Redesigning Plastic Products

CRISTIAN COSMA*, **DANIEL ROTAR, CRISTIAN CIOANA, IANCU SERBAN**
University Politehnica of Timisoara, 1 Mihai Viteazul Blv., 300222, Timisoara, Romania

The present paper aims to present a method for redesigning plastic products using the Reverse Engineering technique. The originality of this paper stems from its integration of modern scanning techniques and reverse engineering with traditional manufacturing techniques. The paper presents a case study about the redesign of an existing product for which no technical documentation is available, using three distinct phases: reverse engineering, modeling analysis and redesign, manufacturing and testing..

Keywords: redesign, reverse engineering, mould, polymeric material

Concepts relating to Reverse Engineering and rapid prototyping techniques

In recent years, the continuous improvement in products and their increased performance, combined with a reduction in the manufacturing cycle and costs have popularised Reverse Engineering as well as other techniques.

In particular, for processes involving the injection manufacture of plastic products and their related tools (moulds), it has become increasingly necessary to optimise the conception phase and minimise the manufacturing time by aligning the concept with the rapid development of a product.

Existing papers published on the injection process refer to injection process parameters for obtaining a product [1-3], finite element simulations [4-5], aspects relating to mould manufacture [7], and modern techniques for manufacturing polymeric products [8].

Unlike these, the present paper is concerned with obtaining a new product starting from an existing one (for which no technical documentation is available), integrating both modern and traditional design and manufacturing techniques, etc.

The main concepts relating to product redesign using the techniques of reverse engineering, CNC and injection moulding of the new product are presented below. Reverse Engineering is a process of redesigning an existing product to improve and broaden its function, add quality and increase its useful life. An additional goal is to reduce manufacturing costs of the new product, making it competitive in the market place.

Reverse Engineering is usually undertaken in order to designs / redesign a product for better manufacturability, or to take advantage of modern equipment and manufacturing practices.

Reverse Engineering initiates the redesign process, wherein a product is predicted, observed, disassembled, analyzed, tested, "experienced", and documented in terms of its functionality, form, physical principles, manufacturability and possibilities of assembly.

Figure 1 shows the general composition of our reverse engineering and redesign methodology.

Three distinct phases embody the methodology:
-reverse engineering technique;
-modelling analysis, and redesign;
-manufacturing and testing.

The first step (reverse engineering) is to experience the actual product in both function and form. This phase includes the full disassembly of the product, scanning the entire possible components and obtained the geometric models of the parts.

The second step is to redesign the product based on the results of the reverse engineering and modelling phases. The methodology takes into account both ergonomic and functional aspects.

The third phase of the methodology consists of obtaining the mould cavities for the new product, as well as injecting and testing the product. Since applications regarding the reverse engineering technique have been presented before, we would like to show certain aspects related to the virtual (digital) prototyping part VP. Studies have shown that virtual (digital) prototyping can be used to identify all problems before production is started.

Using virtual prototypes, especially during the early development/design stages for mechanical systems, enables efficient cost decisions to be made. Costly production of physical prototypes is generally impractical.

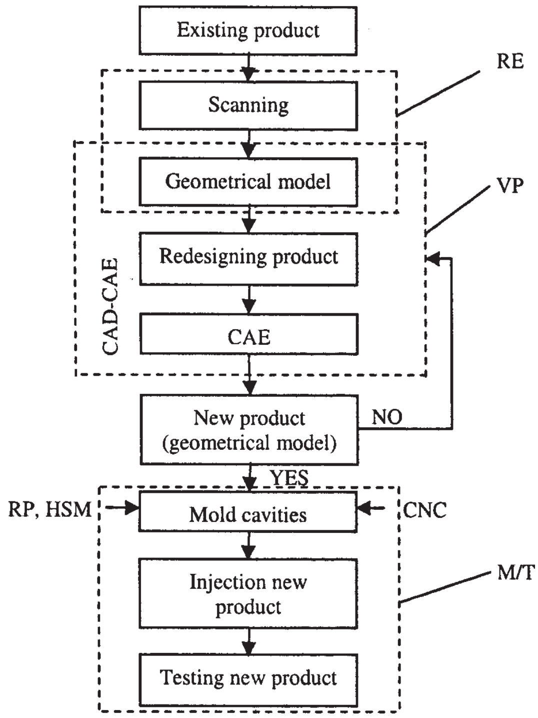

Fig. 1 Methodology proposed
RE – Reverse Engineering, VP – Virtual Prototyping, M/T – Manufacturing/Testing, RP – Rapid prototyping, HSM – High Speed Machining, CAD – Computer Aided Design, CAE – Computer Aided Engineering, CNC – Computer Numerical Control

* email:ccosma@eng.upt.ro

Since the geometry of the virtual prototype is highly accurate, companies can check for any interference that could occur during prototype assembly and problems that could change the sequence between the development and the production phases; companies can also simulate the product during the early stages of the development cycle to prevent any problems during the testing or manufacturing phase.

