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AUTHORS: Kemal ERSAN,Yunus Ali DEMIROGLU,Burhan GÜLDÜR

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Design and Manufacturing of Real-Scale-Mockup-Car Door Via 3d Printer

Kemal, ERŞAN[a] *, Yunus Ali, DEMİROĞLU[a] , Burhan, GÜLDÜR[a]
[a]Faculty of Technology, Automotiv Engineering Department, Gazi University, Ankara, Turkey
** Corresponding author: kersan@gazi.edu.tr*

ABSTRACT: In this study, a door of a real-scale-Mocap-electric-car that we previously produced , was designed by using package design programs available for the production of the body elements. In this comprehensive design, connection interfaces between the door and the car body, the door handle, the elements for window mechanisms, the elements for door locking and the door hinge were designed in detail. Before the production of these designed parts, conformity analysis and tests were performed in the computer environment. Instead of the conventional car manufacturing processes, modern, fast and economical 3D printers were used for manufacturing. The door, door components and their 3D printer production data which were created and assembled in computer environment were further manufactured via 3D printer.
Keywords – *Automobile door design, Production with 3D printer*.

1. Introduction

Nowadays, the production stage of vehicle design and production is reached by making necessary drawings, simulations and analyzes in computer environment. With such an approach, vehicle production reduces time and cost, and all function tests of the vehicle can be examined in detail before production.

Production through computer technology requires utilization of many package programs These programs are compatible with the production machines to be manufactured, the design data can be translated into production codes and data can be transferred.

One of the areas where the innovations in today's technology are the fastest to implement instantaneously is in the automotive sector. It is inevitable to use the newest simulation, design program and production technique in the automotive sector, which is the area where innovations in technology are applied most and instantly reached to the final consumer. In today's technology, there are package programs commonly used for industrial design, such as Catia, Solidworks, Autocad, Inventor, and additional analysis programs.

In this study, it was aimed to realize real production by using new package programs and new production technology in the automotive field due to the reasons explained above. For this purpose we have considered the design and production of a real-size MOCKUP car door that was previously made by us yet unproduced. The door design was also made using the 3D printer method, which was made using the Catia program and the new production technique. The production process is described in detail.

3D printing (3DP) was developed with the modification of the old inkjet printer. It continues to develop rapidly today. Despite the fact that the number of existing 3D printer technologies reaches up to 20, little is known about the other methods except the most popular FDA method. It seems that new applications are being introduced with new 3D printers and printer materials in various fields almost every week. Health, automotive, aviation and defense industries can be mentioned among the application areas of 3DP applications (Campbell at al 2011; Dodziuk 2016).

The evolution of the current and potential applications of 3D printer and the probable effects at both micro and macro level, have been explored from a broad perspective. At the same time, the current and possible steps to take advantage of all the advantages of this technology have been discussed. Countries that support the adoption of 3D printing technology and its use in production are anticipated to be able to capture new opportunities in various fields of production technology (Karagöl 2015) .

As a result of 3D printer technology, it is said that the automobile development process has changed irreversibly and summarizes the history of automotive use (Park 2015) .

In addition, many companies partially produce automobile parts, and some of these parts are supplied in bulk (web 3dhubs 2017) .

Besides, automobile production was carried out. The first Starti automobile (localmotors web 2017) (with the local company 3D printer) was not made for production purposes. The same company produced the LM3D Swimi (localmotors web 2017) for four people in 2015 for retail sales, about 75% of which was printed with a 3D printer, and 50 pieces were produced in about 44 hours. In 2016 it produced an Olli van for 12 people (localmotors web 2017).

Honda presented a newer version of a previously produced Micro Commuter(hybridcars web 2017) model in CEATEC 2016 expo-fair. The panels, the body and the majority of the single electric vehicle with a driving range of about 80 km are printed in 3D. This year, in 2017, HONDA Company closed one of its factories in Japan to transform it into a factory where new technologies are used (honda web 2017) .

