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# Rapid product development – a case study

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**ABSTRACT**

In the present day scenario rapid product development (RPD) becomes essential for product manufacturers for their survival. However, success of RPD depends on advancement and effective utilization of many more available technologies. Now with the availability of Computer Aided Design (CAD) / Computer Aided Manufacturing (CAM) for RPD making the demands of the present day industry are taken care. The product development by CAD/CAM reduces the considerable time of equipment and is made with higher accuracy and repeat-ability resulting in faster development of products and less rejection in the long run this approach to product developing results in cost effectiveness. This paper reviews the technological advancements in CAD/CAM Systems. This paper also depicts the lead-time reduction in product development through modeling with CAD/CAM and application of reverse engineering, Rapid prototyping and CNC approach to RPD.



## Introduction

For developing any product in time is the most challenging parameter at present, as the fast and successful positioning of new products on the market has become vital for a company. The traditional method of product development largely dependent on the hand skills of the product developer, this method of product development through combining new technologies, the speed of manufacturing and levels of accuracy that can be achieved. The concept of automation of complete process of the product development in a single computerized environment will reduce prototyping lead-time. Networks and fast Ethernet enables a quick and save exchanges of relevant data and supports the development process tremendously. All these new technologies have been in focus of scientific and industrial interest. Initial investment of new technologies is very high for integrating the one continuous process chain, by combining these technologies within an R&D organization effectively; the product development time can be reduced decisively.

Bringing new products to the global market quickly and cost-effectively is a major competitive advantage. Rapid product development allows companies of all sizes and types to gain that strategic advantage and place products in the marketplace days, weeks, or months ahead of competitors. Rapid product development can also be used to streamline the manufacturing of existing products. The key to effective rapid product development is the effective application of rapid prototyping and manufacturing technologies. A good product design must embody all the features that satisfy a customer's requirements; for example, appearance, function, quality and after-sales service. Appearance is a particularly important feature for consumer products and is created by industrial designers or product stylists.

## Reverse Engineering (RE)

Reverse Engineering is the process of analyzing a subject system to identify the system's components and their interrelationships, and to create representations of the system in another form at higher levels of abstraction. Chikofsky and Cross (1990) defined RE to be "analyzing a subject system to identify its current components and their dependencies, and to extract and create system abstractions and design information". Current RE technology focuses on regaining information by using analysis tools (Basili and Mills 1982) and by abstracting programs bottom-up by recognizing plans in the source code (Rich and Wills, 1990, Kozaczynski et al., 1992, Tonella et al., 1996, Rich and Waters, 1990). In corporate settings, RE tools still have a long way to go before becoming an effective and integral part of the standard toolset that a typical software engineer uses day-to-day. Mainly the reverse engineering is derived for a) legacy code is written using rather tricky encodings to achieve better efficiency, b) all the necessary plan patterns in all the variations must be supplied in advance for a particular application, and c) different abstract concepts map to the same code within one application. Even more important, the main reason for doing reverse engineering is to modify the system (Singh, 2013).

The RE allows addition of further plans, realizing patterns, and possibly further intertwining rules to enable a plan recognizer to detect the actual realization that can be found in the code. Thus, the RE not only has to provide the plan pattern for the actual realization of a plan but also the transformations and the justifications for applying them (Singh, 2013). The subsystem view to present information should not require tedious manual manipulation. Instead, the mapping between responsibility and components should be consulted and a script would then generate the required view, with the option for minor, personal customization by the user. Such a script is an instance of a reverse engineering pattern (Wong, 1999) a commonly used task or solution to produce understanding in a particular situation. Recently, data reverse engineering concepts and techniques have gained attention in the reverse engineering arena. Researchers now recognize that the quality of legacy systems recovered data documentation can make or break strategic information technology goals. The increased use of

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data warehouses and data mining techniques for strategic decision support systems (Umar, 1997) have also motivated an interest in data reverse engineering technology.

