International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 6, Number 13 (2011) pp. 1661-1672

http://www.ripublication.com/ijaer.htm

Computer Integrated Injection Mould Split Design-Reverse Engineering Approach

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Abstract

As plastic products become ever more diversified, their life cycles are growing shorter. To reduce Design and development time, production costs, increased process automation and concurrent design are priorities. Therefore, a Computer integrated design methodology is crucial in the mold design. This research develops a Reverse Engineering Integrated Methodology for Injection mold core and cavity design with the CAD application. Providing both Reverse Engineering and Computer Integrated Core and Cavity (mold split design) Development for Plastic Parts is represented to accomplish 3D mold development efficiently and accurately. Results show significant time savings over other mold design process methodologies. The Methodology is demonstrated using as case study for industrial component.

Keywords: Reverse Engineering, Injection Mould Design, CAD, CAE, CAM

Introduction

In manufacturing, the injection moulding is one of the most widely used production processes for producing plastic parts with high production rate The process consists of injecting molten plastic material from a hot chamber into a closed mould, allowing the plastic to cool and solidify and ejecting the finished product from the mould. For each new plastic product, the injection-moulding machine requires a new injection mould

(IM). Design and manufacture of injection mould is a time consuming and expensive process and traditionally requires highly skilled tool and mould makers. Design of mould is also affected by several other factors such as part geometry, mould material, parting line and number of cavities per mould. With the advances in computer technology efforts have been directed to reduce the cost and lead-time in the design and manufacture of an injection mould (IM). Mould design affects the productivity, mould maintenance cost, manufacturability of mould, and the quality of the moulded part. Most of the work in mould design has been directed to the application of intelligence to eliminate or supplement the vast amount of human expertise required in traditional design process.

Recently, pressure from the competitor has reached the point where rapid product design and optimization need to be embraced within the product development cycle. A short lead-time in product development is strongly demanded to satisfy needs, resulting from the globalization of manufacturing activities and the changes in the market requirements. In engineering areas such as aerospace, automotives, shipbuilding and medicine, it is difficult to create a CAD model of an existing product that has a free-form surface. In these cases, reverse engineering (RE) is an efficient approach to significantly reduce the product development cycle. Engineering is the profession involved in designing, manufacturing, constructing, and maintaining of products, systems, and structures. At a higher level, there are two types of engineering: forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part without any technical details, such as drawings, bills-of-material, or without engineering data, such as thermal and electrical properties. The process of duplicating an existing component, subassembly, or product, without the aid of drawings, documentation, or computer model is known as reverse engineering.

Moulds are essential components in the manufacturing industry, a notable example being the vast variety of applications for plastic products. In general there are five stages in the mould design: Conceptual Mould Design, Mould Split Design, Mould base Design, Drawing Design, and Design Change (Wen-Ren Jong, et. al (2007). A wide range of Mould Design and Mould makers are adopting the emerging technology of 3- D Scanning and CMM technology in order to improve the accuracy and substantially reducing the time and cost of Reverse Engineering (RE) (Martin Schuster (2005). The most common use of Reverse Engineering has always been generate CAD data from existing moulds or parts in order to build new tooling for manufacturing them or uses them as the starting point for new design. However some companies with innovative designs have discovered that reverse engineering also can be used to guard against competitors copying their design. We aim to build the simple methodology to integrate reverse engineering for plastic product and mould design for that reverse engineered product. We investigate the developed methodology can be adopt with any CAD packages for mould split design. The Planning for mould core and cavity is the time consuming and human skill based activity which may increase the design and development time for mould as well the product development. Products with enhanced quality can be developed and produced in a shorter time period if the application range of reverse engineering is enlarged (Masashi ENDO 2005).

The main objectives of this paper are:

1. To identify, applications of reverse engineering concept in engineering domain.
2. To provide a framework of relationships among reverse engineering and injection mould design.
3. To discuss the practical utility of such a framework for industries with case study.

