aid of a CNC milling machine. Sansoni et al. [5] in their research, demonstrated the use of reverse engineering techniques for large surfaces with high accuracy and reduced processing time for design and reshaped application. In their research, they were had reverse-engineered the Ferrari 250 Mille Miglia vehicle using an optical scanner (the OPL-3D developed by them). They created a mesh file with .stl extension from the scanned data and took 1/10 scaled output from the 3D printer. In addition, they created CAD models with non-uniform rational Bezier curves (NURBS) and evaluated the amount of deviation between the scan data. Thus, they showed that reverse engineering methods can be applied on large surfaces. Sokovic et al. [6] were investigated how reverse engineering in some product development processes allows the production of surface models with the 3D scanning technique. In a short development period of this methodology, he detailed the manufacturing processes of different parts (automobiles, household appliances, molds, press tools, etc.). The authors also compared the advantages and weaknesses of different scanning systems. Lee et al. [7], tried to reduce the number of points in the point clouds that they obtained digitally from the parts and performed rapid prototyping directly without any surface modeling work. In the point clouds were observed almost eighty percent reduction. Kacmarcik et al. [8], have chosen cast-bearing support as the sample part and converted this part into CAD with the aid of reverse engineering method. Then, they used the finite element method to determine the maximum radial bearing load that the part can carry.

In this study, as reverse engineering, a combine harvester part used in the agriculture field was scanned with the non-contact method and CAD geometry was obtained. In addition, the same part was modeled in a 3D model with the help of caliper in the Geomagic Design X software as forward engineering. The 3D models created with these two methods were compared morphologically and their accuracy values were determined. By comparing these two methods, the advantages and disadvantages of the methods were determined. In this study, it was tried to reveal which part should be modeled by which method.

*__Corresponding author:__ Özgür Verim
*E-mail address: ozgurverim@aku.edu.tr
https://doi.org/10.56158/jpte.2022.30.1.02

2. Material and Method

For the combine harvester part, primarily 3D modeling was carried out by reverse engineering method. At the beginning of reverse engineering methods, the cleaning of the part surfaces is very important. The surfaces of the parts are cleaned of dirt and dust and accurate scanning is ensured with this cleaning. For this reason, pre-cleaning of the part was carried out and then markers were placed on certain areas on the part. Marking was done so that more than one scanning result can be matched with each other correctly. Finally, the process that should be done before scanning is to remove the brightness of the part surfaces. In this context, the powdering process was applied to the surfaces of the part. In the 3D scanning process; The 3D model was created by following 3D Scanning, the data capture, data processing, segmentation, feature classification, modeling, CAD model and rapid prototyping steps (Fig 1). After the solid model was created, accuracy analysis was performed in Geomagic Design X software. In this way, the differences between the first scanned mesh model and the final solid model should be determined and necessary updates should be made to the solid model.

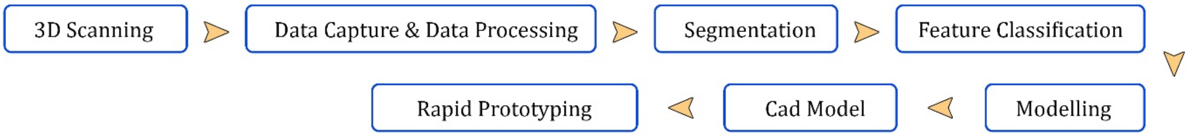


Figure 1. Reverse engineering processing

Forward engineering that to be the second method for the combine harvester part is the creation of the CAD geometry with the help of caliper. In this part, support was taken from the CAD program and a 3D CAD model was created by making measurements on the part.

2.1.Reverse Engineering Method

3D scanners are used to scan the part geometries and the scanning process creates mesh model with point clouds that define the surface geometries. Scanning devices are divided into contact and non-contact. In contact scanning devices, sensitive probes touch the surface of the part, creating point clouds. In non-contact scanners, point clouds are obtained by using lasers and optics. In this study, the combine harvester part shown in Fig 2-a was scanned using the NextEngine (NextEngine Inc.) device, which performs contactless scanning.