In engineering, the use of reverse engineering can arise in the following situations: when any technical data on parts is not available, technical data is proprietary or incomplete, and/or obtaining replacement components from the original parts. The reverse engineering process chain consists of five basic steps, via: -Digitizing, aligning, surfacing, solid modeling and exporting. The available sample is digitized to capture the product geometry either by contact method or by non-contact method. The digitized data represented in the form of different shots of point cloud aligned, this aligned point cloud is then used for further modeling work like B-spline curves, NURBS surfaces, solid modeling are directly generating STL file depending on type of end applications. The software's like IMAlign, Imageware Surfacer used at the stage. The NURBS curve generated on point cloud data is used for generating NURBS surfaces and further to do solid modeling, manufacturing the replicate or variant of original part using CAD-CAM software. In contact method coordinate measuring machines (CMM) consisting of base machine and software package, along with analogue scanning probe may be used for digitizing. In non-contact method, the scanner is used to capture product data, the type of devices currently being used includes: Computed tomography, Moiré Interferometry, White Light Triangulation, Laser scanning. Using 3-D White light scanner, which can captures the product geometry up to the minimum distance of 0.3mm, this cloud is then used for surfacing with an accuracy up to 1μm, which is sufficient for many engineering applications.

**Rapid product development**

Reverse engineering, a physical model to a CAD representation, is only the first step in the process of producing the necessary tooling to mass produce the part. The next step is to quickly convert the CAD data into a usable form. Components for consumer items, such as plastic casings or housings, are produced through injection molding. This requires that complex injection mould tooling be produced based on the part's CAD representation. Injection molding was developed to provide an economical production means in situations where costs are spread over very large volumes. It is no longer economical, however, for the much lower volumes, which are now routinely required by many manufacturers. The mass market has been turned upside down and so-called niches are now the norm. Therefore, companies in the injection molding business must be able to rapidly produce prototype and short-run tooling. The phrase rapid product development refers to product development in the decreased development lead times and the resulting methods that have been developed to meet these reduced lead times. Reverse engineering utilizing 3D sensor technology, and associated CAD/CAM software, can help meet these new challenges. The schematic of Figure 1 shows the relationships between the various phases in the rapid product development process.

**Data flow in reverse engineering**

Once the object has been digitized, using a 3D vision system, the user typically has a dense map of surface points that must be further processed to achieve a form suitable for manufacturing applications, specifically CNC machining or rapid prototyping. Over the last five years, the Advanced Manufacturing Laboratory, at the University of Victoria, has developed several data modeling techniques suitable for converting the large cloud data files into standard CAD/CAM representations, for example see Bradley and Vickers (1992), Milroy et al. (1996) and Weir et al. (1996). Typically, the following sequence of steps would be followed (Colin, 1998).

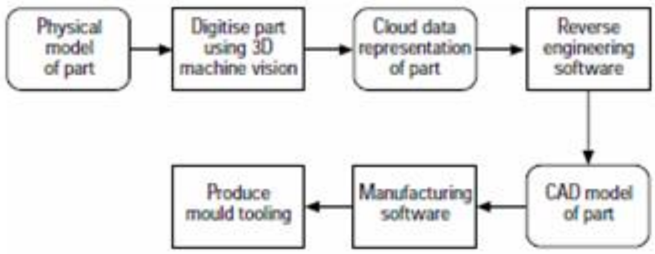


**Fig. 1 Phases in rapid product development**

**Split object into major geometric entities:**

Distinct surface regions are typically evident on the object. For example, the object shown in Plate 2 has many patches and the data falling on each patch are generally fitted with a distinct modeling entity (e.g. plane, cylinder etc.). The cloud data segmentation is typically accomplished on a workstation-based software package by drawing boundary curves around the various patches and then separating the data contained within from the overall data set. Figure 2 shows the object of Plate 2 split into its major geometric entities.