The remainder of this paper is organised as follows: Section 2 provides a literature review Injection Mould design, Reverse Engineering and CAD application in Mould design. This review is followed by a discussion on the RE-CAD methodology for Mould Split design, a very important stage in injection mould design. This section is followed by a case study for industrial component where for RE a CMM technology used and for split design CAD package used. Finally, the results are presented along-with the discussion and conclusions.

Injection Mould Design Process

Today, there is a clear trend to use more plastics and composites in engineering industry. The time to market for plastic injection products is becoming shorter and more crucial, thus the lead time available to making the injection moulds is decreasing. This will need an integrated optimizing of product, process and material properties. To achieve product, tool and process optimization, early decisions in design process must be supported. Injection molding is an essential element of near net shape manufacturing process, where it may account for over 25% of the total product cost and development time in engineering industry, especially when order quantity is small. Nowadays, mould design faces increasing deadline pressure and the design itself is predominantly based upon the experience of the mould designer. Mold designers are required to possess thorough and broad experience, because detailed decisions require knowledge of the interaction between different parameters.

Overall mold design process includes product design, material selection, manufacturing process selection, mold design and mold manufacturing process selection, shown in Fig 1. Mold design process includes mold base design and core/cavity design. In mold base design process engineers have to select mold type, mold dimensions, machining methods and mold material according to plastic product parameters. In core and cavity design process engineers have to select melt feed system, cooling and venting system and ejection system depending on plastic product parameters. The frequency of use of three dimensional (3D) data in the designing of dies and molds has increased. This is because, since designing has meant producing drawings, the data created in past designing endeavors have been retained on the drawings. The retrieval and re-use of the data from old design drawings was a critical issue in increasing the efficiency of design processes in new projects.

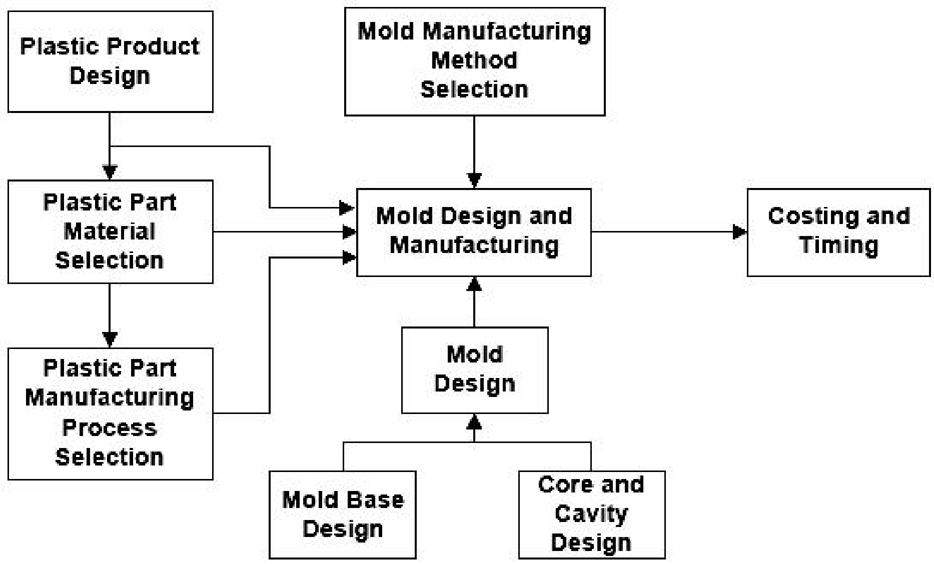

Figure 1: Overall Process flow chart for Injection Mould design.

Design is, within the scope of engineering applications, a hierarchical series of transformation processes from a functional description of a product to a physical entity. The design process involves creative, analytical, theoretical and experimental work in a complex, iterative and recursive manner. In this respect, the object of rational design is to make the specifications such that the designing, production and utilization of the product consume a minimum of resources and information. A rational design strategy differs from an exhaustive generation- and-test problem-solving technique; in that it has criteria for evaluating design decisions and indices for generating design alternatives prior to the expensive and time-consuming prototype tooling.

