REVERSE ENGINEERING APPLICATION ON BUILDING THE MODEL ACCORDING TO SAMPLES, ERROR EVALUTION OF DESIGN AND MANUFACTURE OF MOULD CORE WITH 3D CURVE SURFACE

Bui Khac Khanh[1*], Tran Vinh Hung[1], Vu Trung Tuyen[2],
Phan Thi Ha Linh[1], Nguyen Thanh Phu[1]
1 Hung Yen University of Technology and Education
2 National Research Institute of Mechanical

.

Abstract:

Reverse engineering has been increasingly popular researched and applied widely in the field of quick product development, especially 3D design from available products with support of computers. This technology plays an important role in designing products according to available models without corresponding CAD models. In previous time, taking samples of a product required measurement and sketching (traditional sampling) that gave inaccurate results, wasting time and being difficult for complex part. Nowadays, with support of digital technology, sampling of these parts is highly accurate; the CAD model can also be edited if needed. Implementation includes sampling to build the mode, evaluating the error, designing and manufacturing the model. This paper will present application of reverse engineering on sampling of computer mouse case and mould core design to manufacture this product. Processes include sample scanning, data processing, complete design of pressing mould, error evaluation and conducting experiments to manufacture mould core. The result of model for the computer mouse case ensures technical requirements.

Keywords: *Reverse engineering; sampling; model building; data processing; error evaluation; design; product.*

1. Introduction

Normally, in order to create a product, designer gives the idea, sketching out the product, calculating the design, testing and finalizing the sketch, selecting the optimal project and then put the product in to mass production. This method is called traditional manufacturing technology. In recent times, with the development of technology, a new type of production has emerged and goes against the traditional manufacturing, it is manufacturing a new products basing on available product, called reverse engineering. This technology happened basing on actual production needs, sometimes people need to manufacture products according to existing models without corresponding CAD models such as unknown details, reliefs, human body parts or animal parts or to copy results of the available

products to improve them in a new way. In order to create samples of these products, it was previously required to measure and then sketch or erase wax or plaster to print the pattern. These methods are not highly accurate, time-consuming and labor-intensive, especially for complex parts. Nowadays, people use scanners image to digitize the shape of the parts and then use specialized CAD software processes to create 3D CAD models for details with high accuracy. This CAD model is also editable if needed.

With changeable and developing market nowadays, the company that can soon launch a new model will gain market share and earn the highest profit. Therefore, the role of improving product design is very large and vital for businesses [5]. With time requirements, it does not allow us to make

entirely new designs, but base on the optimized products that meet testing standards to redesign the new product appropriately [6, 10]. New product depends on original one which is standard samples, including broken part [4, 10]. Therefore, in the future, reverse engineering technology will really be the focus of product design technology and research and application of the reverse engineering in product manufacturing is very urgent today.

Reverse engineering is done in sequence: Using a scanner to digitize the shape of a part, then the specialized CAD software will processes digitized data to create a 3D CAD model for detail with high accuracy. This CAD model is also editable if needed. From the CAD models, we will calculate, analyzing and test specifications on the CAE software. Following issues application on technologies (CAP), machining programming (CAM), rapid prototyping machining or machining programming on CNC machines or other machine tools, actual inspection and finally put into mass production (Figure 1) [5, 8, 10].
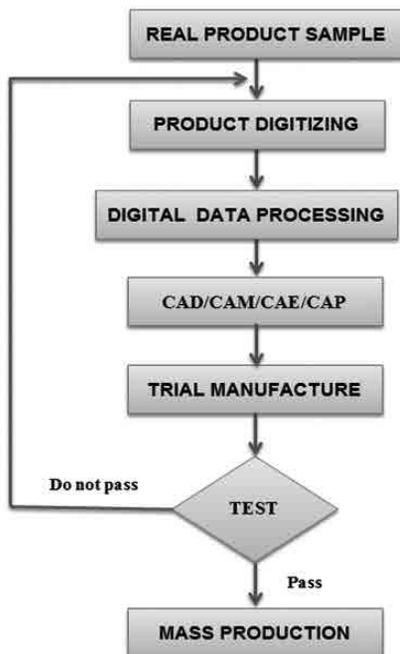

Figure 1. Implementation steps of sampling, processing and manufacturung the new products

2. Sampling Test

The test product is computer mouse case.

