REMANUFACTURING OF PARTS USING ADDITIVE PROCESSES. CASE STUDIES

GHEORGHE OANCEA[1]*, GEORGE BUICAN[1]

Abstract. The remanufacturing process is placed in the worldwide context of circular economy and is used for different consumer goods or industrial products. In the remanufacturing process the Reverse Engineering technique and Additive Manufacturing processes play an important role because of their flexibility in designing and manufacturing. In the Department of Manufacturing Engineering, "Transilvania" University of Brașov, using these technique and processes, have been developed different case studies. In this paper, are presented three case studies: how a damaged gear from a collection sewing machine is redesigned and remanufactured, using selective laser melting process, how are (re)manufactured human teeth using selective laser melting process and how a damaged gear from a fishing reel is redesigned and remanufactured using polyjet technology.

Key words: Remanufacturing, Reverse engineering, Additive manufacturing, Selective laser melting, gear, tooth.

1. INTRODUCTION

In last decade the concept of remanufacturing become more popular because it is placed in the worldwide concept of circular economy and a lot of companies from different industrial branches have been established objectives depending on what kind of remanufacturer they are and the type of product to be remanufactured, [1, 2, 3].

In the literature the remanufacturing is defined by different authors or authorities[1–4], it has to mention that it is a process used to extend the life of products or goods and is defined as a process where a particular product is taken apart, cleaned, repaired, and then reassembled to be used again, [3]. A suggestive definition for the remanufacturing "is the finest art of recycling", [4].

The use of remanufacturing offers a lot of advantages from economic and environmental points of view, saving a lot of money and resources with significant effects in reducing the CO2 emissions and pollution. Also, from social point of view it creates new skilled jobs, and finally offers warranty of products equivalent to a new one.

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Nowadays, the remanufacturing is used in different domains such as: aerospace industry, automotive industry, military industry, medicine (including machinery and equipment), entertainment industry, clothing and footwear industry, architecture and arts.

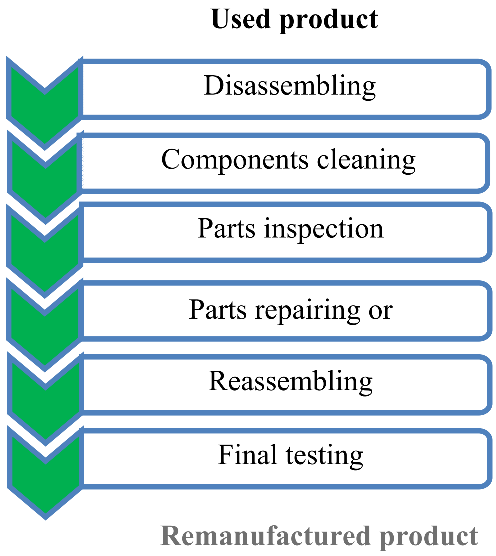


Fig. 1 – Steps used in remanufacturing of goods or industrial products [1].

To remanufacture an industrial product, usually the following six steps, Fig. 1, has to be performed [1]: disassembling the product, components cleaning, parts inspection, parts repairing or remanufacturing, reassembling and final testing the product. There are three types of manufacturing processes which can be involved in remanufacturing: additive, subtractive and material redistribution processes. Considering the performance and advantages of additive manufacturing technologies it could be the first choice to be used in remanufacturing processes. Together with Reverse Engineering technique it plays a key role in any system used in remanufacturing process.

In this paper are presented three case studies from the area of parts remanufacturing, developed at Department of Manufacturing Engineering from “Transilvania” University of Braşov. Two of them are gears from mechanical systems and the other refers to manufacturing of real teeth.

2. REMANUFACTURING OF A GEAR FROM A SEWING MACHINE

A gear from a collection sewing machine was partially destroyed in the area of teeth (Fig. 2). Because no documentation is available for this sewing machine, stages for remanufacturing the part have to be followed.