Case study for a plastic part

The product chosen to be redesigned is a barrier remote control. The factors that prompted this product redesign were both functional (rapid damage to the remote control buttons – fig. 2) and ergonomic (the aim was to use a smaller electronic circuit board and adapt a new casing).

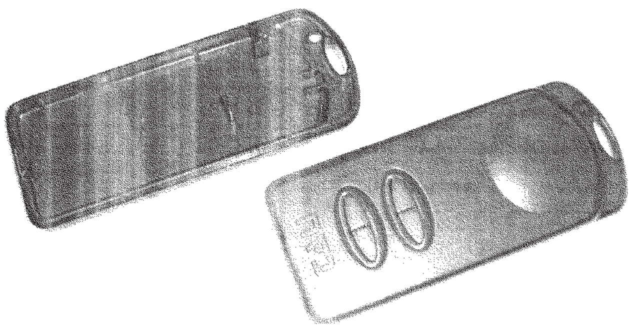

Fig. 2. Initial product

Stage RE – Scanning the plastic parts

A Modela MDX 15 scanning machine was used to obtain geometric models of the plastic components. We must specify that, due to the very small space between the buttons and the rest of the casing, it was necessary to remove them (to prevent any damage to the scanning machine needle).

The entities obtained by scanning were processed using specialised RE software. The geometric models thus produced were then transformed from an STL file into a solid to allow processing at a later stage (redesign). Finally, geometric models of the initial product were obtained (fig.3).

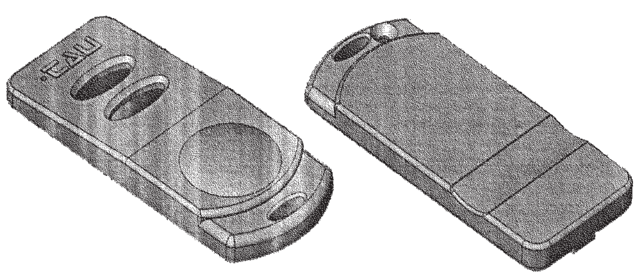

Fig. 3. Geometric models of the initial product

Stage VP – Redesigning the plastic parts

Redesigning the lower casing involved the following stages:

-removing the retaining elements for the control board and ribs;

-redesigning the retaining elements for the new control board to be installed in the new casing;

-deepening the base of the casing; the control board is equipped with a battery with a larger capacity (and thus larger dimensions);

-creating an element for centring and retaining the control board.

Redesigning the upper casing involved the following stages:

-removing the external lettering;

-the next step consisted of creating a 3D model of the buttons so they could be centred with the control board. Since the new buttons are made of a rubberised material, it was not possible to scan them using a needle scanning machine (the needle got stuck in the material); laser scanning was also attempted but the laser beam went through the transparent material. The solution was to use a paper template made to a 1:1 scale for calibration of the exact position of the buttons;

-inserting slanted cavities to facilitate their activation (provide easier access), thickening the wall beneath the buttons to retain contact with the switches located on the control board, creating pins for fixing the buttons onto this surface.

Finally, the assembly is checked for any assembling problems (fig. 4).

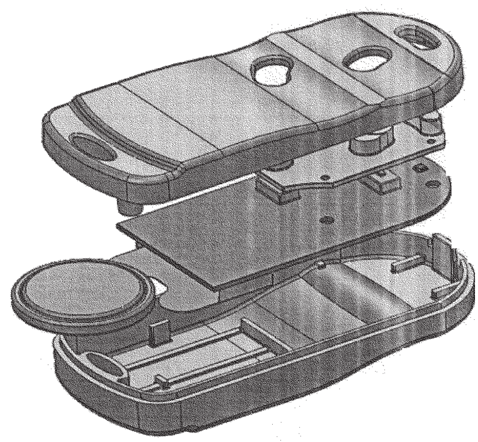

Fig. 4. Exploded view of the new product

In addition, flow simulations were carried out aiming at predicting defects that can occur following the injection process. This study was done using PP with excellent surface appearance, strength, stiffness, toughness, and chemical resistance.