Vehicle Model Design Stages

Design is to produce products that will have sufficient strength, sufficient stiffness, low wear, low friction, minimum material usage, easy to obtain, easy to install and durability besides appealing to the consumer.

Doing a lot of work with little material in design is one of the most important principles. Cost and material usage should be minimized. In addition to this, maintenance costs should be considered.

The next step is modeling. In this step, by considering the producibility of the design a solution is sought and drawings are made. Nowadays, Solidworks and Catia programs are preferred in terms of overall ease of use. After the drawing, necessary analyzes are made. After the desired results are obtained, the prototyping step is started. The operation is repeated until the optimum design iss achieved. In this way, the most suitable design can be achieved (designTech web 2017) .Prototyping is required to obtain the necessary results.

In prototyping stage, the first and most suitable option that was the 3D printer. The first step of producing a prototype, which was a whole, was to produce individual parts.

Then the modeling section is passed. Now, we are going to search for solutions by adding the possibility of designing the design and drawings. Today, Solidworks and Catia programs are preferred in terms of overall ease of use. After the drawing, necessary analyzes are made. Here, after the desired results are obtained, the prototyping phase is passed. The operation is repeated until the optimum design is achieved. In this way, the most suitable design is achieved (designTech web 2017).

In this stage, 3D printer is thought to provide the fastest solution. Prototyping is required to obtain the necessary results. The first step of producing an entire prototype is to produce the parts.

Digitization and Production of Part

By particularly using the digital imaging techniques, it is possible to carry out many reverse engineering and inspection operations, such as confirmation of manufacturing tolerances, geometry determination for re-manufactured parts, and deformation problems (turkcadcam web 2017) .

Digitization Steps

In today's CAD / CAM applications, manufacturing process starts after achieving appropriate CNC data which is created based on the computer-generated three-dimensional model. In the "reverse engineering" method, the data is first obtained by scanning with a model scanner, then corrected and adjusted into a surface in an appropriate manner, and finally, the appropriate insert operation is carried out to process on the CNC workbench.
Three dimensional digitization techniques allow collection of spot cloud data of the part to be produced and thus the creation of the CAD model. The 3D CAD data of a part with complex geometry are obtained very quickly and precisely. Then, using the relevant modules of the software, the design of the scanned part can be redesigned parametrically, or modification can be made (turkcadcam web 2017) .

Numerical Data Collection Technique

When reverse engineering is applied, component development and design data can be obtained as numerical data through imaging via cameras. This numerical data is used in a practical and successful manner (Görür at al 2003) .The reverse engineering workflow diagram is given in Figure 1.

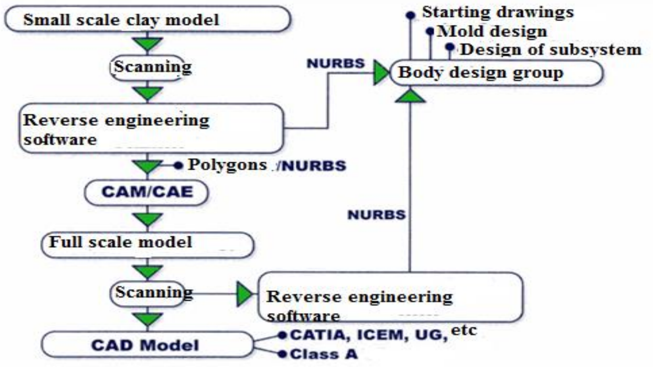

Figure 1. Optical 3D Digitization

Numerical data collection techniques are divided into two as touch and non-touch methods. The use of digital cameras in the non-touch method and the laser measurement method are recognized among the most commonly used optical data collection techniques (turkcadcam web 2017).

In optical scanning, the resolution and the optical quality of the scanned image are important. The part to be scanned must have a dull surface suitable for the device. If the resolution and optical quality of the part are at the desired level, the amount of reflected light from the surface is sufficient and the desired scan data can be obtained (Görür at al 2003) .

