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Management of the reverse engineering process in the plastics industry

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Abstract

The management of the Reverse Engineering (RE) process for polymeric parts is a relatively complicated one. Composition on this market segment is tough due to the fact that approximately 85% of the machinery and equipment industry has migrated from the steel parts industry to the plastics industry over the last 30 years. This is why not only old mechanical parts and assemblies are subject to the RE process, but also new parts / products that competition is trying to reproduce. Therefore, the goal is to achieve the RE process of superior quality at the lowest cost and in the shortest possible time (if possible in a fully automated system). The RE process management involves selecting the hardware, selecting the RE software, and adopting the proper technique for obtaining surfaces (or solids, as the case may be). All these steps depend on the quality of the product to be achieved and the speed at which the results are obtained. The paper presents a concrete case of RE, solved by a certain process, but also other possible variants, as well as their impact on the quality of the final product (precision / price / effort).

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Keywords: reverse engineering; management; CAD; 3D scanning device.

1. Introduction

For the plastics industry the mold is the most important tool in the manufacturing process. Molds are produced in two different circumstances: (i) when a new product is being put into production, and (ii) when replacing an old, used die. In this first case it is assumed that there is a well-documented technical documentation, with all the data necessary for the integration of a new product in the manufacturing, and the need for reverse engineering is reduced

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or even null (Marguta, 2015). . In the second case, where replacing a used old mold is required, the situation is more complex. On the whole, there may be all the necessary documentation, but small corrections of the active elements are required, or the technical documentation of the re-fabrication of the mold does not exist at all. In the latter cases, the need for reverse engineering is crucial for a company that wants to produce parts as quickly and efficiently as possible.

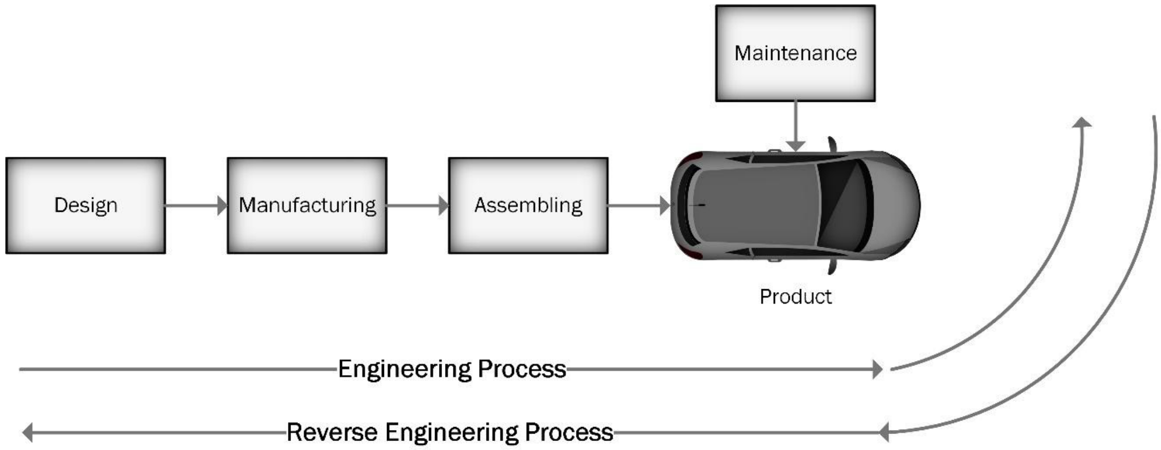


Fig. 1. Reverse Engineering Process.

The engineering process of RE is a wider concept, as shown in Figure 1. It refers to all stages: design, manufacturing, assembling and maintenance. By this definition RE refers to product improvement, improved manufacturing technology (Bingöl, Atashafrazeh, 2015), cost reduction, and product quality improvement in general.

In the present paper, we refer to the RE process for mechanical components, as shown in Figure 2. There are three major stages in the RE process. The primary is the data collection and analysis. The precision with which this stage is achieved has a major influence on the whole process. Reverse Engineering hardware can be with (i) contact methods; (ii) noncontact methods; (iii) destructive method.