Reverse Engineering

Engineering is the profession involved in designing, manufacturing, constructing, and maintaining of products, systems, and structures. At a higher level, there are two types of engineering: forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part without any technical details, such as drawings, bills-of-material, or without engineering data, such as thermal and electrical properties. The process of duplicating an existing component, subassembly, or product, without the aid of drawings, documentation, or computer model is known as reverse engineering.

Reverse engineering is very common in the fields such as software engineering, entertainment, automotive, consumer products, microchips, chemicals, electronics, and mechanical designs. For example, when a new machine comes to market, competing manufacturers may buy one machine and disassemble it to learn how it was built and how it works. A chemical company may use reverse engineering to defeat a patent on a competitor's manufacturing process. In civil engineering, bridge and building designs are copied from past successes so there will be less chance of catastrophic failure. In software engineering, good source code is often a variation of other good source code. In some situations, designers give a shape to their ideas by using clay, plaster, wood, or foam rubber, but a CAD model is needed to enable the manufacturing of the part.

As products become more organic in shape, designing in CAD may be challenging or impossible. There is no guarantee that the CAD model will be acceptably close to the sculpted model. Reverse engineering provides a solution to this problem because the physical model is the source of information for the CAD model. This is also referred to as the part-to-CAD process. Another reason for reverse engineering is to compress product development times. In the intensely competitive global market, manufacturers are constantly seeking new ways to shorten lead-times to market a new product. Rapid product development (RPD) refers to recently developed technologies and techniques that assist manufacturers and designers in meeting the demands of reduced product development time. For example, injection-molding companies must drastically reduce the tool and die development times. By using reverse engineering, a three-dimensional product or model can be quickly captured in digital form, re-modeled, and exported for rapid prototyping/tooling or rapid manufacturing.

Ten Reasons for Reverse Engineering a part or product.

1. The original manufacturer of a product no longer produces a product
2. There is inadequate documentation of the original design
3. The original manufacturer no longer exists, but a customer needs the product
4. The original design documentation has been lost or never existed
5. Some bad features of a product need to be designed out.
6. To strengthen the good features of a product based on long-term usage.
7. To analyze the good and bad features of competitors' product
8. To explore new avenues to improve product performance and features
9. To understand competitor's products and develop better products
10. The original supplier is unable or unwilling to provide additional parts.

Reverse engineering enables the duplication of an existing part by capturing the component's physical dimensions, features, and material properties. Before attempting reverse engineering, a well-planned life-cycle analysis and cost/benefit analysis should be conducted to justify the reverse engineering projects. Reverse engineering is typically cost effective only if the items to be reverse engineered reflect a high investment or will be reproduced in large quantities. Reverse engineering of a part may be attempted even if it is not cost effective, if the part is absolutely required and is mission-critical to a system. Reverse engineering of mechanical parts involves acquiring three dimensional position data in the point cloud using laser scanners or computed tomography (CT). Representing geometry of the part in terms of surface points is the first step in creating parametric surface patches. A good polymesh is created from the point cloud using reverse engineering software. The cleaned-up polymesh, NURBS (Non-uniform rational B-spline) curves, or NURBS surfaces are exported to CAD packages for further refinement, analysis, and generation of cutter tool paths for CAM. Finally, the CAM produces the physical part.

The Reverse Engineering process

The RE process can be divided into three steps: A) digitizing B) data segmentation C) data fitting.