Converting Point Cloud to CAD Datum

It is necessary to convert the data obtained by the digitization methods into CAD data for the production.

Measured data, measured through a reverse engineering process and achieved as a point cloud, on its own, lacks topological information and therefore it is frequently transformed into a more useful form such as a triangular mesh or CAD model. Point clouds are not compatible with most 3D software, so reverse engineering softwares convert these point clouds into data format which can be used in visualization or in applications such as; 3D CAD, CAM, CAE (avrotas web 2017).

In this transformation method, CAD models are created in a very short time with the help of curves which are preciely obtained from data in STL (Stereolithography) format or point cloud format that are obtained via 3D laser or optical scanning systems. STL data is used to obtain 3D surface and solid models. When it is desired to create changes on the part of CAD data, it is possible to obtain a brand new model by making the desired changes (avrotas web 2017) .

Model Making

It is necessary to make the models in the first stage before digitization of the parts to be produced. Based on this process, advanced engineering applications such as 3D Optical Scanning, 3D Modeling, 3D Dimensional Control and Analysis are used in parallel with the developments in CAD / CAM production process (quora web 2017).

A parametric CAD model is created by using the point cloud data obtained from 3D measurement. Then the assembly of the assembled parts is done taking into account the 3D drawings, mounting criteria and working tolerances.

Modern prototype model making machines using fast prototyping techniques are used. These machines are designed to produce an individual model of the 3D drawing in a few hours directly from the 3D CAD drawings prepared on the computer. From these machines, which have material extraction and material addition techniques, the latter is used by 3D printers. These machines can be grouped based on the materials they use in production as plastic using, polymer based composite material using and metal based materials using machines. The most important factors that limit the widespread use of 3D printer in the production process of automotive parts are the strength of the used materials and the processing speed.

Modeling can avoid the faults that may appear after production (imbalances, misalignment, unbalanced distribution, etc.) by detecting them prior to the production process (quora web 2017).

Actual Manufacturing Steps of Vehicle Parts

The classical manufacturing steps of vehicle parts (quora web 2017; caranddriver web 2017) are explained in detail. In this study, manufacturing was made with 3D printer, thus only this method was explained in this study.

Classical Manufacturing Technique

Both machining and non-machining methods are used as manufacturing methods in the production of automobile parts.

The designs are made in the research and development center that makes the first step of manufacturing. In this step, the shape, material selection, strength calculations and manufacturing methods of the parts are developed (imalusulleri web 2017) . The mold of the part with a defined manufacturing technique is made in CNC machines based on the design drawings. Generally, in serial production of automobile parts, molds are used. The mold types vary depending on the parts to be produced. Some parts are produced by machining (wikipedia web 2017) .

Production of parts by 3D printer method

When it is desired to produce a part by conventional machining methods, the desired geometry is cut to the final shape by trimming the excess from a bulk material. The manufacturing methods thus carried out are generally referred to as “Subtractive manufacturing” methods. Because in order to give the final shape to the piece, it is necessary to remove the excess (mühendishane web 2017).

The desired part to be produced in a 3D printer that has a different production procedure than the subtractive manufacturing methods, is obtained by combining the materials with each other so called "joint manufacturing method".

Production of parts with three-dimensional printers could be done by using polymer materials as shown in Figure 2 (specialchem web 2017) or by sintering the powdered materials as shown in Figure 3 (materialgeeza web 2017). This method, which is usually used to produce metal and ceramic parts, also allows the production of polymer parts .

Joint manufacturing method starts with a model in the computer. This model can be drawn by a computer-aided design (CAD) program or by translating the shape data of the object to be printed into a data pattern that the computer understands by means of three-dimensional scanners. This model was then cut into thin, "digital" layers in computer. Subsequently, starting from the lowest layer, step by step, the material of liquid, powder, or thin-leaf material were stacked on top of each other in a cross-section. Finally, these layers, which correspond to the digital sections of the model in the CAD program, were merged together, or merged during stacking, to arrive at the end of the part (mühendishane web 2017).