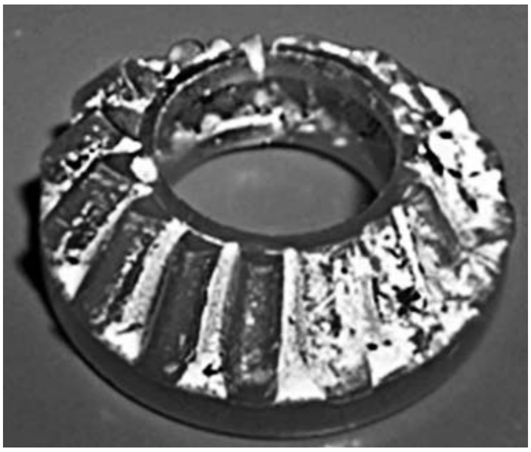


Fig. 2 – Damaged gear [5].

After the first two stages before mentioned, in case of remanufacturing of this part using Selective Laser Melting (SLM) process for which no data are available, the following sub-stages are performed, [5, 6]:

• scanning of the damaged gear using a 3D scanner and obtaining the point cloud;

• eliminating the noise point from the point cloud;

• converting the resulting point cloud into surfaces;

• redesigning the part, obtaining the CAD model and saving it in STL file;

• based on CAD model the AM files are generated (adding the construction supports to the digital model and obtaining the sections for the additive manufacturing machine);

• remanufacturing of the part;

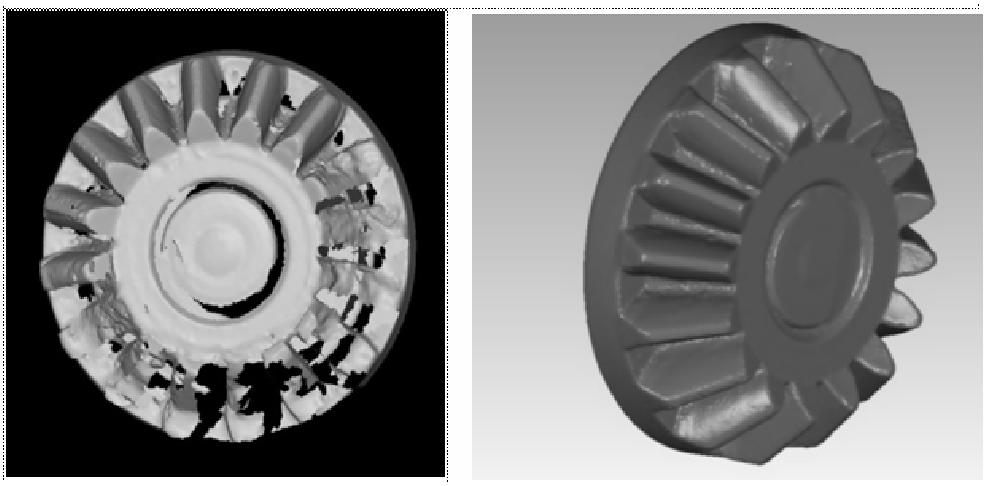
• eliminating the supports;

• sandblasting the new part;

• measuring and comparing the part with the original one (point cloud).

For the digitization of the parts and measuring process a Comet 3D scanner is used. It is an optical scanner with blue light and offers the possibility to digitize objects with 8 μm precision. Because the maximum diameter of the gear is 25 mm it is used the scanning volume of 100 mm^3. To have one of the best precision the part was scanned 30 times and the data were combined to obtain the final point cloud in precisely manner, [5].

Based on the point cloud is generated a mesh representation for surfaces, Fig. 3a), and then using specific CAD tools for generating the teeth, the final model of the part is obtained, Fig. 3b). Once the CAD model is ready, it is exported as STL file to the Autofab software which is connected to the SLM250 HL machine to positioning the part on the building platform at an inclination angle of 45 degrees, to generate and attach the construction supports, Fig. 4, and to specify the working parameters (layer thickness – 30 μm, laser power – 100 W, scanning speed –150 mm/s) [5]. In the manufacturing strategy the laser beam path is like a chess table, with a rotation of 45 degrees after each layer. The total number of layers is 737 and the material used for gear is stainless steel 316L powder [5].



a) before redesign b) after redesign

Fig. 3 – CAD model of gear [5].