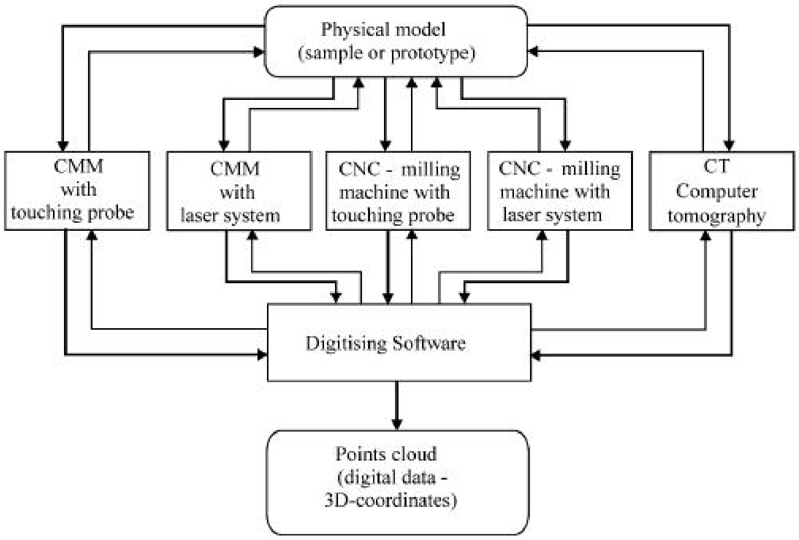

Figure 2: Digitising techniques for the 3D-geometries and generated data.
Source: M. Sokovic, et al. (2005).

The first objective of RE methodology is to generate a conceptual model (example: surface triangulated) from a physical model: a sample (part or tool) or prototype. In this sense the 3D-scanning (digitizing) techniques aided by specialized software's for model reconstruction are necessary. 3D-scanning (digitizing) is the process of gathering data from an undefined three-dimensional surface. During the scanning process, an analogue-scanning probe is commanded to move back and forth (contact or non-contact) across the unknown surface. During this process, the system records information about the surface in the form of numerical data—generates a point's cloud matrix (3D-coordinates). This data may then be used to create a CNC-program to machine a replica or geometric variant of the shape. (y). In order to reverse engineer a product or component of a system, engineers and researchers generally follow the following four-stage process:

- Identifying the product or component which will be reverse engineered
- Observing the information documenting how the original product works
- Implementing the technical data generated by reverse engineering in a replica.
- Creating a new product (and, perhaps, introducing it into the market).

In the first stage in the process, sometimes called "prescreening," reverse engineers determine the candidate product for their project. Potential candidates for such a project include singular items, parts, components, units, subassemblies, some of which may contain many smaller parts sold as a single entity. The second stage, disassembly or decompilation of the original product, is the most time-consuming aspect of the project. In this stage, reverse engineers attempt to construct a characterization of the system by accumulating all of the technical data and instructions of how the product works. In the third stage of reverse engineering, reverse engineers try to verify that the data generated by disassembly or decompilation is an accurate reconstruction the original system.

The final stage of the reverse engineering process is the introduction of a new product into the marketplace. These new products are often innovations of the original product with competitive designs, features, or capabilities. These products may also be adaptations of the original product for use with other integrated systems, such as different platforms of computer operating systems. Often different groups of engineers perform each step separately, using only documents to exchange the information learned at each step. This is to prevent duplication of the original technology, which may violate copyright. By contrast, reverse engineering creates a different implementation with the same functionality. A full parametric 3-D CAD model can be developed, using one of our customer compatible CAD platforms, making the reverse-engineered model ready for tooling or additional design modifications Some customers require 2-D drawings of the component. The time of product model changing became shorter and shorter and requirements push all in the production chain in great hurry with time. In this case are very useful and successful the methods of reverse engineering (RE).

The very important tools, which help in this process, are different scanning systems, which ensure in the short time exact dimensional description in digital concept, which is useful for direct control on machine tool in advance. The RE is now an accepted part of contemporary product design and manufacturing process. The RE process can be loosely defined as process that result in the creation of a mathematical model from a physical one. Measuring methods and surfacing tools have been described as they relate to reverse engineering. Products with enhanced quality can be developed and produced in a shorter time period if the application range of reverse engineering is enlarged.

