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Reverse Engineering of Parts with Optical Scanning and Additive Manufacturing

Matej Paulic[*], Tomaz Irgolic, Joze Balic, Franc Cus, Andrej Cupar, Tomaz Brajlih,

Igor Drstvensek

Faculty of mechanical engineering, University of Maribor, Smetanova ulica 17, 2000 Maribor, Slovenia

Abstract

This paper presents reverse engineering of car volume button. The purpose of article is to introduce reverse engineering procedure, what we need to do this kind of procedure and how we can remanufacture car's volume button. The purpose of reverse engineering is to manufacture another object based on a physic and existing object for which 3D CAD is not available. The first we need digital version of object. Because our car's volume button has free formed surfaces we decided to use 3D scanning technology to obtain the point cloud of existing object. With the help of point cloud we can developed 3D CAD model which will be used for manufacturing of button pair. We used for manufacturing of pair of buttons machine for selective laser sintering Formiga P 100. In the paper are also described costs of making of one pair of buttons and whole workspace.

Keywords: Production engineering; reverse engineering; optical scanning; selective laser sintering

1. Introduction

Reverse engineering is a kind of engineering which takes advantage of an already created object. The final purpose is to create another object similar to the existing object. Getting this is essential to get information about the physic object. Reverse engineering can be applied in different fields like software, electronic components, big pieces, small pieces.

In this paper we presents reverse engineering which is focused on objects. This method is the most used. It consists of getting the virtual model 3D-CAD of an existing object with the help of software [1, 2]. The virtual model has to be obtained with a scanner.

*Corresponding author. Tel.: 00386-2-220-75-98

E-mail address: matej.paulic@um.si

The scanner converts the physical object into point cloud. This kind of reverse engineering can be used to make digital 3D record of the objects, for security copies, shows it in presentations to the competitors about how it works, identify potential patent infringement [3].

In our case, we will take advantage of a plastic object. More specifically a plastic button of which we will manufacture both sides, right side and left side form polyamide PA2200 [3, 4, 5].

This button is used for turning up the volume of a car's radio. It has surfaces which have to be perfectly copied because it is the most important part of the button. Behind this surface there are three cylinders and a square which will be used to fix the button on the car's steering wheel.

2. Scanning of button

Clearly our case is a case about reverse engineering applied to objects. We are going to scan a physical object which has a complicated geometry and some surfaces. Our piece is small and therefore we need to use the lens with the size 350 x 280 x 280 mm. The lens permits to get a better mesh with more points [6].

The button has to be provided with encoded points which are situated strategically for ensuring a correct mesh. Fig. 1 shows button from front and back side and there are also encoded points.
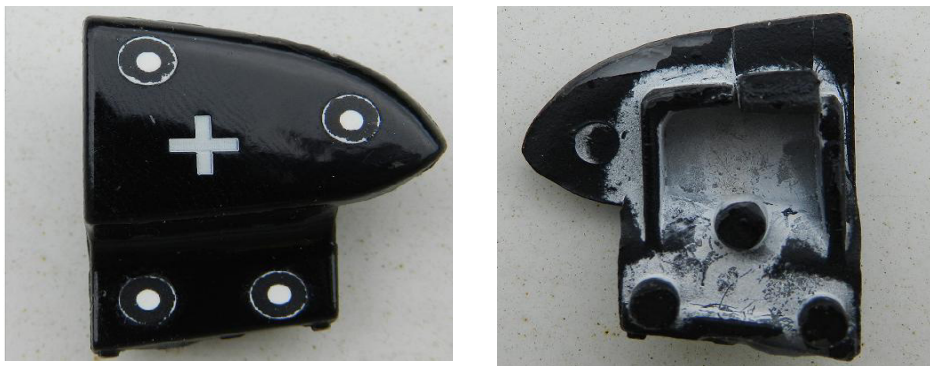

Fig. 1. Button front and back side with encoded points.

For scanning the whole button we have to rotate few times to get every views of the button.