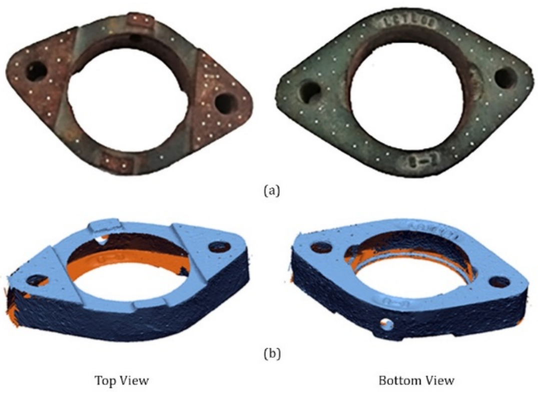


Figure 2. The combine harvester part

Scanning can be done more than once at different angles for the best modeling according to the complexity of the part. However, This leads to some disadvantages. For example; such as the lost time during scanning or delays in computer processing. For this reason, in the process before scanning, it should be aimed to create a solid model that is closest to the truth with the least number of scans. In the reverse engineering, the mesh model obtained by scanning the combine harvester part in 360 degrees was used. Support was obtained from the Geomagic Design X (3D System Inc) software for the processing of the scanned data. After scanning, mesh model was created. The purpose of mesh structures is to transform point clouds into surfaces. The mesh structure of the combine harvester part was shown in Fig 2-b. The mesh structure consists of 175681 nodes and 336226 triangular elements.

The first established mesh structures contain some flaws. For example, gaps between mesh structures and irregular dimensions of triangular elements. Such defects can be healed with a particular editing protocol. In this study, healing was carried out by using the commands "Mesh Healing, Global Remesh, Decimate, Filling of Holes and Mesh Optimization", respectively. Mesh Healing enables the detection of abnormal multiple surfaces in a mesh and their automatic correction.

The command that improves mesh quality by regenerating multiple surfaces with uniform multiple lengths on mesh globally is Global Remesh. Decimate command helps to reduce the number of multiple surfaces in a mesh by combining multiple peaks. The Filling of Holes command performs the optional filling of the gaps on the part. Finally, the optimization mesh, we use optimizes the shapes of a mesh structure according to the originals and improves the mesh quality. After this step, the number of nodes was calculated as 538303 and the number of triangular networks was calculated as approximately 1009875. The surfaces obtained with each step are shown in Fig 3.

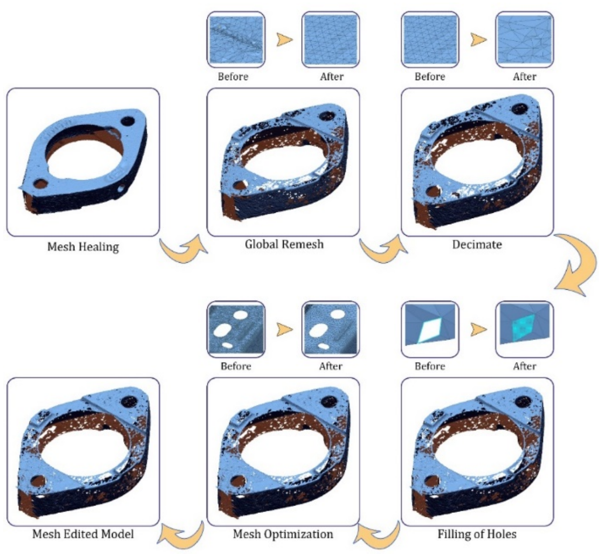


Figure 3. Demonstration of data processing stages in reverse engineering

After the mesh structure was created, the segmentation process was started. With the segmentation step, it is possible to classify the regions that are close and connected to each other on the mesh. The purpose of this process is to obtain easy reference planes. In the modeling phase, 2D drawings are made with the help of these planes and these drawings are turned into solid models by using various commands. Fig 4 shows which commands are applied in the segmentation step and modeling step, respectively. The final state of the created solid model is shown in Fig 5.