2. RE – equipment, software applications and technologies

The most common contact methods data acquisition equipment is: articulated arms and CMM machines. Advantages for contact methods are: high accuracy, low cost (for articulated arms, but high cost for CMM), possibility to measure deep holes, and insensitivity to color or surface quality of the object. Regarding the disadvantages of this method, we mention: Very low data acquisition speed (manual acquisition), and failure to scan soft rubber parts or lack of precision when scanning pieces of plastic, which deform.

Equipment based on noncontact methods is the most widespread in the RE process. There are various classifications of noncontact equipment. A very useful classification we encountered in (Raja, Fernandes 2008). paper. Non-contact methods may be Reflective or Transmissive (i.e., CT, MRI). Reflective methods can be of two kinds: Non-Optical and Optical. Examples of nonoptical methods are microwave radar or sonar. Optical methods are also two-way: passive and active. The advantages of this non-contact method are: it is suitable for automation; average accuracy; the possibility of color detection and texture of the surface; the ability to scan complex objects with many geometric details, impossible to scan with contact methods. The main drawbacks of the noncontact method are: there are problems with the reflection of light on the surfaces to be scanned. This is solved by applying a powder spray on the respective surfaces, which reduces scanning accuracy. Also, this method is with a lower accuracy class than contact scanning on CMM machines.

Destructive RE methods can be considered hundreds of years old. They are based on the removal of the layers of material from the piece and the subsequent measurement of the part by contacting or noncontacting methods. Most often, the 2D milling process is used, which removes successive layers of material from the workpiece. After each removed layer, the machine can scan the remaining part profile. As you can see, the process is somewhat rudimentary, relatively imprecise, lasting and costly (Raja, Fernandes 2008).