Because the button is black the light is reflected, and we cannot get the right point cloud. This is the reason why we have to paint the piece with a developer spray which paints the button in white, so the button is prepared to be scanned.
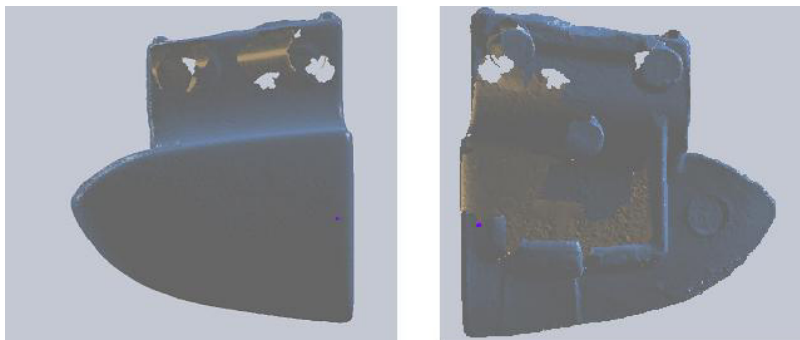

Fig. 2. Mesh after scanning.

The scan has to be done in a dark space, it helps to accomplish a more accurate point cloud, and also it is good to avoid damages on the mesh.

After some scans and picking the best one, we have to orientate the mesh with the software. Fig. 2 shows mesh after scanning.

3. Getting 3D-CAD model by Solidworks

We are starting the procedure to convert the point cloud in a solid 3D cad model. The idea is to draw a solid taking advantage of the mesh. At the end, the 3D solid has to look like the mesh. Other thing is that reverse engineering is always an approximation of the original piece, in other words, at the end our piece will be approximately the same that the original piece [7].

After this, we will be able to manufacture the piece in the machine of selective laser sintering.

To work better and easier we are going to divide the button in two parts called upper part and lower part. After drawing both parts we will do a fillet between two parts.

The mesh is not perfect (Fig. 2) it contains some holes and some damages on the surfaces. But SolidWorks has a feature which helps to repair the mesh. It consists in filling the holes and to join the damages to the parts. At the end, the mesh looks much better than before and it is really an approximated version of the real button.

We can see some holes and some areas that are not filled (Fig. 2). The feature called mesh wizard is capable of repairing this mesh. On the picture (Fig. 3) we see the mesh perfectly repaired.
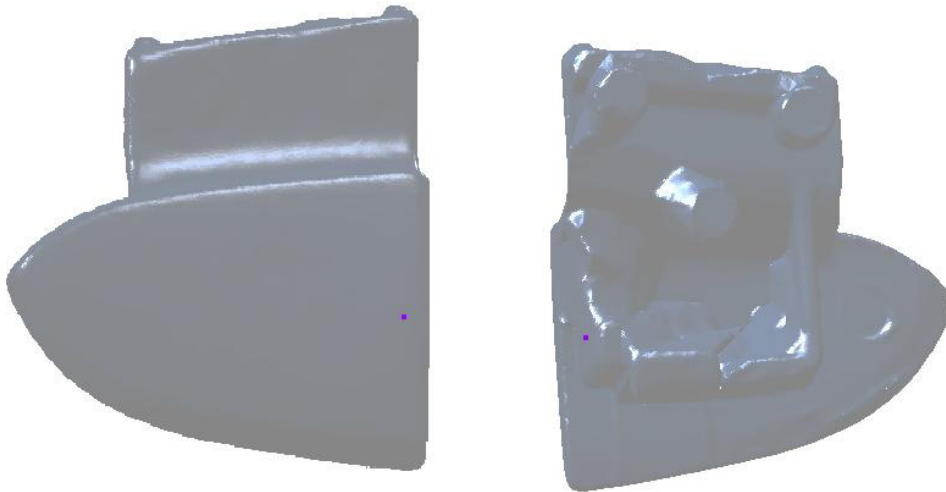

Fig. 3. Repaired mesh.

4. Reverse engineering of the surfaces

We are drawing the surfaces of the upper part of the button. We have to take care of this part because it is the most important surface.