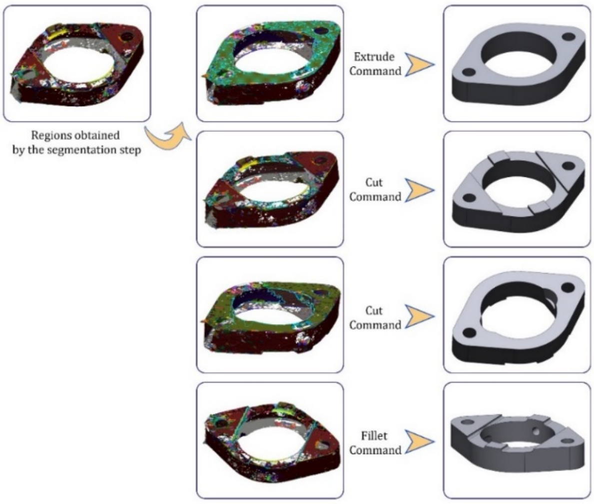


Figure 4. Regions (left part) created by the application of the segmentation process and solid models obtained by applying various commands to some selected regions

2.2.Forward Engineering Method

The solid model of the part was created with the Sketch and Model sections of the Geomagic Design X (3D System Inc) software. At this stage, the measurements of the part were made with the help of a caliper. The solid model is shown in Fig 5.

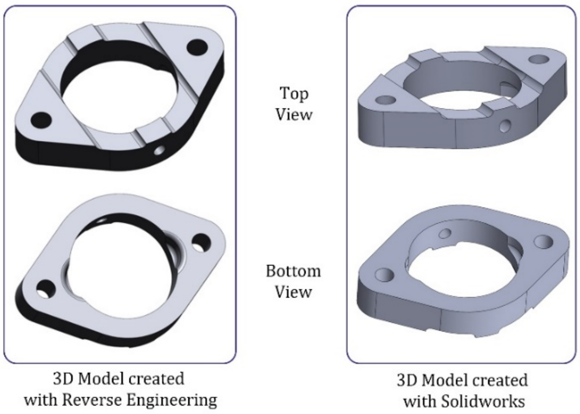


Figure 5. Solid geometry created with reverse engineering and Geomagic Design X

In the forward engineering method, Sketch, Extrude Boss/Base, Extrude Cut Boss/Base, Fillet commands are used for the 3D Modeling process. At the beginning of the modeling, the outline of the part was drawn as a 2D sketch and then it was converted into a 3D form by giving thickness with the extrude boss/base command. Afterwards, the holes of the part and the forms in the middle part were removed with the Extrude Cut boss/base command and the sharp edges determined with the last Fillet command were rounded.

3. Results and Discussion

In this study, solid models were created with reverse engineering and forward engineering methods for a part used in the combine harvester and the two models were compared dimensionally. In addition, accuracy analysis was carried out within the reverse engineering and forward engineering methods with the Geomagic Design X program. In the accuracy analysis, a comparison was made between the arranged mesh model and the revealed solid models. The accuracy analyses created for these parts are shown in Fig 6.

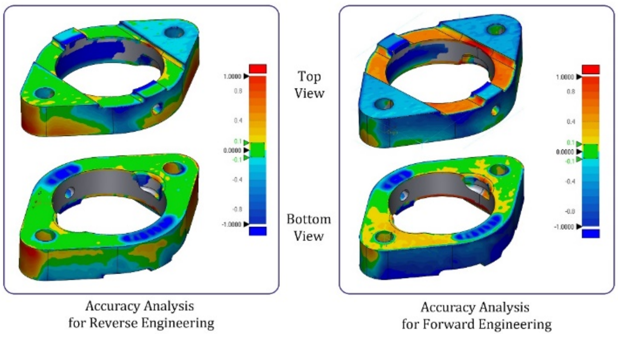
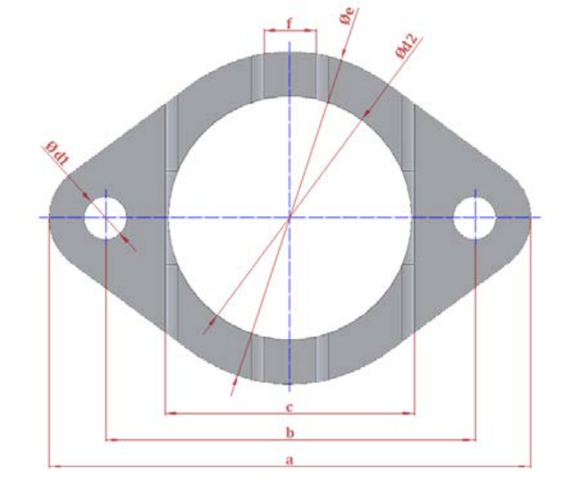


Figure 6. Accuracy analyses between the mesh model and the final solid models

In the accuracy analysis, red and blue colors indicate deviations between the scanned model and the final solid model. Green colors represent the regions where the deviation is the least or not. There are non-deviations regions in the different regions of the part. However, since these parts are not modeled in the solid model, it is quite logical that deviations don't occur in these regions. In the middle part, not much deviation was observed in the inner circular regions. The reason for this is that the interior parts are not scanned in order to speed up the process in the scanning process. The blue regions represent where the solid model is higher than the mesh model, and the red regions represent where the solid model is lower than the mesh model. It was determined that the results of reverse engineering analysis were more efficient than the results of accuracy analysis. because it was observed that green areas are more frequent and therefore deviations are less. In both methods, the accuracy analyses on the back surfaces of the part are very close to each other.