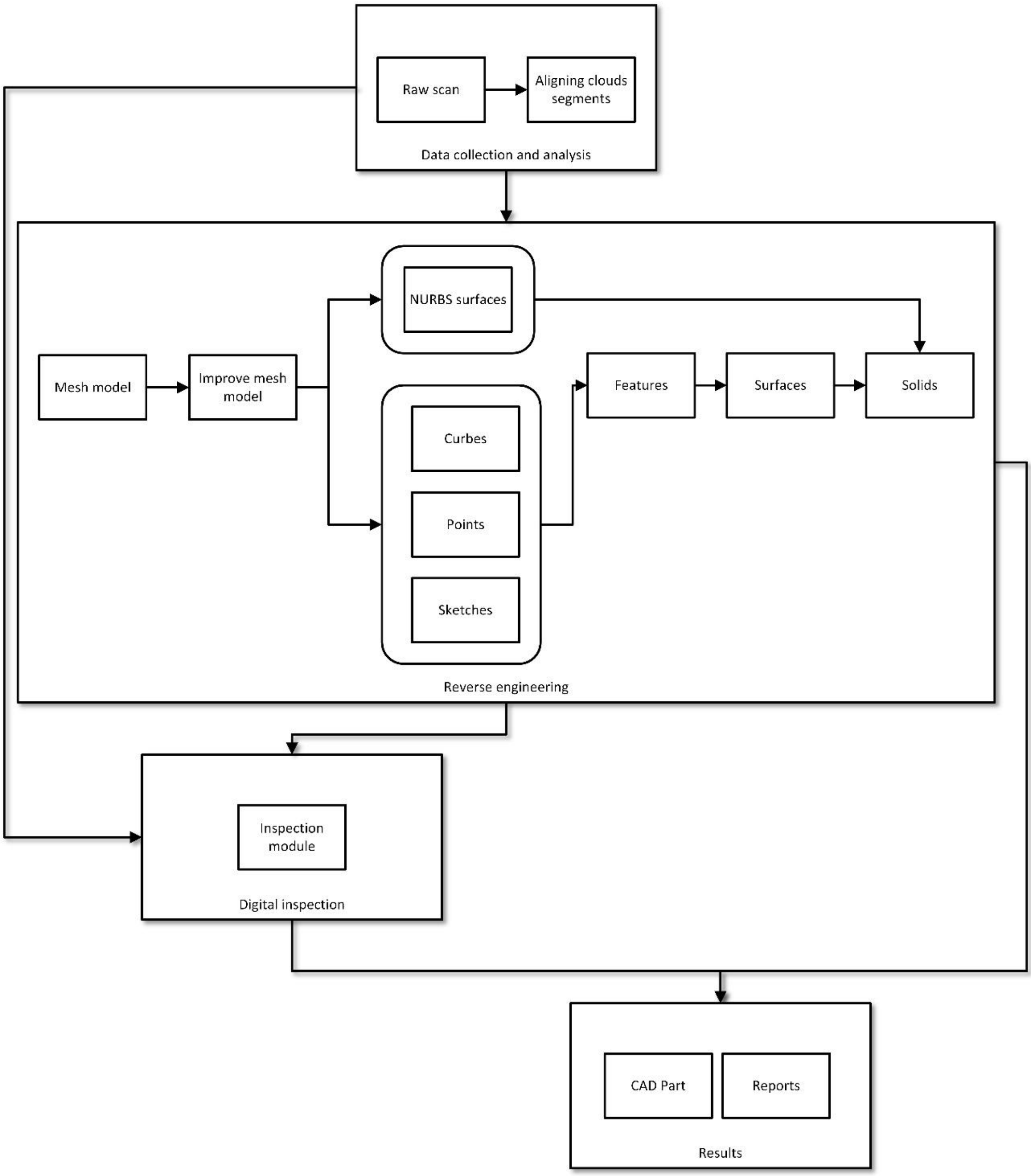


Fig. 2. RE process for mechanical components.

For the plastics industry, the RE process relies heavily on contact-type and noncontact Reflective / Optical / Active equipment (Puiu, Vaideanu, Bacaita, Agop 2017). With regard to Figure 2, what has been discussed above only refers to the first box, data collection and analysis. The RE process, as seen in Figure 2, is predominantly in the second box, which involves the intensive use of dedicated applications. RE software applications are based on CAD modules, which have the ability to manipulate point clouds, mesh objects and hybrid modeling.

The authors used two top applications in this area: PolyWorks® and 3DS Geomagic®. These two software applications represent the cutting edge of 3D metrology and RE process, applications that maximize productivity, quality and profitability when integrating 3D measurement technologies into an industrial manufacturing process.

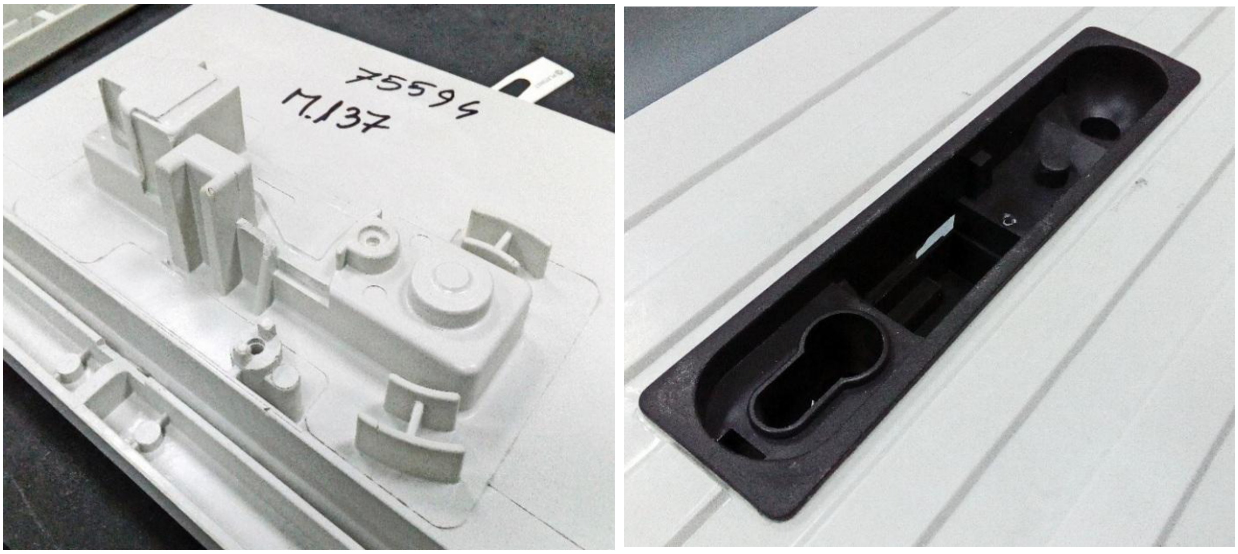
Polygonal modeling. The first stage in the RE process consists in transforming point clouds into a polygon mesh. The mesh object is obtained by sophisticated techniques, which involve point smoothing and cloud sampling based on curvature. The object thus obtained becomes as close as possible to the real object. In some cases, the RE process stops here because from the polygon mesh the part can be obtained using CNC technologies or 3D printers. However, for plastic parts where the mold is intended to produce the piece, the precision of the polygon mesh is not sufficient (Polyworks, 2017).