For doing this surface we were use the feature called surface wizard. This feature helps us to create the surfaces automatically (Fig. 4), but we have to take care and check if the mesh is drawn correct. Also we can check if the sensitivity is correct because it depends on the sensitivity if it can be more accurate. Anyway, we can draw the surface manually by painting the mesh there where we want a surface, also we can paint manually if the painted part does not adjust correctly [8, 9].
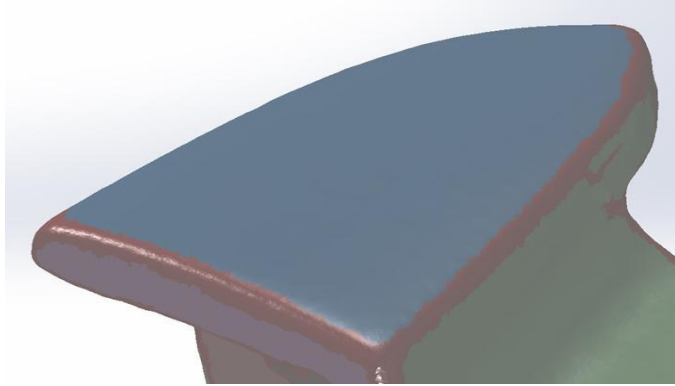
Fig. 4. Mesh painted automaticly.

Three surfaces have to be created and adjusted perfectly (Fig. 4). The order of the procedure does not matter, because after this we are going to cut and extend the surfaces. Final result of cutting of excess of surfaces is shown on figure (Fig. 5).
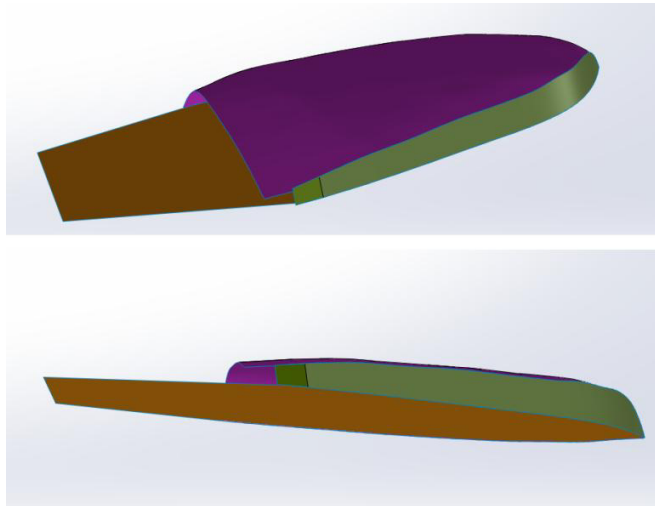

Fig. 5. Created surfaces and excess cutted away.

For creating these surfaces, we will follow the similar process as before. With the feature surface wizard we are going to do the reference surface. In this case it will be planar surface. To avoid the problems we are going to draw the first surface (reference surface) and other surfaces will be refers to this surface.

The other surfaces can be created by just creating a plane perpendicular to the reference surface and selecting, with the option coincidence, the part of the mesh where we want to create a plane. Considering this last rule we draw a line in the sketch and we extrude it, in direction of reference surface (Fig. 6).
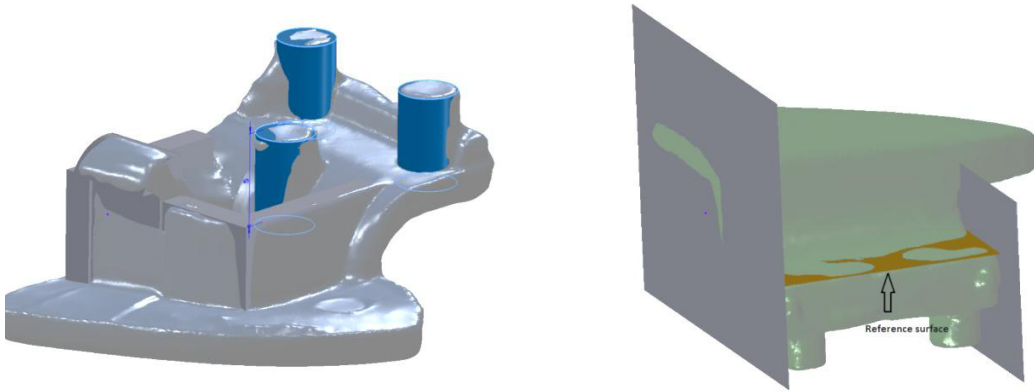
Fig. 6. Created surfaces, reference surface and cylinders.