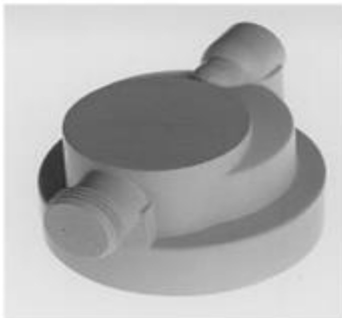

**Fig. 2. Plate 2, Photograph of a part showing surface patches**

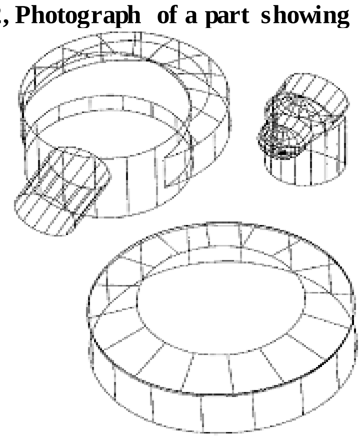

**Fig.3 Constituent surface patches for the part shown in fig.2**

**Convert each patch surface into NURBS:**

The CAD/CAM industry standards dictate that surface modeling of each patch be performed in the non uniform rational B-spline (NURBS) surface form. NURBS offer several advantages in that they can describe the quadric in addition to free form surfaces using a common mathematical form. The weighted control points available using NURBS can give more flexibility in approximating the object's surfaces and NURBS also have a wide assortment of geometric modification tools available such as knot insertion, knot removal, degree elevation, etc. The surface data contained within a patch is approximated, to within a specified absolute error tolerance, by the NURBS surface, thereby giving a smooth surface. The net result is that several thousand 3D data points have been replaced by a compact mathematical representation that is compatible with modern CAD/CAM software packages. The surface model can also be described using industry standard graphics data exchange formats such as IGES.

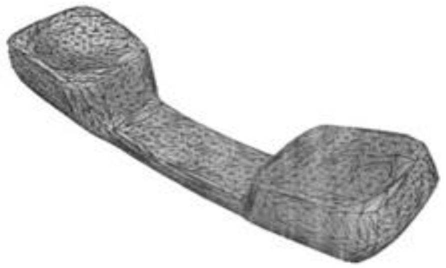

**Fig.4 Polyhedral mesh representation (.stl file) of a part**

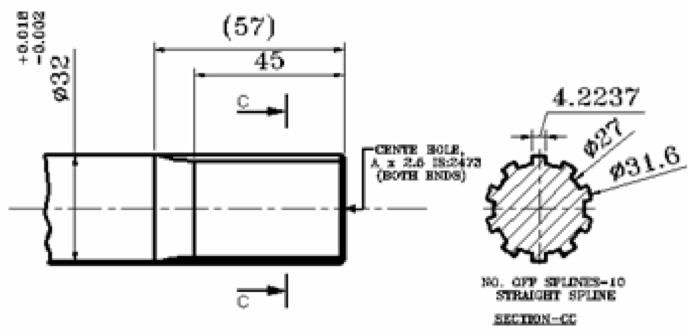


**Fig.5 2D view of the shaft (One end) and spline detail**

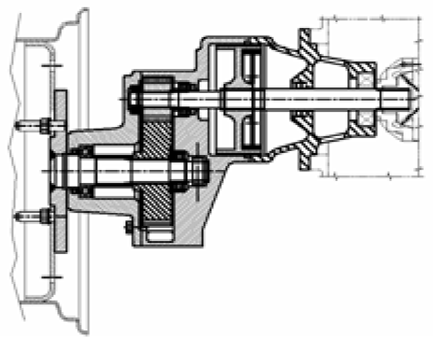

**Fig.6 Assembly (2D) of the shaft (developed part)**

**Applications in rapid product development**

The CAD model, generated through the reverse engineering process, can be utilized in two ways for the rapid production of injection mould tooling (Colin, 1998):

1. The generation of a CNC machine tool cutter path from the CAD model for the production of the mould tooling; and
2. The production of a stereo lithography master model from the CAD model if a rapid tooling approach is to be employed in manufacturing the mould.

The first technique is straightforward once an accurate CAD model is available through the reverse engineering process. Many CAM packages accept the surface models and can generate the cutter paths once all the manufacturing data has been assembled, e.g. cutter type and size, cutter feeds and speeds and machining strategy.

Injection molding businesses are now beginning to examine the rapid tooling approach using any of the new layered manufacturing techniques, such as stereo lithography. Stereo lithography machines also require that the part to be produced is defined in CAD. The CAD representation is an ".stl" file, which is an object representation comprising a polyhedral triangular mesh. The mesh can be generated from either the CAD model or directly from the 3D cloud data (Colin, 1998). Generation of a ".stl" triangular mesh model directly from cloud data is shown in Figure 4.

**CAD-CAM Technology**

Computer aided design refers to the design process using sophisticated computer graphics techniques backed up with computer software packages to aid in analytical problems associated with design work. Computer aided manufacture concerns any automatic manufacturing processes which is controlled by computers. The 3-D models created on a CAD system are wire-frame, surface, and solid models. Wire frame models are used as input geometry for simple analysis work such as kinematics studies, surface models are used for visualization automatic hidden line removal, and animations, solid models are used for engineering knowledge and visualization and are mathematically accurate description of the products and structures. The solid model can be shaded to improve visualization of the product, structure, and physical models are automatically generated from the geometric models through rapid prototyping technology.