Surface modeling. Unlike a CAD application, in RE software there is 3D modeling tools for polygonal models. The simplest, fastest and intuitive method that converts the polygon model into 3D surfaces is the ability to fit a network of NURBS surfaces over a polygonal model built from digitized point clouds. These NURBS patches (previously obtained) are used to control the fitting to continuously join and obtain a complete surface – G2, G1, or G0 continuity control over NURBS patch boundaries (Polyworks, 2017).

Solid modeling. The RE process using a dedicated solid model application consists in extracting features from the polygon or point cloud model. Sometimes, it not even need point cloud, only a few points are drawn on the surface of the piece and the feature is built like in any CAD application: a workplane is selected, then lines, arcs, and other geometric elements are created, (sketches). The parametric sketches are then transferred to the solid CAD modeler by using add-ins (for SolidWorks, CATIA, NX, Creo etc). The solid thus obtained is error free, all exterior surfaces are closed, and can be very well machined on CNC machines (Polyworks, 2017).

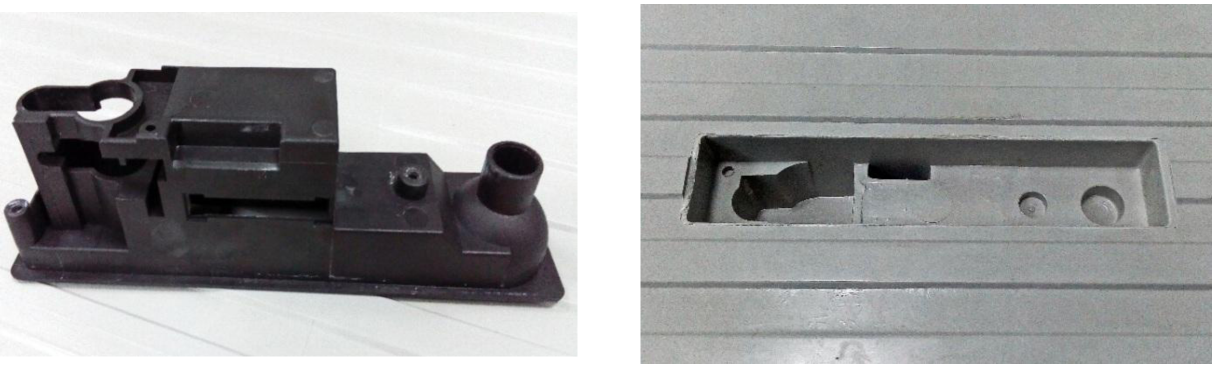
3. Study of an RE process example

In the example below, the task was to perform the RE process for the door lock hole of an electric cabinet. The geometry of the piece can be seen very well in Figures 3 and 4. The mold making this product is over 30 years old. The company that makes the plastic parts still has a market for this product, but due to the wear of the mold, the manufactured parts have a large number of scrap.



a) b)

Fig. 3. The door lock hole of an electric cabinet. a) the lower part geometry; b) the upper part assembled with the intermediate piece.



a) b)

Fig. 4. The door lock hole of an electric cabinet. a) the intermediate piece; b) the upper part geometry.