With the feature combined we joined the parts. When the cylinder and square have the right geometry it is time to combine everything. Finally we have a single solid (Fig. 7).

If everything is correct and there are no offsets or two surfaces at the same place, we are able to do a fillet on the specified edges.

Finally we have our button and it looks like the real button (Fig. 7), we can compare with the mesh in SolidWorks.
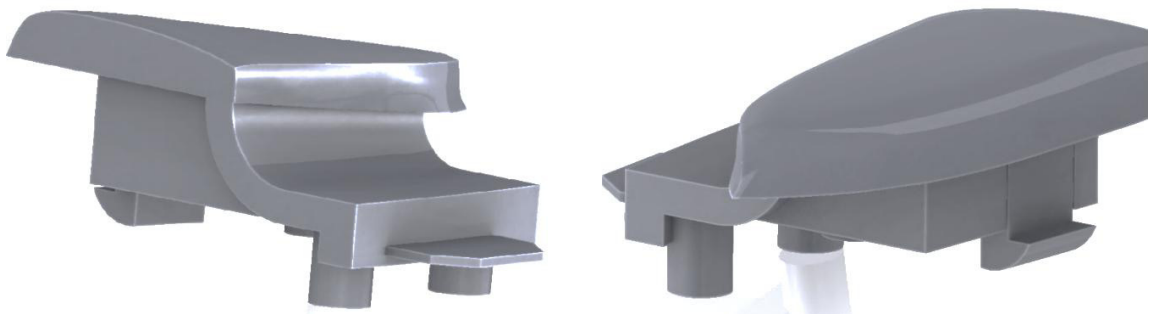
Fig. 7. 3D Cad model done.

Now, we have the right side of the button, we save this solid as "buttonright.SLDPRT". Now we want to do the left button. With "SolidWorks" this is very easy because there is a feature called mirror for which we have to specify the plane of the mirror, and the same piece is created on the other side of the mirror. We deleted the right side of the button and save this solid as "buttonleft.SLDPRT" (Fig. 8).
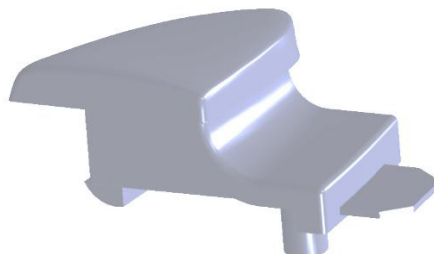

Fig. 8. Left button.

The extension of the file is .SLDPRT, for working as a mesh we save this file with the extension .STL. We open the file with the software Netfabb studio basic which will helps us to orientate and define the position and also, to define the layers of the mesh.

The first thing that we have to do is to add both parts "buttonleft.stl" and "buttonright.stl". These parts have to be orientated and positioned correctly.

After that, we defined the slices the default option is a slice each 0.015 mm, for the button this is correct. The height to start is 0 mm and the height to finish 12.711 mm.

The slices will be created and with the control of the simulation we can observe how the piece will be created.

5. Machine of selective laser sintering

The machine of selective laser sintering is available in the Faculty of mechanical engineering in Maribor [9]. This machine is compact, cost-efficient and a highly productive system for the additive manufacturing of plastic parts. It is ideal to manufacture small series production. It can manufacture piece with complex geometry. The maximum height that it can manufacture is 330 mm.

The next table (Table 1) shows the technical data [8, 10, 11]:

Table 1. Technical data of FORMIGA P 100.