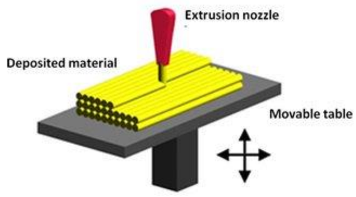

Figure 2. Production of 3D printer (Additive manufacturing process)

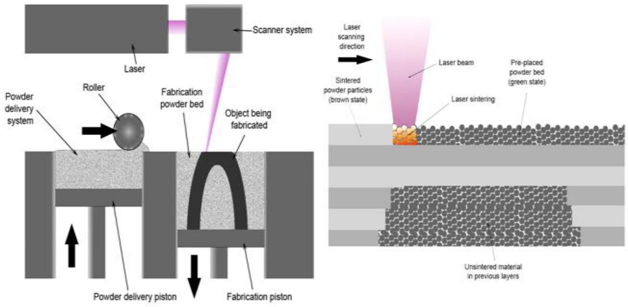

Figure 3. Selective Laser Sintering

At the same time, the printing process starts by spreading the powdered material onto a piston which can move up and down, then, with a very high power laser such as carbon dioxide laser, the dust on the platform is scanned to reveal the structure of the lowermost section and welded to each other. Once the bottom layer has emerged in this way, the piston is moved downwards and the process is repeated by relaying powders to form an upper section. This production method is also called selective laser sintering .

The most important advantage of three-dimensional printer technology is that it allows the production of parts in almost any geometry. The most important disadvantage is that it is a slow process and there is no material to provide sufficient strength (mühendishane web 2017).

Material selection

Major materials that are used in 3D printing are listed below.

Polymer materials are strong rugged materials that can be reinforced with fibers. Wood, resin, ceramics, metal powders and ABS materials can also be used in 3D printers (3d hubs web 2017).

2. Material and Methods

Previously made mockup was used in the present study. The digitization data (point cloud) obtained from the clay model for making the mockup in the optical scanning was first meshed and then edited with the Rapid Form XOR 3 program. Curves were taken over the edited data and networked, and then with reference to these curves, the surface model of the MOCKUP was achived as given in Fig 4 (Sapmaz 2014).

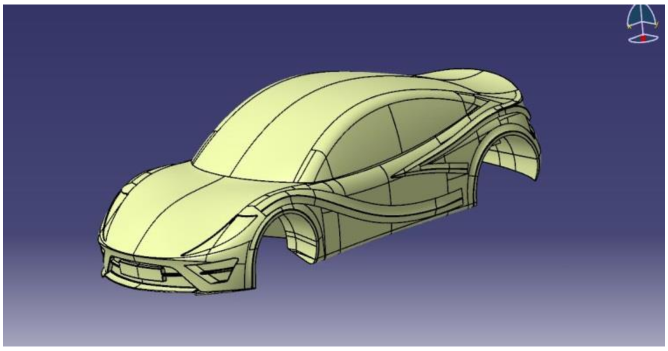

Figure 4. MOCUP in-surface model at real scale

Model Design and Production of Parts

The design data of the MOCKUP car shown in Figure 5, which was designed and manufactured in Gazi University Department of Automotive Engineering in accordance with the standards and on a real scale, was obtained through a private interview (Sapmaz 2014). The exterior dimensions of the car are defined in the real surface model drawn in the Catia program obtained Figure 4. The outer dimensions of the door were outlined as in this drawing. Since this data was not sufficient for production, it should be adjusted accordingly. In the first given surface modelling, necessary arrangements were made and the parts of the surfaces which did not fit were corrected.

Figure 5. In the Catia package program, the point cloud is created, the surface model is created, and the whole scale of the vehicle, in which a real scale MOCKUP model is produced, is seen.