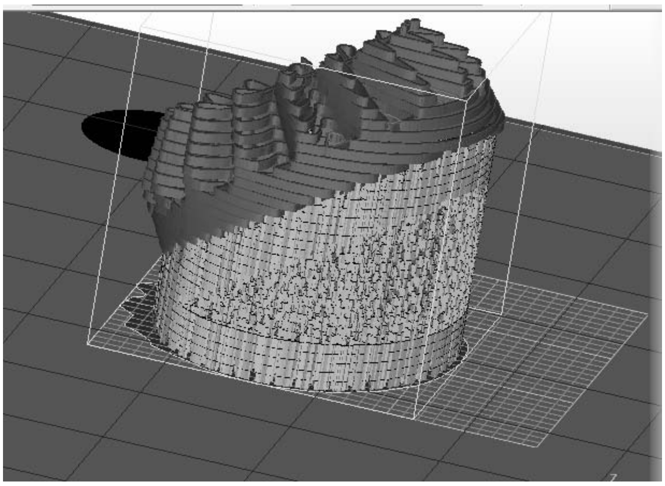
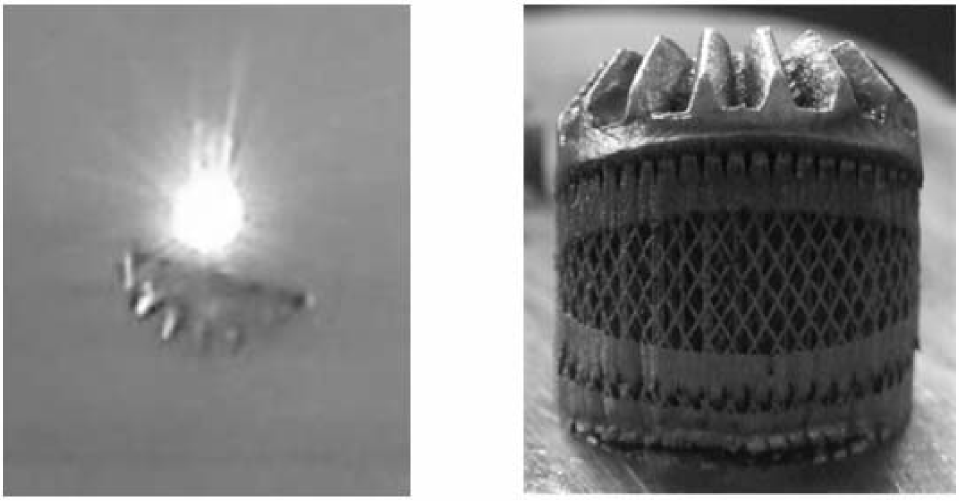


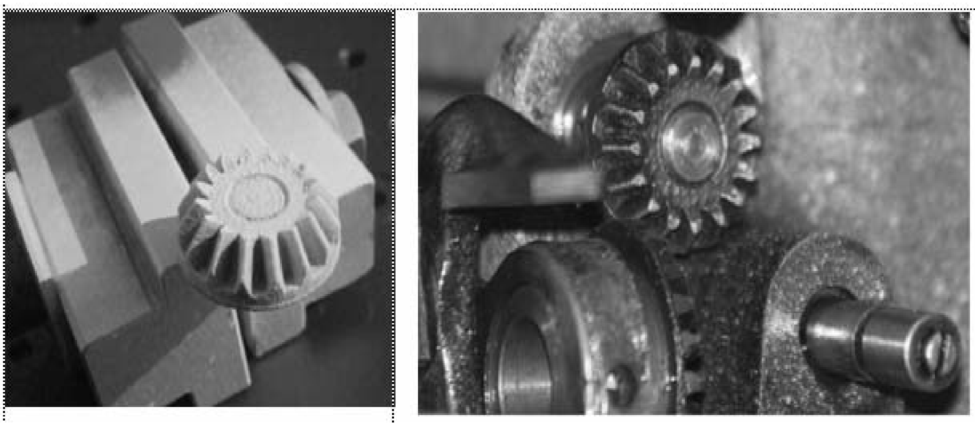
Fig. 4 – Part position on the building platform [5].