FORMIGA P 100	
Effective building volume	200 mm x 250 mm x 330 mm
Building speed (depending on material)	up to 24 mm/h
Layer thickness (depending on material)	0.1 mm
Laser type	CO_2, 30 W
Scan speed during building	up to 5 m/s
Power supply	16 A
Power consumption	2 kW
Compressed air supply	10 m3/h
Dimensions (W x D x H)	
System incl. powder containers and touch screen	1320 mm x 1067 mm x 2204 mm
Weight	approx. 600 kg
Unpacking and sieving station (optional)	1200 mm x 700 mm x 1500 mm
Data preparation	
PC	Current Windows operating system
Software	EOS RP Tools (optional); Desktop PSW
CAD interface	STL (optional: converter to all common formats)

This machine is capable of manufacturing pieces with a complex geometry. To build plastic pieces it uses STL files with three-dimensional geometries.

The basic principle is based on the sintering of the plastic powder using a CO_2 laser. The laser sintering process is, basically, heating the plastic powder above the melting point (184°C) by exposure with the laser beam.

The heater has an important job which is to maintain a homogenous temperature in the workspace. This is very important because if in the process the temperature is not equal around the platform the piece can be deformed and the machine can have serious problems. After melting the plastic powder and making the geometry of a layer, it is refrigerated by nitrogen. The shrinkage of the solid when is melted is compensated by appropriate scaling. The last process is repeated layer by layer to form the final solid.

6. Manufacturing the buttons

To manufacture the button, previously drawn by "SolidWorks", orientated, positioned and the slices defined by "Netfab studio basic", it is time to use the selective laser sintering machine Formiga P100.

This machine is provided with the software "EOS PSW" which is used to define the position and the quantity of the pieces that we want to manufacture in the platform, to define the parameters of the machine and to simulate the process which the machine will follow.

The principal screen of the software "EOS PSW" is the view of the work platform. We added a pair of buttons and situate the buttons in the middle of the screen and then we can see a preview of the platform (Fig. 9). This principal screen has important tools which help us to get information about the work that we have to do.
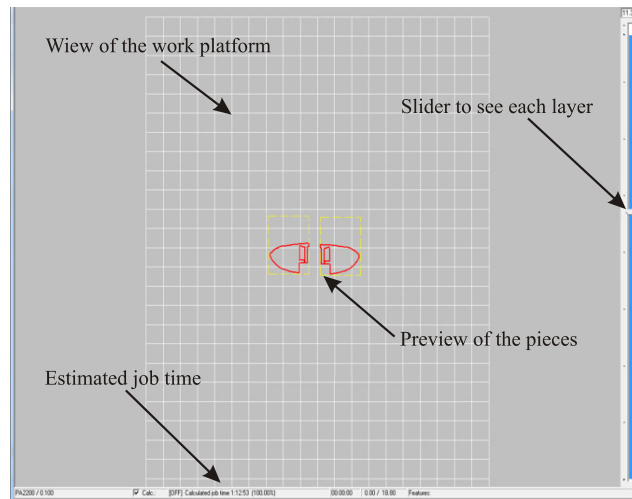

Fig. 9. Workspace.

The machine is capable of taking advantage of almost all workspace, so we try to fill of the workspace with buttons to get more production (Fig. 10). It is really good for the production because it only elevates the production time slightly and in this case we can obtain 21 couples of buttons. In our case, for one couple of buttons the estimated job time is 1:12:53 and for 21 couple of buttons is 1:25:50, proving that the time is just a little bit increased.

Also, it is important to define the position of the button 0.5 mm upper from the platform, otherwise it could be stuck with the platform.
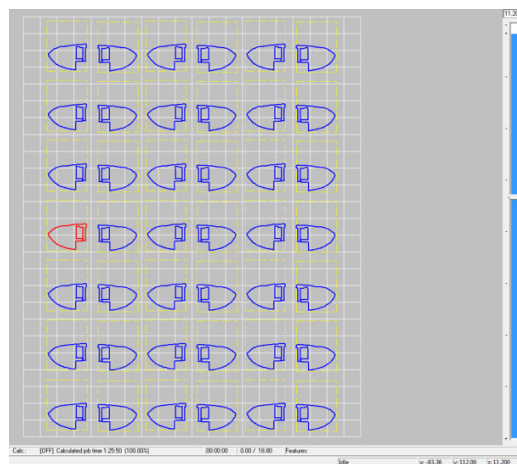

Fig. 10. Platform full of pieces.