Drawing of the parts

Afterwards the locations of the doors and the windows were defined and these locations were illustrated with lines in 3D Figure 5.

As can be seen in Figure 6, interior of the car was represented with empty planes. In order to produce this car, the primary requirement was a defined thickness. The door of the car was demounted by cutting through the lines illustrated in 3D for the left door. Afterwards, the back window was cut off for the model. The door was removed first in order to remove the door jamb. When the removed parts are examined it was seen that the door of the car and the window are in the form of planes. For drawing, it was necessary to work on the left door of the car and the door jamb separately.

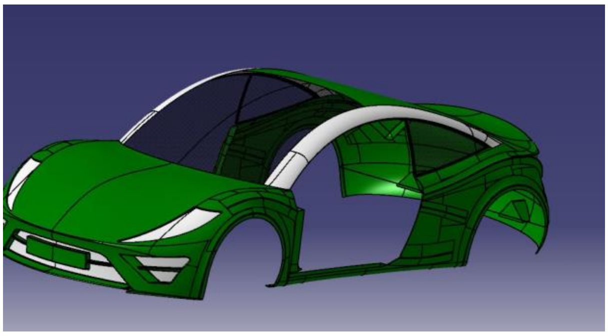

Figure 6. Surface model of the MOCK UP car

Since the hinges were following the side chassis, it was more convenient to start working on the door first. Therefore, the design of the side chassis was postponed until the door was designed. In door design, the first step was the design of door handle.

The door handle was previously designed in the form of a triangle by the external designer. In order to make it more handy, it was redesigned to a more ergonomic shape Figure 7.

Moreover, the door handle was designed by considering all the details from user side and placed in the door frame without affecting the interior door design. The overall triangle shape of the car is conserved while finalising the design.

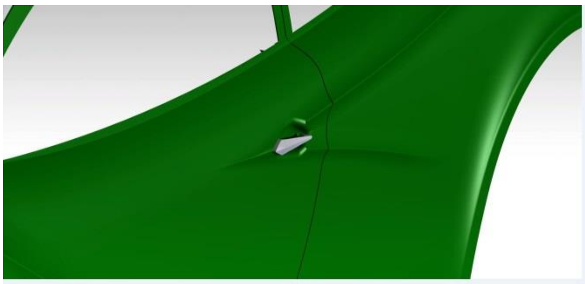

Figure 7.Designed door handle

The door jamb design was started from the door side. The actual design was as a plane, so in the first step a thickness is defined for the 3D design. The thickness of 1.25 mm which is the conventionally used metal-plate thickness in vehicles was considered at the first place. However, the thickness for 3D printing was chosen as 2.50 mm since the material used for 3D printing would be a mixture of carbon fiber and polymer. The chosen 2.50 mm thickness corresponded to combination of inner and outer metal-plate thickness of conventional vehicles. This provides a perfect match of the designed door and the car, in case the car is made of metal-plates.

As can be seen in Figure 8, in order to make the door seating surface on the inside of the vehicle, two planar forms are formed in front of the door.When the door was placed into the door jamb with a 90° angle to the car’s horizontal axis, the door would open with an angle and the door would collide with the side chassis jamb. By making the form such overlapping was avoided. Besides, since there was a risk of overlap between the formed inner surface and the side chassis jamb, their contact surfaces were angled for 5°.

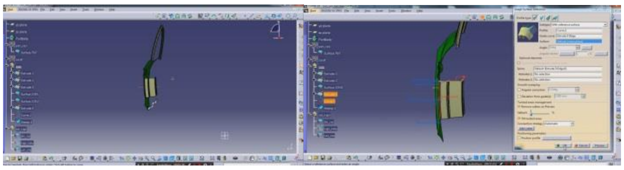

Figure 8. Door seating surface design

In order to form a jamb for the bottom of the door, another two-stage line was created. The first stage was angled for 8°. The second stage was angled for 6°. After the angling process, the surface was created.