When we evaluated reverse engineering in itself, the accuracy analysis obtained in Fig 6 gave positive results. However, this study also shows us the convergences and divergences between forward engineering and reverse engineering (Fig 6 and Table 1). There are significant differences between the front surface of the model created by the reverse engineering method and the front surface of the model created by the forward engineering method. When the part is evaluated in general, part elements consist of primitive models (square, rectangle, sphere, etc.). Therefore, the dimensions on the part can be easily measured with a caliper. In this study, the forward engineering method is seen as the control group. The convergence of the solid model created by the reverse engineering method to the control group is given in Table 1. When these results are compared, the average accuracy value between the forward engineering and the reverse engineering solid models was calculated as 97.89 %.

Table 1. Dimensional comparisons between the two models.



Dimension Name	Reverse Engineering	Forward Engineering	Deviation (%)
d1	13.50	13.80	0.9782
d2	78.00	77.50	1.0065
a	152.00	152.96	0.9937
b	117.50	118.36	0.9927
c	78.00	78.51	0.9935
e	107.00	107.70	0.9935
f	17.00	19.00	0.8947
Average Accuracy			**97.8971**

***** Dimensions are taken in mm

4. Conclusion

As a result of the study, when the solid models created by reverse engineering and forward engineering methods were compared (Fig 6 and Table 1), it was observed that the solid models were close to each other. In order to increase the convergence of the solid model obtained from the reverse engineering method, it is necessary to obtain the scan data in a healthy way. Besides a good scan data, the arrangement of the mesh model is as important as it is. As a result of performing these sections well, the most accurate model is obtained. This study showed us that the 3D models obtained by reverse and forward engineering are morphologically close to each other. In addition, as a result of the study, it was seen that there is no need for reverse engineering method for 3D modeling of parts with regular and primitive features. It has been observed that it is sufficient to create such parts only by forward engineering method. In future studies, studies can be conducted on which methods should be used more actively in modeling mechanical parts. It can also be developed in hybrid methods on modeling of parts.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to concerning the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

References

[1] Demir, H., Savaş, V. and Altuğ, M., *Tersine mühendislik yöntemi ile Cad Datası oluşturma: Femur Kemiği örneği.* Batman University Journal of Life Sciences, 9 (1), 82-87, 2019.

[2] Buonamici, F., Carfagni, M., Furferi, R., Governi, L., Lapini, A., & Volpe, Y. *Reverse engineering modeling methods and tools: a survey*. Computer-Aided Design and Applications, 15(3), 443-464, 2018.

[3] Buonamici, F., Carfagni, M., Furferi, R., Governi, L., Lapini, A., & Volpe, Y., *Reverse engineering of mechanical parts: A template-based approach.* Journal of computational design and engineering, 5(2), 145-159, 2018.

[4] Zhang, Y., *Research into engineering application of reserve engineering technology.* Journal of Materials Processing Technology, 139, 472-475, 2003.

[5] Sansoni, G. and Docchio, F., *Three-dimensional optical measurement and reverse engineering for automotive applications*. Robotics and Computer-Integrated Manufacturing, 20, 359-367, 2004.

[6] Sokovic, M. and Kopac, J., *RE (Reverse Engineering) as necessary phase by rapid product development*, Journal of Materials Processing Technology, 175, 398-403, 2006.

[7] Lee, K., H. and Woo, H., *Use of Reverse Engineering Method for rapid product development,* Computers and Industrial Engineering, 35 (1-2), 21-24, 1998.

[8] Kacmarcik, J., Uzunovic, N., Z. And Lemes, S., *Reverse Engineering Using 3D scanning and FEM analysis*, International Conference “New Technologies, Development and Applications III”, 285-291, 2020.