All the calculations that led to the generation of the 2D sections, for each manufacturing layer are saved and later loaded into the computer of SLM 250 HL machine, in order to manufacture the gear (Fig. 5a).



a) melting the powder b) after manufacturing process

Fig. 5 – Manufactured part [5].



a) measuring process b) reassembled in sewing machine

Fig. 6 – Final remanufactured gear [5, 6].

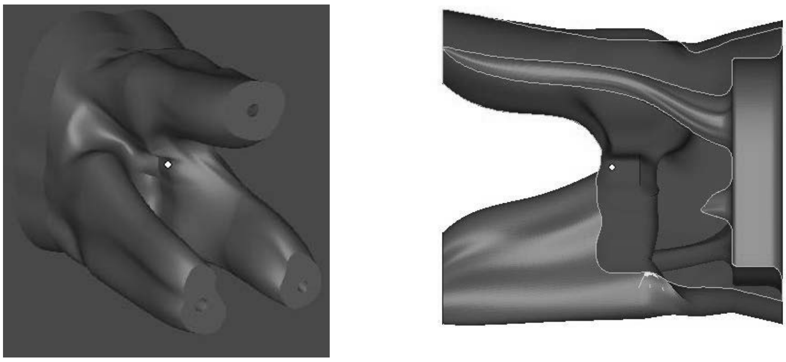
After the manufacturing process (Fig. 5b), the supports are eliminated, the part is sandblasted and finally digitised/measured (Fig. 6a). This new measurement is compared to the initial digital model and the deviations of the part are compared to the existing model. The result of this comparison is an expected one and the values are bigger then layer thickness.

To obtain the hole for the shaft, the gear was drilled and then assembled in the sewing machine. After assembling, the machine was tested, and it has been working in a properly manner (Fig. 6b).

3. MANUFACTURING OF HUMAN TEETH

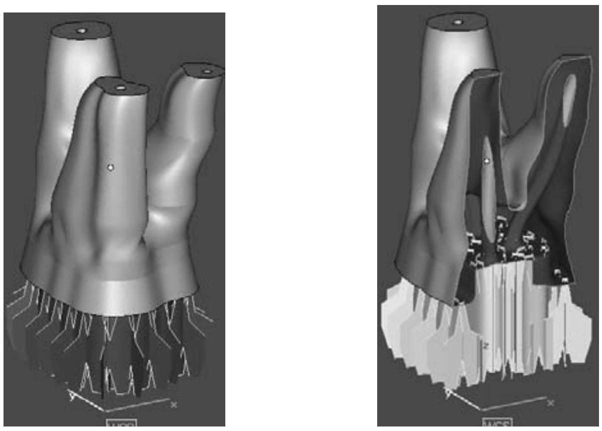
In practice, the fatigue resistance of endodontic instruments are determined in vitro using canals which are closer to the real teeth canals [5, 7]. In fact, it is necessary to (re)manufacture teeth which have to be like real ones including root canals, and it is well-known that to determine the fatigue are necessary many cycles. In this case, is better to be manufactured from a material with good properties at least in the area of canals, then real teeth.

Based on these, in the Department of Manufacturing Engineering, “Transilvania” University of Braşov, were manufactured two teeth (maxillary first premolar and mandibular first molar) from stainless steel 316L powder, using the selective laser melting process available on the SLM 250 HL machine [8].



a) isometric view b) section

Fig. 7 – CAD model of mandibular first molar [5].



a) isometric view b) section

Fig. 8 – Mandibular first molar positioned on building platform [5].