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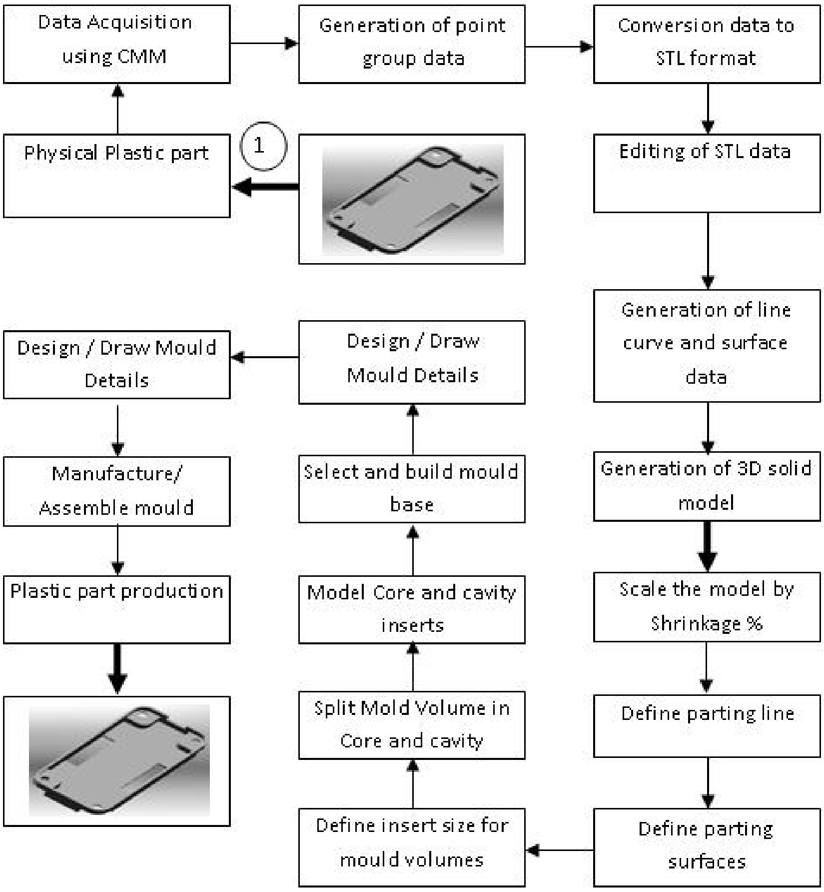

Figure 3: Reverse Engineering and Mould Design Methodology.

Experimental

The reverse engineering process begins with identifying the project scope. Once defined, the appropriate method to capture geometry is selected based on accuracy required, part geometry, and how the final output will be used. The part can be physically measured using traditional hand tools, by using non contact inspection equipment by using a touch-probe. In the reverse engineering process, the geometry can also be "captured" by mapping the surface with 3d scanning services such as a laser scanner, coordinate measuring machine (CMM)...or a portable CMM....through the use of a white light scanner by using a full contact CMM scanner or by a process called Capturing Geometry Internally (CGI).

These various methods of 3d scanning services are used to capture a part's geometry during the reverse engineering process. It is important that the correct method be used to capture geometry for any reverse engineering project. The method is dependent on the part shape, required accuracy, project goals, and how the final results will be used. Once the geometry is captured, the reverse engineering project continues and the point cloud is produced and surfacing can begin. To understand the concept of the reverse engineering in the field of plastic product development and its core / cavity extraction a small appliance component is considered. Initially the physical component is taken and with the help of CMM point cloud data captured. For capturing data the contact type data acquisition method was adopted. The generated cloud data transferred in the form VDL format to STL format and opened in commercial CAD software. Here Solidworks Package used for editing STL data, further the data cleaned and converted into 3D solid model. Fig.4 Shows the solid model Developed from CMM data represents all the features clearly.