The machine to clean the pieces (Fig. 11) has two hoses, the small one ejects air, and the big one sands. The big one is used to clean the piece in general and the small one for cleaning the small holes or edges (Fig. 12). It is

important to take special care with the hoses of sands, because if a part of the piece is exposed for a long time to the hoses of sands it could be damaged.

Fig. 11. Cleaning machine.

Fig. 12. Hoses.

And finally we get one couple of buttons with both sides (Fig. 13). Right side can be compared with the first button from which we obtained the data and check if the button is quite similar to be accepted.
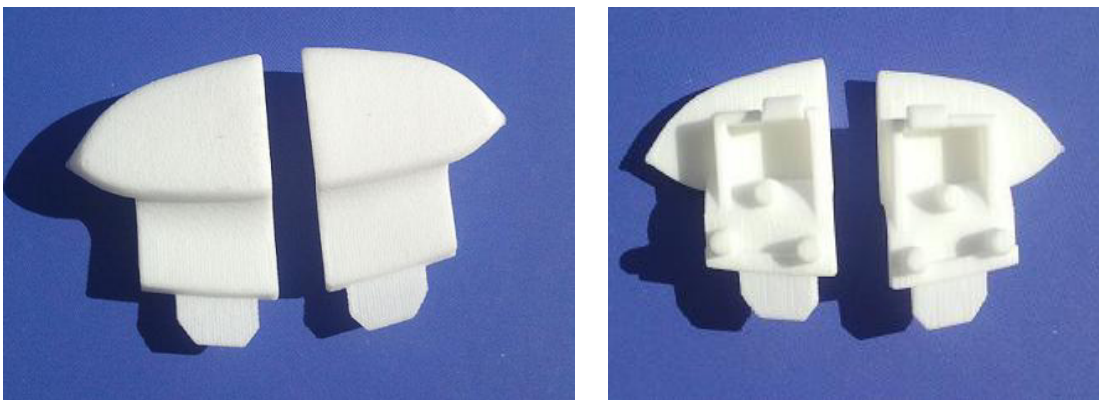

Fig. 13. Front and rear buttons manufactured.

7. Costs

We are going to calculate the price for the manufacturing of one pair, left side and right side (Fig. 13). We have basically two prices, the cost of material and the cost of consumption of the machine. The material that will use is polyamide PA2200 which is cheap in easy to find, the melting point is 184ºC and the density 0,6 g/cm³ [9].

In Table 2 and Table 3 are shown costs by calculation without recycling and with recycling for 1 pair of buttons and 21 pairs of buttons.

Table 2. Calculation without recycling.

	Volume platform [cm³]	Volume buttons [cm³]	Density Remaining polyamide [g/cm³]	Density polyamide [g/cm³]	Mass remaining polyamide [g]	Mass button [g]	Mass of polyamide to add [g]	Cost of material [€]
1 pair of buttons	1100	2.81	0.6	1	658.31	2.81	661.12	**46.28**
21 pairs of buttons	1100	59.06	0.6	1	624.56	59.06	683.62	**47.85**

Table 3 : Calculation with recycling

	Volume platform [cm³]	Volume buttons [cm³]	Density Remaining polyamide [g/cm³]	Density polyamide [g/cm³]	Mass remaining polyamide [g]	Mass button [g]	Mass of polyamide to add [g]	Cost of material [€]
1 pair button	1100	2.81	0.6	1	329.16	2.81	331.97	**23.24**
21 pair button	1100	59.06	0.6	1	312.28	59.06	371.34	**25.99**

8. Conclusion

The case studied has permitted us to discover how the reverse engineering can be useful for manufacturing already existing pieces.

In this paper we showed how a 3D scanner works and its applications in the reverse engineering field. We showed how to get data from the objects with the scanner. Also, with different software we could repair the mesh, orientate it and define the position of the mesh.

Thanks to the complex form of the button we showed how to create a solid by SolidWorks, drawing the different surfaces and solids.

In our case we did not have the left side of the button and thanks to the creation of the solid we could make the mirror part and reverse engineering permitted to us to manufacture this part.

Reverse engineering is one of the best forms to manufacture prototypes or short productions. The selective laser sintering machine permits an easy and cheap manufacturing of pieces.

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