2.1. Used equipment

- Green light scanner 3D ATOS CORE shown

as Figure 2 [10] is GOM brand and made in German (is available at AID 3D Technology and Service Center) to digitalize the product.

Figure 2. ATOS scanner system

ATOS CORE system includes: ATOS scanner, computable, turntable table, view lenses, signal cables, turntable table controller. The ATOS CORE machine can be stationary, on a mobile rack or mounted on a robot for automated inspection applications. ATOS CORE machine has many versions, and the author uses the professional version which is specialized in processing Complex optical applications.

- Other supported software:

+ *Rapid Form XO Redesign software* (*Korean*): Process data from Scan to CAD which create CAD model from cloud data of scanning point.

+ *Inventor software*: Used in design of mold core. After reconstructing the 3D model of product by using the reverse engineering with Rapidform software, this model was transferred to specialized mold design software (Inventor) to perform mold separation [1]. Transitioning data from environment of the reverse engineering to mold design environment without distorting the original data, not through an intermediate format, is one of the advantages of combining Rapidform and Inventor.

+ *MasterCAM software*: is a support tool for mold programming for CNC digital controller.

+ *GOM Inspect software*: is a specialized testing software for assessing Errors of mold core parts after machining with the original CAD model.

+ *Processing machine*: use the milling machine CNC - Makino F5, as Figure 3 (F5 Vertical Machining Center) to process the mold core.

Figure 3. Milling machine CNC- Makino F5

2.2. Sampling test and results

Step 1: Sample scanning:

Firstly, installing the scanner and scanning table, connecting the cable system and preparing a computer. Secondly, lightly coat on detail surface with a layer of white paint, gluing on surfaces to create reference points (circle), and place the details on scanning table (this table can be rotated and moved). Scan sequentially on both sides of a computer mouse case, then combine 2 sides (there are at least 3 things in common) to form a complete scan. Once you have obtained the complete shape of the scan template as figure 4, we will save the file with the STL extension, and switch to the reverse engineering software to rebuild the CAD model for details.
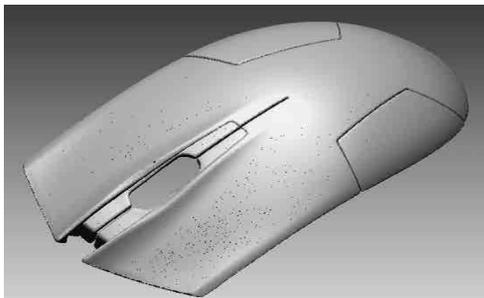

Figure 4. Point cloud data of plastic material

Step 2: Application of XOR software to build the model as sample:

- Raw data obtained need to be edited, optimized and partitioned before CAD modeling. After data entry commands; grouping of data regions; rebuild the coordinate system; rebuild surfaces of parts (external surface, internal surface, surrounding surface, etc.) from digitized data and complete the 3D CAD model design as shown in Figure 5 and Figure 6.
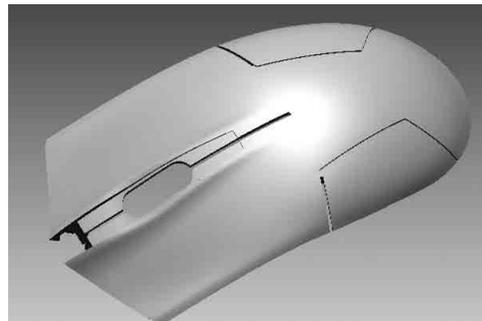

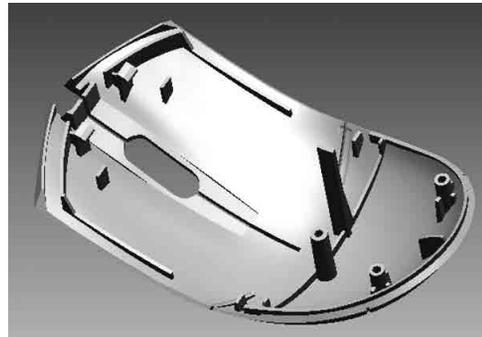Figure 5. Finished design goods (External face)

Figure 6. Finished design goods (Internal face)

- Convert data to other CAD / CAM software: 3D CAD model is just reverse engineering software and does not have the ability to export to 2D drawings or mold design. Therefore, to facilitate the process of rapid prototyping for the product and get a 2D drawing of the sample details, we first need to save the file with the formats Step, IGS. Then switch to other 3D design software such as Catia, Inventer, Soild Works, etc. to Export with STL extension format for rapid prototyping and 2D drawing creation.