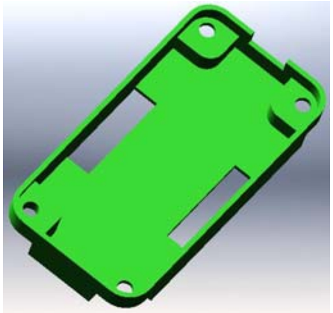

Figure 4: Part Solid Model.

With the next step developed 3-D CAD model directly taken up for the core and cavity extraction process and opened in mold environment of Solidworks CAD. Initially as per design methods the component dimensions must be added with appropriate shrinkage value so the component will have advance shrinkage with some percentages as per defined material. Here we ABS type of plastic material is selected as per the industrial requirement.as shown in fig. 5. Once the shrinkage added 3 D model is ready opened further for defining pull direction so that the correct prediction of draft on component and ejection system tentatively. These are essentially required for defining the parting line for cad model. The parting line can be developed as by selection of edges manually or can identify automatically. Fig. 5 shown clearly the blue color line as parting line. Fig. 6. also describes that all internal features as per requirement of component are closed by patch up surfaces. In CAD terminology this process known as shut-off surfaces.

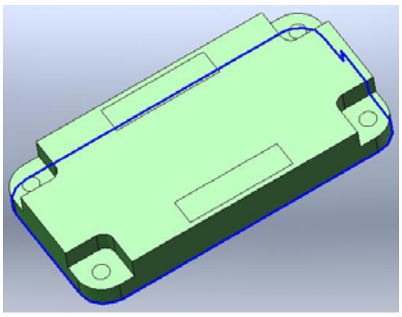

Figure 6: Shut Off Surfaces.

Figure 5: Define Parting Line.

The parting surfaces of the mould are those portions of both mould plates, adjacent to the impressions, which butts together to form a seal and prevent the loss of plastic material from the impression. The nature of the parting surface depends entirely on the shape of the component as shown in fig. 7. CAD Programme automatically generates the parting surface from defined parting line as shown in Further the component 3d model is required to enclose into the box of certain size so that core and cavity inserts can be separated along the parting surfaces. This process is known as automation core and cavity extraction methodology in CAD. Once parting clearly defined the mold box can be split into two sections and separated as core half and cavity half. With the next step size of the insert size or box size can be defined along with its cross section as rectangular, round or square. As shown fig. 8 the rectangular of 80 X 50 mm size is considered the box size to extract the core and cavity inserts.

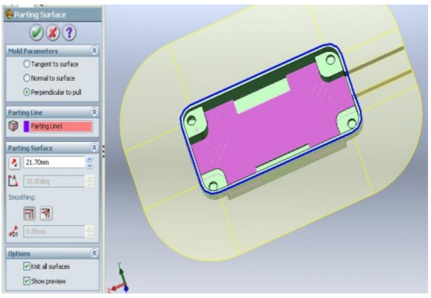

Figure 7: Define Parting Surfaces.

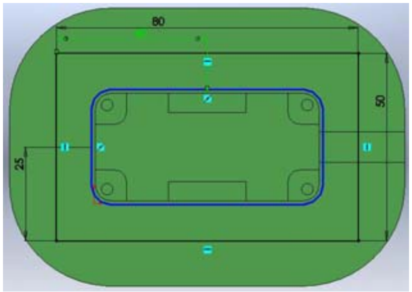

Figure 8: Define Insert Size.

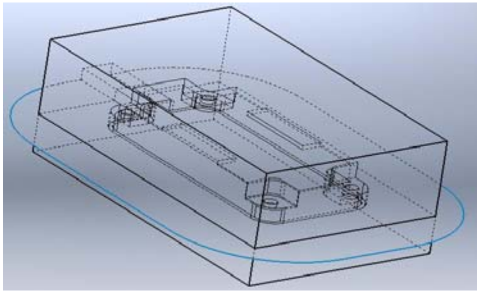

Figure 10: Split Volume -Wire Frame Model.