In the first stage, the tooth was digitized using two radiographies a buccolingual and a mesiodistal and then the 3D model of the tooth is obtained in a CAD software system (Fig. 7.

To manufacture the maxillary first premolar using SLM process, which has complex surfaces, a challenge is to find the best position on the building platform.

Many parameters are influenced the position of the tooth on building platform. Three solutions were considered [5]: the premolar is positioned parallel with the building platform, premolar root is positioned parallel with the building platform and premolar crown is positioned parallel with the building platform.

Based on a complex analyses [5], the best position is premolar crown is positioned parallel with the building platform (Fig. 8). In this position, there are no supports in the canals.

Once the positioning solution for the part is established, 3D model are imported into Autofab in order to generate the manufacturing strategy, including working parameters.

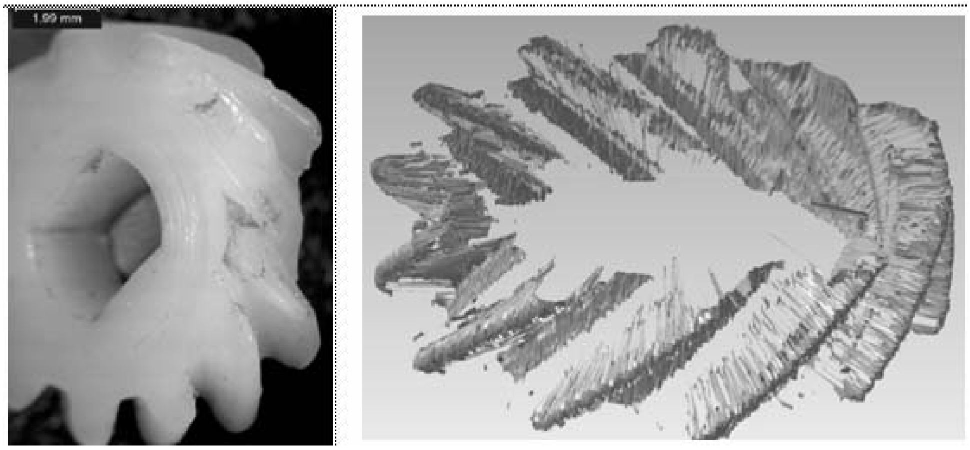
In this case, the strategy "Hull (thin_walled_parts) – Stripes with skin", with a layer of 30 μm is used. This strategy was used because the tooth canals can be compared to a part that has thin walls.

The working parameters depend on the area of the part which has to be obtained. The scanning speed has values between 550 mm/s and 750 mm/s, and laser power 100–175 W. Finally, the tooth was fabricated using the crown parallel with the building table (Fig. 8).

Fig. 9 – Manufactured mandibular first molar using SLM process.