Step 3: From 3D model, we transfer from specialized mold design software (Inventor) as Figure 7 to separate the mold core.
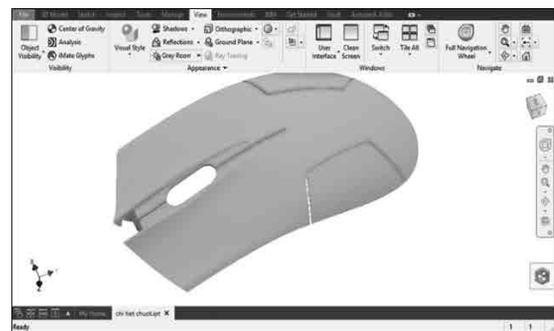

Figure 7. Convert data of point cloud is processed directly to INVENTOR software

Step 4: Design the mold core for mouse computer case:

+ Use Inventor 2017 software to design mold of product.

+ Select materials to produce computer mouse case: From material library, select ABS plastic materials [3]

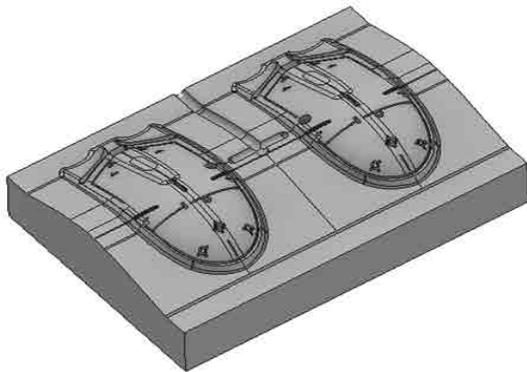+ Separation of mould core: Figure 8 is mould core model after separation.

Figure 8. Mold core

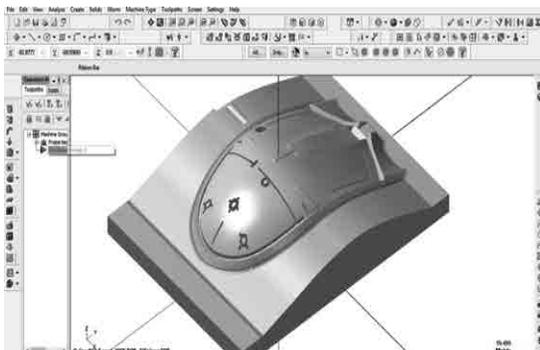*Step 5*: Programming the mold core. Figure 9 is mould core put into processing of MasterCam software [2].

Figure 9. Moud core model

+ The material chosen for mould core processing is NAK80 (Japanese brand – Hitachi) which has components as Table 1.

Table No. 1. Chemical composition of material for mould core (%)

Steel brand	Chemical composition (%)					
NAK80	C	Si	Ni	Cu	Mo	Al
	0.15	0.3	3.0	1.0	0.3	1.0

+ Processing result of mold core as Figure 10.

Figure 10. Processing result of mold core

3. Error Evalution of Design and Processing
3.1. Design error evaluation

Error between the redesigned CAD model and cloud digitalized data can be obtained thanks to Accuracy Analyzer (TM) tool in XOR. This tool will compare designed CAD model with cloud model to give specific errors for details at each time, each surface, and angle. This Error is shown directly by color on designed Image CAD model with chosen tolerance. The designer can see parts and areas of which Error is not within the allowed error area to redesign and correct it on the CAD model.

With mold core surface, choose a tolerance of ± 0.01mm and use 200 result points, we get a very accurate surface and the smallest error is ± 0.0001mm compared to the sample and the largest error is - 0.02 mm as Figure 11. With the mould core surface, selecting tolerance ± 0.1mm and using 50 control points give us a very accurate surface, the Error is mostly within ± 0.02 as Figure 12.
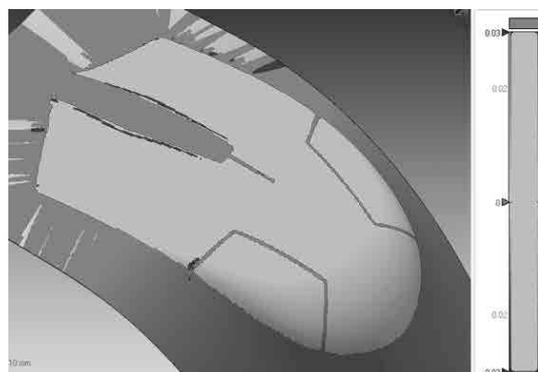