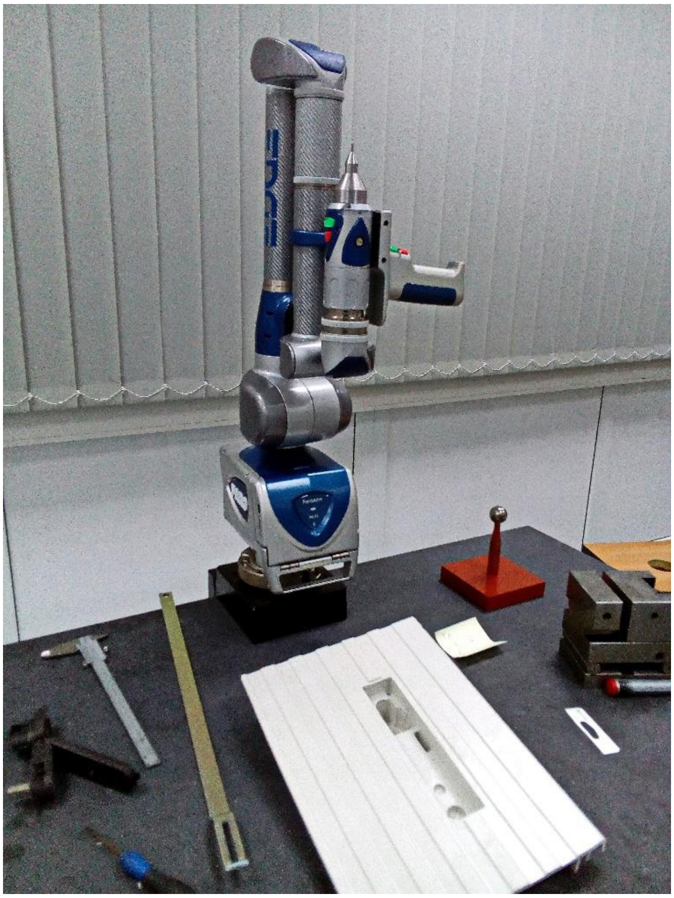


Fig. 5. The FaroArm Edge® polyarticulate arm, along with the laboratory stand.

The company had to hire additional workers to fix the defects manually because it was impossible to order a replacement mold. The company that produced the mold no longer exists, and obviously there is no documentation for the active elements of the mold. In this case, the only solution was the use of a RE system. In our laboratory we have the following alternatives:

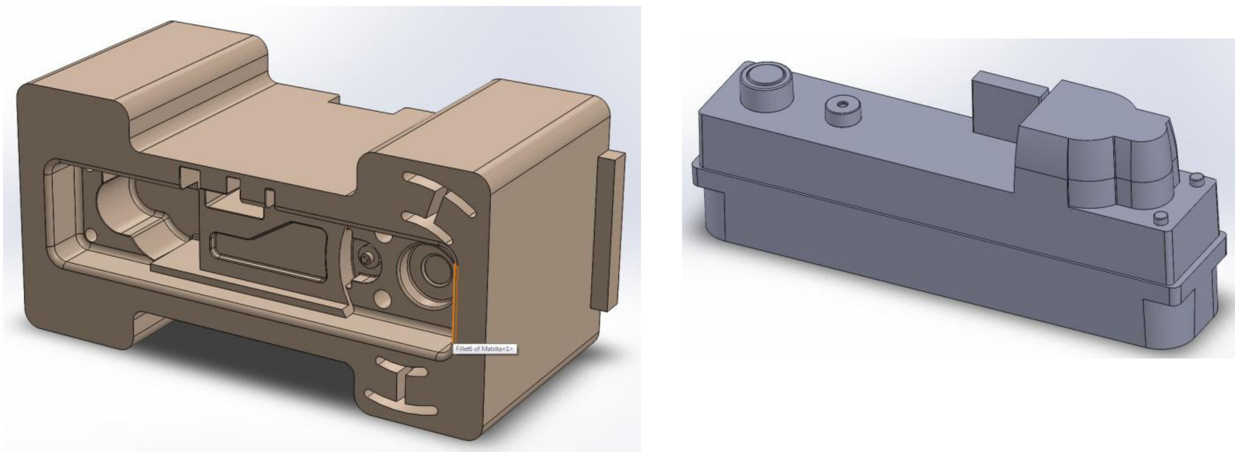
- The use of the FaroArm Edge® polyarticulate arm, together with a RE soft, i.e. PolyWorks® or Geomagic® .
- Using a Creaform HandySCAN® 300, a 3D scanner, together with a RE soft, i.e. PolyWorks® or Geomagic® .