In this stage we tested the fill of the plastic parts searching for defects which can influence the aesthetics and resistance, but also to acquire the cavity fill time (fig. 5).

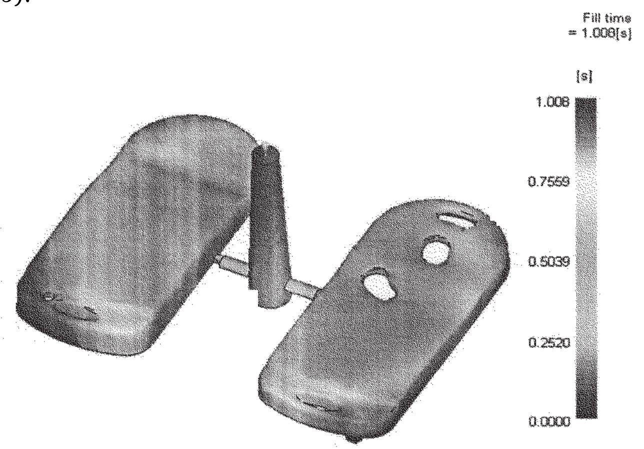

Fig. 5. Simulation of cavity fill time

One of the defects we looked for was the formation of air bubbles, which appear when the melt traps and compresses an air bubble between two or more converging flow fronts, or between the flow front and the cavity wall.

The result are empty holes on the surface of the part, but air bubbles can cause burn marks if the air is under enough pressure, or short shot effect (fig. 6).

Fig. 6. Air Bubbles

To eliminate or reduce the number of air bubbles, caused by poor venting, we can move the injection locations so that the air traps form in easy-to-vent areas such as at the parting plane.

Weld lines appear at convergence as two flow fronts meet. They can cause structural problems and can also make the part visually unacceptable. Weld line strength is influenced by the temperature at which the weld line is formed and the pressure exerted on the weld until the part freezes (fig. 7).

Fig. 7. Weld lines

To improve the quality of weld lines we can increase the melt temperature, injection speed, or packing pressure. This will allow the flow fronts to weld to each other better, increase the diameters of gates and runners.

Molded part surface quality largely depends on the injection parameters (pressure and temperature) and the cavity surface quality. The Quality prediction result (fig. 8) estimates the expected quality of the part's appearance and its mechanical properties.

Stage M/T – Manufacturing and testing the product

This stage comprises several phases that require knowledge of the field of design and mechanical manufacturing (machine tools, tools, devices), as well as familiarity with concepts relating to the injection process (polymer materials, injection parameters).

Obtaining the geometric model of the mould cavities

The geometric model of the mould cavities can be obtained using any CAD design software equipped with this type of module.

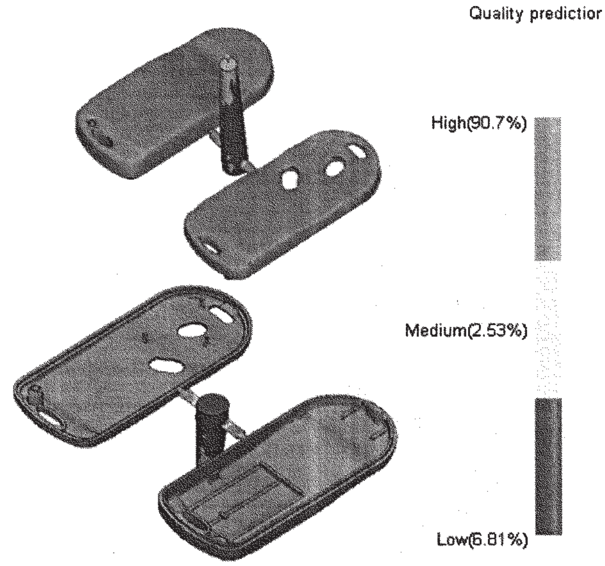

Fig. 8. Quality prediction

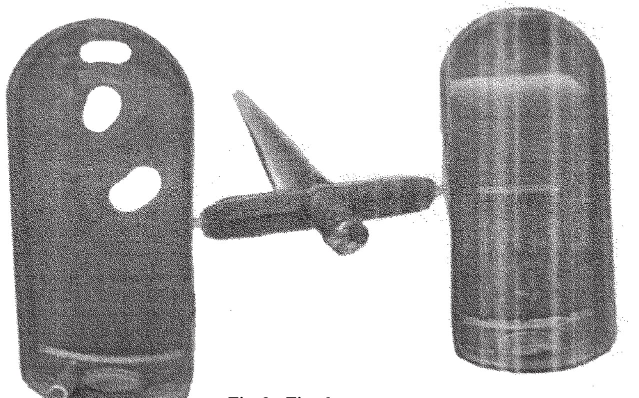

Fig.9. Final parts

In our case, the Euclid program was used, which also has free-form or reverse engineering capabilities. This program enables certain restrictions to be enforced or eliminated during any design stage, and the model to be changed at any time, regardless of the technique used for its creation.