Upon surface creation, the bottom and the two side surfaces of the door were connected in the form of a door Figure 9. Afterwards, the perfect alignment of the surfaces and the connection between them were controlled.

Additional surfaces were created by individually selecting the empty spaces between the outer metal-plate and the previously created surfaces, and the boundary lines of these empty spaces.

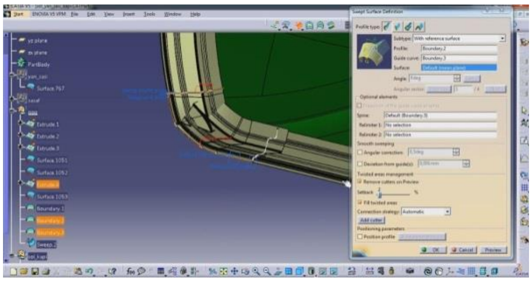

Figure 9. Joining of door side and bottomseatig surface

Drawing of the locking mechanism was made after measuring the necessary space for implementation of the lock and the door catch. The drawing was further merged in the previous drawings of the door. After that the necessary connections were drawn between this new drawing and the other surfaces.

Created door lock surfaces combined with the door frame surface. The gaps appearing between the two surfaces were further connected with the frame to create a suitable surface Figure 10.

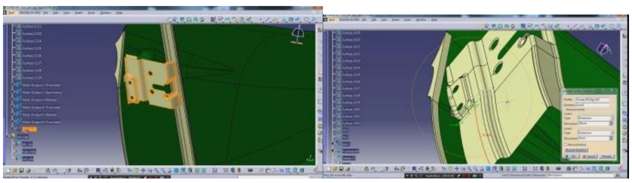

Figure 10. Door lock design

The surfaces on the side of door jamb and the top moulding were also completed. Moreover, door hinges were placed accordingly. Considering the door's weight and the corresponding load analyses it was decided to use two hinges. In order to prevent

overlaping of the door with the glovebox, the upper left corner of the door was slightly curved. Since the door would be manufactured by using a 3D printer, pieces inside the door such as roll bars were not designed and thus the inner door case was designed as a whole.
The final shape of the door was given and the surfaces of the car door, the outer metal-plate, the inner metal-plate, the top outer mould and the top inner mould were designed. The car’s door was ready for 3D manufacturing Fig.11. It was decided to manufacture the door at 1/9 scale. In order to enable the cable connections, a hole was created between the two hinges. After finalizing the shape of the door, the door jamb and the side chassis were designed.

The spacing of 3 mm that was intentionally left as door spacing on the door jambs were directly offset to the side chassis of the car. After that the gaps in between were refilled to correct the surface inaccuracies. In order to create the pocket surfaces of the hinges located on the side chassis of the car, the side chassis was designed until the hinge locations. Therefore, the side fenders were not included in design of the side chassis. It is the conventionally used method as well. The hinge connection points on the side chassis were designed and in order to ease the bonnet design, in the design the profile crossing that the hinges of the bonnet would connect was placed in front of the chassis. Subsequently, connections were made by aligning the hinge locations with the door hinges. The interfaces between the door frame and the door jamb were aligned and the overlaps were fixed.

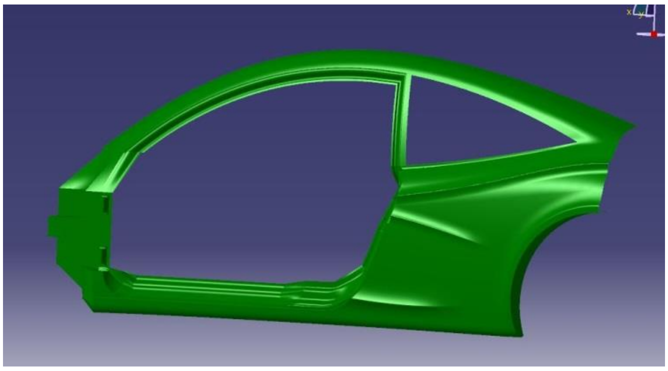

Figure 11. Comple door seating surface on the body

3. Results and Discussion

Before moving further to the manufacturing of the side chassis via 3D printer, the overlaping of the surfaces with each other was eliminated.The elimination of these overlaps has been accomplished by merging the surfaces into a single surface, and the voids that appear on the surface have been checked and completed.