The FaroArm Edge® polyarticulate arm, along with the laboratory stand, is shown in Figure 5. The active elements of the worn mold are shown in Figure 6. The CAD parts obtained by the RE process is shown in Figure 7.

b)

a)

Fig. 6. The active elements of the worn mold.



b)

a)

Fig. 7. The CAD parts obtained by the RE process.

For CAD, the SolidWorks application was chosen. As mentioned, the RE process was accomplished in two ways: (i) complete scanning of parts and obtaining a cloud of points with Creaform scanner, and (ii) 3D measurement / modeling with FaroArm.

4. RE process selection

We must point out that the authors have no link with any particular vendor, so this paragraph does not attempt to influence potential customers.

To compare the results of the RE process for the previously presented parts, we have prepared the matrix of desired system attributes and their overall importance. In the literature, it is customary that the importance of a particular attribute takes values between 1 and 5, where 1 means no importance and 5 means extremely important.

Table 1 presents the weighting grid for RE processes. In the RE 1 process, the 3D scanner was used, and in the RE 2 process the polyarticulate arm was used. The RE 1 process used RE one software from the above, the RE 2 process used the other software. For copyright reasons in Table 1, we did not specify the exact name of the software. Table 1 should be understood as a management tool for selecting the RE process and not as a competition between software and hardware manufacturers for RE applications (Raja, Fernandes 2008).

Table 1. A rank weighting grid for RE processes.

Specific Feature			RE process 1 (surfaces)		RE process 2 (solids)	
		Importance of feature	Score	Weighted score	Score	Weighted score
Hardware	Accuracy	5	3	15	4	20
	Resolution	5	3	15	5	25
	Measured volume	3	5	15	3	9
	Operator ability	3	5	15	2	6
	Time of data collection	3	5	15	1	3
	Cost and maintenance	2	1	2	5	10
Software	Inspection module	4	3	12	5	20
	CAD module	5	2	10	4	20
	RE module	5	4	20	4	20
	Learning curve	3	2	6	5	15
	Engineer skills	3	3	9	3	9
	Time of RE	3	4	12	2	6
	Cost and maintenance	2	2	4	4	8
Total				150		171

Also, Table 1 is relevant only for the specific case presented in paragraph 3. For other types of parts, it is very likely that the configuration of the table will be quite different. It is noted that there are not too large differences between the RE 1 process and the RE 2 process. That is, there are no big differences between 3D scanning and polyarticulate arm measurement. However, in this case, polyarticulated arm measurement and direct solid construction in SolidWorks is more beneficial than obtaining NURBS surfaces (Geomagic, 2017).

Due to the fact that the scores are so tight, it may be that a company prefers an RE process instead of another, precisely because it has more skills in that area.

5. Conclusion

The paper presented the RE process for polymeric material parts. A classification has been made of the possibilities to achieve this process, from hardware, software and current RE technologies. Also, the paper tries to help managers in the polymer materials industry make a decision when they are using a RE process. The correct (optimal) selection of the RE process is very difficult.

The difficulty lies in the fact that there are a multitude of parameters to be correlated, and they are in a continuous movement. In the paper, two hardware and two RE software applications were selected to conduct experiments.

It has been assumed that there is the same level of competence in using the RE system in one case and the other. Note that the results obtained are suitable for a particular type of parts, and that the level of generalization is somewhat reduced.

In the future, our desire is to deepen research and increase the level of confidence of results through a more in-depth comparative analysis for both hardware and software applications.

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