**Problem Description**

Initially, the 3D model of a part called rear axle shaft for a new vehicle was developed, through Reverse engineering, CAD/CAM route & utilizing Rapid Prototyping Technology. The product was made from the 3D model later on through different machining operations like CNC lathe, milling, wire cut, grinding, etc. The part was developed using process as discussed above typically called the rapid product development. This part is basically a shaft in the rear axle assembly of a newly developed tractor in our Institute. The 2D view of this shaft has shown in fig.5. This rear axle shaft actually fits in the differential assembly of the vehicle (as shown in Fig. 6).

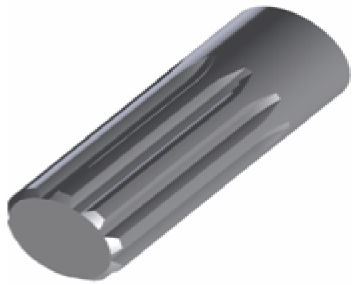

**Fig.7 3D model of the shaft**

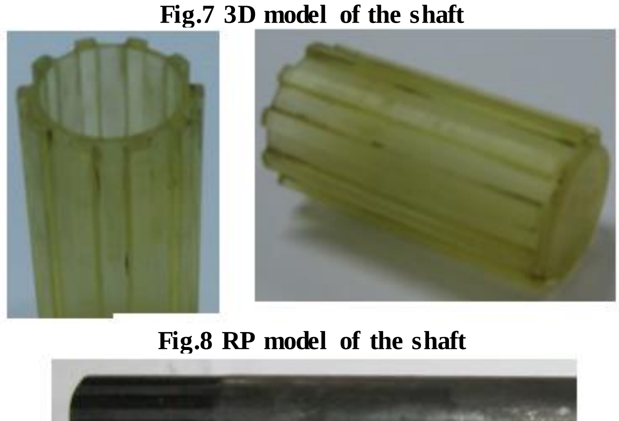

**Fig.8 RP model of the shaft**

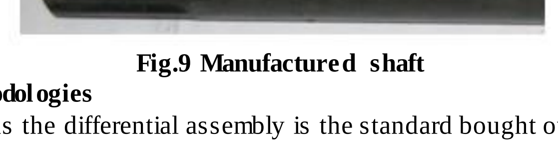

**Fig.9 Manufactured shaft**

**Methodologies**

As the differential assembly is the standard bought out part from the market, the exact spline profile was not known and hence difficulties were faced for the development of the shaft which will fit in the differential assembly. The entire available BIS standard was studied and it was decided that the shaft should be developed following the route of rapid product development. The following sequence of activities was carried out:

- Spline profile of the existing differential assembly was scanned in the form of 3D dot points using 3D while line scanner
- Using IMALIGN software, cloud points were aligned properly and filtered the unwanted data
- Surfaces were built over the cloud points in Imagewere surface software
- Surfaces were converted into solid model
- Output taken of this model as .stl file format to make the part in RP machine (SLA)
- Fitment checked of this RP part along with the existing differential assembly
- 2D manufacturing drawings were made from solid model for development of the shaft

**Table 1. Total cycle time for rear axle shaft development through RPD process**

| Sl. No | Processes | Design & Development time (approx.) in days | |
|---|---|---|---|
| 01 | 3D scanning & data alignment | 1 | Design time = 5 days |
| 02 | Surface modeling | 1 | |
| 03 | Solid modeling | 1 | |
| 04 | RP part making | 1 | |
| 05 | Manufacturing drawing after fitment checking | 1 | |
| 06 | Manufacturing | 3 | Machining time = 3 days |

Developing the present product with the help of latest design tools have been compared with the estimated time required for conventional approach to show the advantage of Rapid Product development.

## Conclusions

In this paper the complicated rear axle shaft (with spline) matching with differential assembly has been developed following the reverse engineering technique or the rapid product development process. Researchers will continue to develop technology and tools for generic reverse engineering tasks, particularly for data reverse engineering but future research ought to focus on ways to make the process of reverse engineering more repeatable, defined, managed, and optimized. Reverse engineering, utilizing 3D machine vision technology, provides a means of efficiently generating accurate CAD models of complex physical models. This process reduces product development time and permitting the efficient manufacturing by means of either CNC machining or stereo lithography. The results are very important for the development of the rear axle shaft commercially.

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