After filling the gaps, the chassis was scaled down by 9/10 for production of a model. This side chassis model that was designed in Catia was further converted into a solid model. In order to prepare for manufacturing, final checks were made. In between two hinges a hole like the one in door design was placed to enable cable connections. Furthermore, a door catch was designed to enable closing of the door and locking in a proper way.

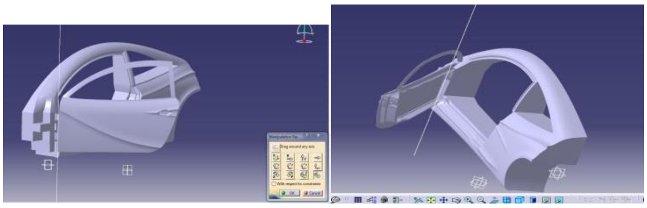

Figure 12 Test the door on the computer

The side chassis, the door and the door top mould which would be send for manufacturing, were virtually montaged and analysed in computer environment. Any overlapping that might occur during the opening and closure of the door was checked and no problems were found during the analyses which indicated that the door was ready for manufacturing Figure 12. The manufacturing process in 3D printer was planned to be in three consecutive steps; production of the whole side chassis, production of the whole door and the production of the door's top mould.

Manufacturing in 3D printer

In order to manufacture the parts in 3D, the designs were converted into STL format in Catia. The parts were produced horizontally by making the necessary adjustments in the software (Repetier host program) of the 3D printer. The printing path was calculated in the software and it was found that the production of the parts would use 27 metres of filament material and the production would take 4 hours 19 minutes and 12 seconds by following a code of 151,415 rows.

Manufacturing doors through moulding is a slow and costly process. Therefore, the recent 3D printing technology was thought to be a good alternative. Implementation of 3D printing technology for production of car parts will improve the product supply and data transfer in automotive sector as well as leading to straightforward production process.

In this study, after contacting with the producers that uses 3D printers, the cost for production of 1/1 scaled door was found to be 2500 TL. Since the cost was unaffordable in a research project the door was produced in 1/9 scale. In the first trial, owing to the sensitivity of the used 3D printer the quality of the printed piece didn't satisfy the desired quality requirements. Therefore, the surface drawings that might be problematic during the manufacturing process were revised and converted into a solid model. After making these necessary adjustments the parts were manufactured in the second trial Figure 13. and Figure 14.

Figure 13. Production of door with 3D

Figure 14. Picture of the door manufactured on 3D printer

4. Conclusion

In this study, door production of a MOKAP car that was previously manufactured by us, was conducted.

Pieces of the manufactured door such as door handle, hinge, door lock and window frame were designed. The designed pieces were montaged in virtual environment and the overall functionality of the door was tested. For manufacturing, instead of conventional manufacturing techniques, 3D printing was chosen and by this new method drawbacks of the conventional methods were avoided.

The drawings of the design were converted into STL format for manufacturing. Although the door was designed in full scale, due to the high cost of manufacturing in full scale (2500 TL) the manufacturing was conducted in smaller scale.

In the door manufactured in 3D side chassis, top mould, hinges and door lock were completely compatible with each other and with the other common pieces.

The manufacturing process revealed that it is not only possible to produce the door but also the other pieces of any type of vehicle via 3D printing. However, for useful production, the material used for 3D printing of the pieces should fulfil the strength requirements for vehicles.

If an appropriate material is determined for 3D printing of car parts, this new technique is expected to be a more practical, less time consuming and more cost-efficient when compared to the conventional manufacturing techniques.

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