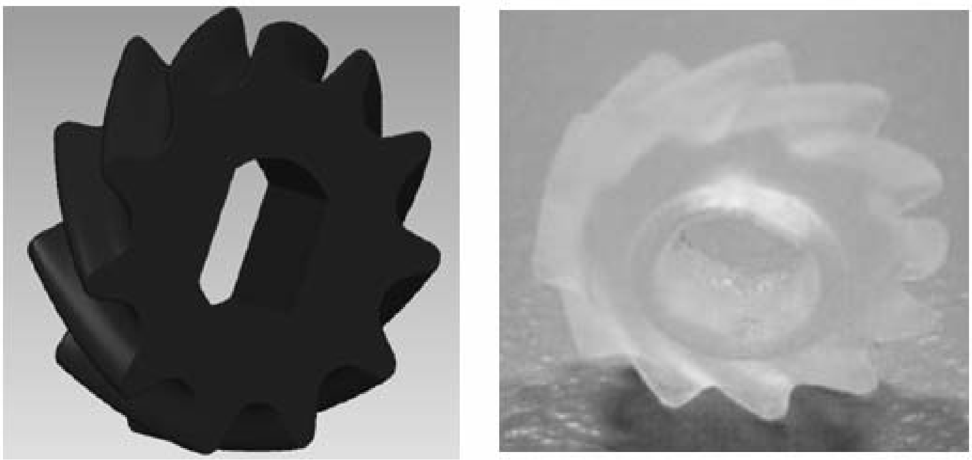
4. REMANUFACTURING OF A DAMAGED GEAR FROM A FISHING REEL

A gear from fishing reel was destroyed (Fig. 10a), and the target was to remanufacture it. Because of the size of the diameter (about 14 mm) and the original part material was chosen the additive process on available the Objet Eden 350 machine. The material used for the new gear is Objet FullCure 720.



a) damaged gear b) point cloud

Fig. 10 – Damaged gear and associated point cloud [9, 10].



a) redesigned gear b) remanufactured gear

Fig. 11 – Redesigned and remanufactured gear [9, 10].

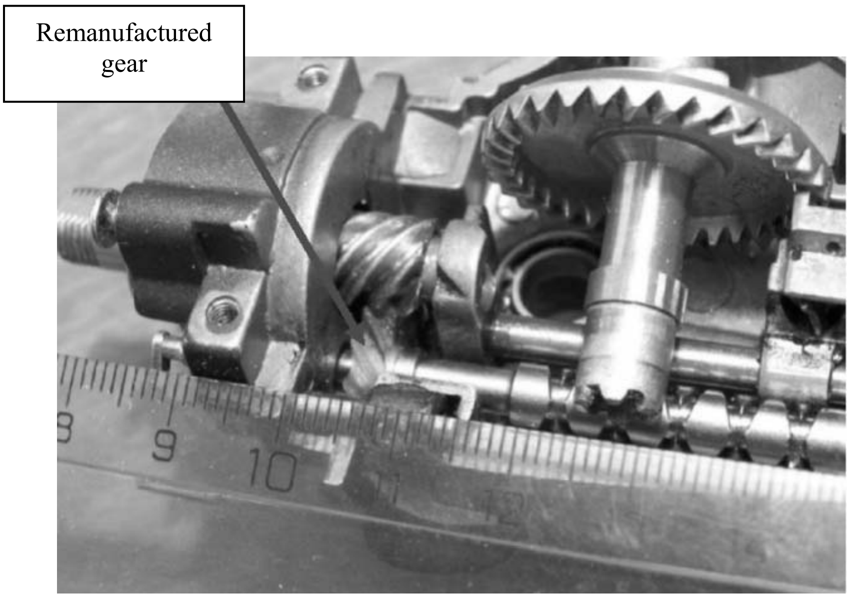


Fig. 12 – Remanufactured gear assembled in fishing reel [9, 10].

Because no data about the part is available, in the redesign process is necessary to be used the Reverse Engineering technique. The part was scanned using LPX-1200 scanner and the obtained point cloud was processed using specific software, Fig. 10b), and exported it, in a TXT file. The file is used by a software tool developed in Visual Basic [11] for extracting data about the points for the main sections and the axis of the part. The sections are used, in the first time to redesign a tooth and then for the whole gear redesigning process, in a CAD software system, Fig. 11a). After the manufacturing on OBJET EDEN 350 with a layer thickness of 16 µm, the new gear was successfully mounted (Fig. 11b, and Fig. 12), and the fishing reel which is properly working.

5. CONCLUSION

The remanufacturing is a useful concept implemented in different companies in many cases according to the strategy of circular economy. In the society, it has been offering a lot of advantages especially from environmental points of view reducing the CO2 emissions and pollution and also from economic point of view, saving a lot of money and resources.

In the Department of Manufacturing Engineering, "Transilvania" University of Brașov have been developed case study in the field of remanufacturing of products. Three of them were presented in this paper: redesigning and remanufacturing using a SLM 250 HL machine, of a damaged gear from a collection sewing machine, (re)manufacturing of human teeth on the same AM machine, and redesigning and remanufacturing of a damaged gear from a fishing reel, using OBJET EDEN 350 AM machine.

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