As shown in fig. 9 & 10 Mold split CAD program is utilized for extraction of core and cavity for the case study component. Along the parting surfaces automatically the box is separated in two mould halves solids. Further these solids saved as separate cad solid models as indusial files which can be edited and modified. As shown in Fig. 11 & 12.

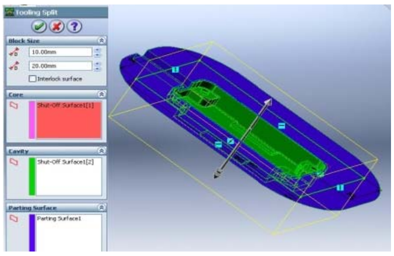

Figure 9: Split Mould Volume.

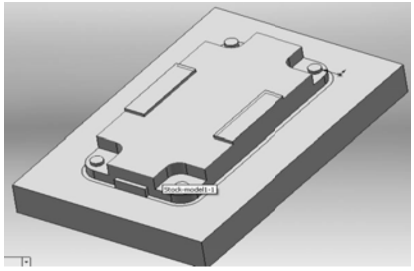

Figure 12: Mould Volume – Core Section.

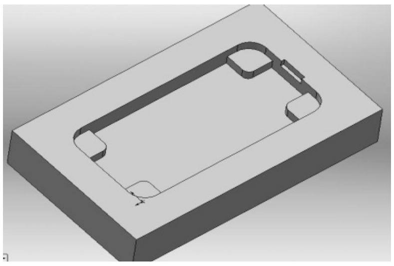

Figure 11: Mould Volume- Cavity Section.

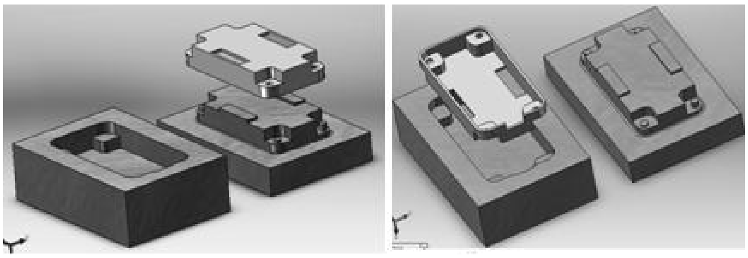

Figure 13: Inserts with Component.

Further these CAD core and cavity models can be transferred to CAM packages for preparation of CNC program and can be manufactured quickly. This process increases quality in mould manufacturing and component manufacturing.

Conclusions

The product (parts, moulds, tools) development via integrated reverse engineering is a recent methodology in research and development phase. If is today this methodology additionally integrated with new rapid manufacturing technologies such as high speed machining (HSM) and five-axis milling, allows manufacturing time reduction and associated costs for product development and management. For these production methodologies and techniques the 3D-scanning (digitising) is the initial activity to capture the product geometries.

This paper shows some possibilities of use and benefit from utilising the RE-methodologies and techniques in product and mould development, especially in the case when exists parts without 3D-CAD support. In this contest, RE is absolutely necessary because allows capturing and digitising the object surface geometry to be utilised in CAD/CAE/CAM. The application of reverse engineering for Rapid plastic product development is being analyzed in this work. The total time for core and cavity design an split development found to be faster with the application of this reverse engineering integrated mould design system. By using reverse engineering, a three-dimensional product or model can be quickly captured in digital form, re-modeled, and exported for rapid prototyping/tooling or rapid manufacturing. The time required for design and development of Injection mould is reduced. Therefore, the RE-process (integrated with the recent rapid prototyping and/or rapid tooling technologies) is granted by numerical simulation the process and product optimization to increase the final product quality, lead to increase the competitiveness in the different cases (parts production, production of parts for household appliance, rapid tool making for these parts). The total time taken is only 20 minuets to develop the core and cavity for RE product. Because of integration of RE and CAD the time required for product development is shortened.

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