Figure 11. Evaluate the Error between CAD (External surface) with digital data
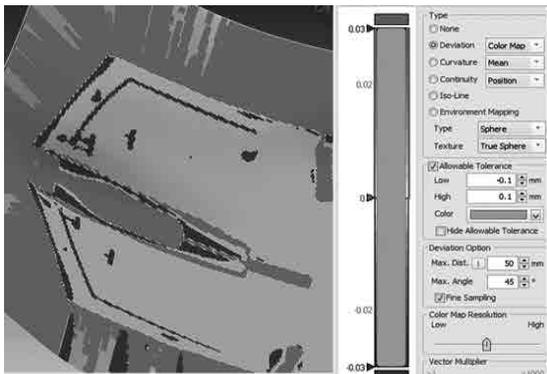
Figure 12. Evaluate the Error between CAD (Internal surface) with digital data

From results (in aforementioned figures), it is shown that the reconstructions of complex surfaces can be achieved with great accuracy depending on number of control points as well as permissible Errors that they are set from the beginning.

However, plastic products have warping, especially in design of plastic parts with symmetric learning figures [3]. The designer will usually choose solution that is half designed and then perform symmetry. Observing the comparison results, we can see accuracy of designed part. Besides, we can see the warping of plastic products. Figure 13 show one half of the product is completely identical and the other half appears a red due to warping. The maximum warping of plastic products is 0.3 mm. However, due to elastic properties of material, the product actually works effectively.
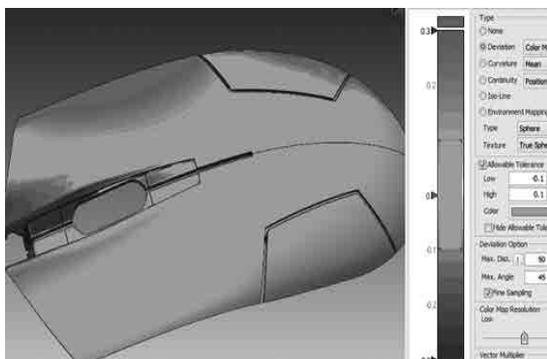

Figure 13. Evaluation diagram of the curve of product

3.2. Error evaluation of mold core processing:

Checking the precision in processing of complex parts such as mold core is very difficult. Traditional testing tools do not meet all the requirements. The development of available measuring devices makes the task of evaluating and testing product quality very convenient. 3D ATOS CORE meter is used to conduct re-scanning of mold sample after processing and combining with GOM software (made in German) to evaluate the geometric Error of mold. The principle of Error is to combine 3D CAD data with scanned data and then evaluate the Errors of the product [6, 9].

The results of geometric Error analysis are presented in the form of color bands as shown in Figure 14 below:
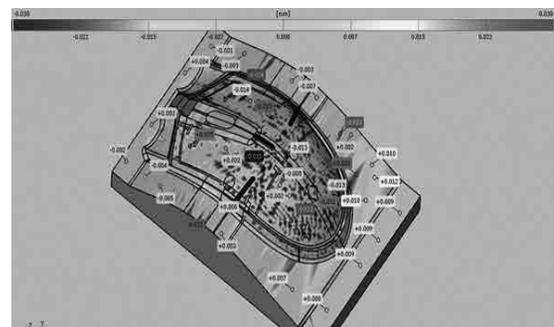

Figure 14. Evaluation diagram of processing error

From figure in the form of color bands, we can easily find errors of mould core surface. The area in dark blue is the negative profile area (i.e., the size tends to decrease), the yellow area is positive boundary area (i.e., the size has an increasing tendency). In addition, we can know the exact value of each deformation position that we want.

Therefore, with this method of visual error evaluation, designers and processors can observe the change exactly on 3D curve surface. The basic faces can achieve accuracy from + 0.002 mm đến + 0.009 mm. However, free surfaces can only achieve an accuracy of ± 0.03 mm. To achieve higher accuracy we can optimize the cutting modes as well as reduce the tolerance to create a more accurate toolpath. In this study, the author has applied the toolpath tolerance at finished processing at ± 0.01 mm.