Manufacturing the mould cavities (insertions)

To reduce the processing time and costs, we started with an existing mould: this was used to process the mould frame and punch frame to the required levels for creating the reference sample for the remote control. The tablets that form the casing of the product will be inserted into these frames.

The tablets were made using a classic milling machine, as well as an electro-erosion machine. Once processing was complete, the punch tablet was fitted into the punch frame, and the mould tablet fitted in the mould frame. The mould was fitted by applying a slight force on a polishing press. Following the final adjustments, the mould was assembled. It was then ready to be sent for initial tests.

The tests were carried out on three materials (polypropylene with green pigment, polypropylene with red pigment and polystyrene with white pigment).

The prototype part (the remote control casing) has shaded areas and thereby, the corresponding mould would have normally been provided with edge grips.

When using the polypropylene in the injection process, the elasticity of the material permits a proper use of the injection machine (ARBURG 75) controls so that the injection and the testing of the part are successfully achieved. This was not the case when polystyrene was

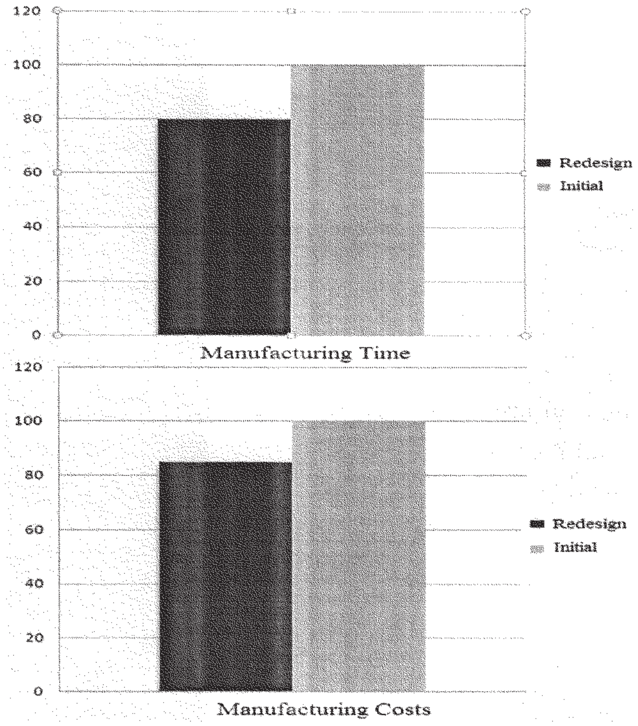

Fig. 10. Manufacturing time and costs

Table 1
INJECTION PARAMETERS

Dosage injection					
Injection speed	2% of 2 m/s				
Injection pressure	12MPa				
Dosage speed	3% of 2 m/s				
Dosage backpressure	1 MPa				
Nozzle back stroke	24.5 mm				
Temperature per cylinder					
Nozzle	1	2	3	4	
	210	210	200	200	
Times					
Injection	2.2 s				
Post-pressure	2.4 s				
Cooling inside the mould	20 s				
Injection cycle time	33 s				

used; in this case, the parts were damaged, regardless of the adjustments made, because the mould is not equipped with sliding dies in the shaded area and the material is brittle.

However, if polystyrene is to be used as the injection material, the mould must be equipped with sliding dies. This can be done without completely remaking the mould. Figure 9 shows an example of an injected part.

Table 1 provides some of the injection parameters of the control sheet.

Conclusions

The purpose of this paper was to present a method of obtaining a new product in the shortest period possible, starting from the characteristics of an existing product, and at minimum manufacturing costs.

Integrating the reverse engineering process with traditional manufacturing processes combined with generating, processing and specific flow simulation software leads to a result that once seemed impossible to achieve; obtaining a new product for which no technical documentation was available.

For the studied product, the following facts have been pointed out:

-a manufacturing time reduction of approximately 20%;

-a production time reduction of approximately 15%;

-improve the ergonomic characteristics and the aesthetics of the part and also the injection process was studied though a series of flow simulations.

Finally, a product was obtained that was new from both aesthetic and functional point of view.

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