From the above results, we can do experiments to manufacture plastic mold core products that meet technical requirements as shown in Figure 15.

Figure 15. Mould core of computer mouse case

4. Conclusion

- Having built sequence of sampling, processing and manufacturing products with complex 3D curve surfaces.

- Reverse engineering technology is widely applied in manufacturing, not only creating and developing products from prototypes but also a very effective tool in restoring damaged products.

- Having built a method of evaluation of redesign accuracy compared to original product, as well as a method for evaluating processing errors compared to the set design.

- Application of reverse engineering has made mold products to meet technical requirements.

References

[1]. Tran Vinh Hung, *Lecture on designing and processing the model,* Hung Yen University of Technology and Education, 2012.

[2]. Tran Ngoc Hien, Tran Vinh Hung, *CAD/ CAM software in controlling the CNC machine*, Publisher for Science and Technology, 2015.

[3]. Tran Ngoc Hien, *Material and technology of plastic processing*, Transportation Publisher, Hanoi, 2014.

[4]. Adrian Ciocănea, Sergiu Nicolaie, and Corina Băbuțanu, "Reverse engineering for the rotor blades of a horizontal axis micro-hydrokinetic turbine," *Energy Procedia* **112**: 35-42, 2017.

[5] Anwer Nabil and Luc Mathieu. "From reverse engineering to shape engineering in mechanical design." *CIRP Annals* **65.1**: 165-168, 2016.

[6]. Ma, Ye, and Xiao-long Li, "Introduction to the main procedures of reverse engineering applied on automotive body by using CAD software," Transportation, Mechanical, and Electrical Engineering (TMEE), *International Conference on. IEEE*, 2011.

[7]. Michal Dúbravčík, and Štefan Kender, "Application of reverse engineering techniques in mechanics system services," *Procedia Engineering* **48**: 96-104, 2012.

[8]. Paulic, Matej, et al, "Reverse engineering of parts with optical scanning and additive manufacturing," *Procedia Engineering* **69**: 795-803, 2014.

[9]. Savio, Enrico, Leonardo De Chiffre, and Robert Schmitt, "Metrology of freeform shaped parts," *CIRP annals* **56.2**: 810-835, 2007.

ỨNG DỤNG KỸ THUẬT NGƯỢC ĐỂ XÂY DỰNG MÔ HÌNH THEO MẪU, ĐÁNH GIÁ SAI SỐ, THIẾT KẾ VÀ CHẾ TẠO LÕI KHUÔN CÓ BỀ MẶT CONG 3D

Tóm tắt:

Công nghệ thiết kế ngược ngày càng được nghiên cứu, ứng dụng rộng rãi trong lĩnh vực phát triển nhanh sản phẩm đặc biệt là thiết kế mô hình 3D từ sản phẩm đã có dưới sự trợ giúp của máy tính. Công nghệ này có vai trò rất lớn trong việc thiết kế sản phẩm theo mẫu sẵn có mà chưa có mô hình CAD tương ứng. Trước đây để lấy mẫu của một sản phẩm phải thực hiện đo đạc, vẽ phác (lấy mẫu truyền thống) cho ta kết quả không chính xác, tốn kém về thời gian, rất khó khăn đối với những chi tiết phức tạp. Ngày nay, với sự trợ giúp công nghệ kỹ thuật số việc lấy mẫu cho các chi tiết này đạt độ chính xác cao, mô hình CAD

cũng có thể được chỉnh sửa nếu cần. Quá trình thực hiên từ việc lấy mẫu để xây dựng mô hình, đánh giá sai số, thiết kế và chế tạo lòng khuôn. Bài báo trình bày ứng dụng kỹ thuật ngược cho việc lấy mẫu chi tiết vỏ chuột máy tính và thiết kế lòng khuôn cho việc chế tạo sản phẩm này. Sau khi quét mẫu, xử lý dữ liệu, thiết kế hoàn chỉnh khuôn ép, đánh giá sai số và tiến hành thực nghiệm chế tạo lòng khuôn. Kết quả chế tạo được lòng khuôn để sản xuất vỏ chuột máy tính đảm bảo yêu cầu kỹ thuật.

Từ khóa: Kỹ thuật ngược; lấy mẫu; xây dựng mô hình; xử lý số liệu, đánh giá sai số; thiết kế; sản phẩm.