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Reverse Engineering – The Review

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Abstract - *In today's intensely competitive global market, product enterprises are constantly seeking new ways to shorten lead times for new product developments that meet all customer expectations. Product enterprise has invested in CAD/CAM, rapid prototyping and a range of new technologies that provide business benefits. Reverse engineering is one of the technologies that provide the benefits in shortening the product development cycle. Using reverse engineering, a three-dimensional physical product can be quickly captured in the digital form, re-modelled and exported for rapid prototyping /tooling or rapid manufacturing. Reverse engineering also used to analyze "as designed" to "as manufactured", this involves importing the as designed CAD model and superimposing the scanned point cloud data set of the manufactured part. The reverse engineering software allows the user to compare the two data sets as designed to as manufactured. Damaged or broken parts are generally too expensive to replace or are no longer available. Reverse engineering involves design of a new part, copy of an existing part, recovery of a damaged or broken part, improvement of model precision and inspection of a numerical model.*

Keywords-*CAD, CAM, Reverse Engineering*

I. INTRODUCTION

Engineering fields are constantly improving upon current designs and methods to make life simple, easier and directly related to fast and accurate. In today's intensely competitive global market, product enterprises are constantly seeking new ways to shorten lead times for new product developments that meet customer expectations. In general product enterprise has invested in CADCAM, rapid prototyping and a range of new technologies that provide business benefits. Reverse Engineering (RE) is now considered one of the technologies that provide business benefits in shortening the product development cycle [1]. Figure1 below depicts how RE allows the possibilities of closing the loop between what is "as designed" and what is "actually manufactured".

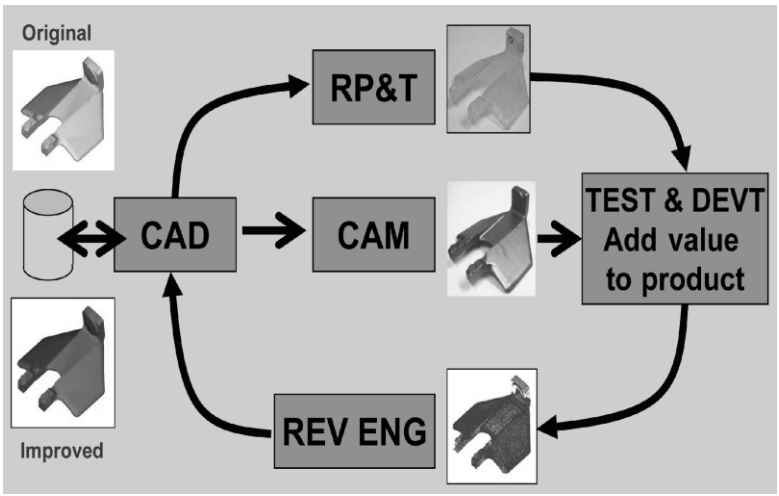

Figure 1 Product Development Cycle [1]

Engineering is the process of designing, manufacturing, assembling and maintaining products and systems. There are two types of engineering, forward engineering and reverse engineering. Forward engineering is the traditional process of moving form high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part/product without any technical details, such as drawings, bills-of–material or without engineering data. The process of duplicating an existing part, subassembly or product without drawings, documentation or a computer model is known as reverse engineering.

Reverse engineering is also defined as the process of obtaining a geometric CAD model from 3-D points acquired by scanning/digitizing existing parts/products. The process of digitally capturing the physical entities of a component referred to as reverse engineering.

Reverse Engineering is also defined as: "Systematic evaluation of a product with the purpose of replication. This involves design of a new part, copy of an existing part, recovery of a damaged or broken part, improvement of model precision and inspection of a numerical model [2]". Reverse engineering is widely used in numerous applications such as manufacturing, industrial design and jewelry design and reproduction, dental surgery. For example new car is launched in the market; competing manufactures may buy one and disassemble it to learn how it was built and how it works. In some situations, such as automotive styling, designers give shape to their ideas by using clay, plaster, wood or foam rubber but a CAD model is needed to manufacture the part. As products become more organic in shape, designing in CAD becomes more challenging and there is no guarantee that the CAD representation will replicate the sculpted model exactly.

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 physical-to-digital process depicted in Figure 2. Another reason for reverse engineering is to compress product development cycle times. Need of intensely competitive global market, manufacturers are constantly seeking new ways to shorten lead times to market a new product. Rapid product development refers to recently developed technologies and techniques that assist manufacturers and designers in meeting the demands of shortened product development time. For example, injection-molding companies need to shorten tool and die development time drastically. By using reverse engineering, a three dimensional physical products or clay mock-up can be quickly captured in the digital form, remodeled and exported for rapid prototyping/tooling or rapid manufacturing using multi-axis CNC machining techniques [5].

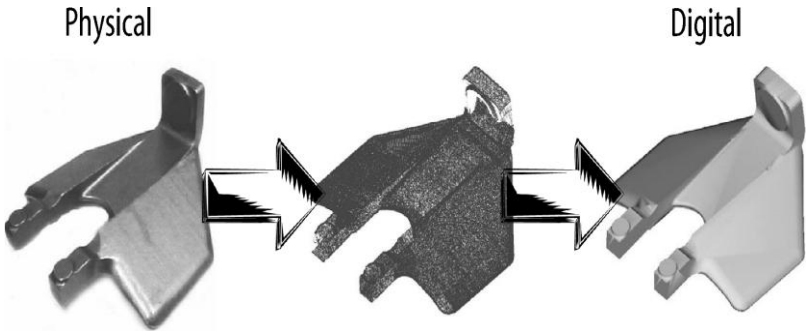

Figure 2 Physical-to-digital process [1]

II. REASONS FOR USING REVERSE ENGINEERING

Following are some of the reasons for using reverse engineering [1]:

1) The original manufacturer no longer exists, but a customer needs the product, e.g., automobile spares required typically after an automobile has been in service for several years and new model in the market.
2) The original manufacturer of a product no longer produces the product, e.g., the original product has become obsolete.
3) The original product design documentation has been lost or never existed.
4) Creating data to refurbish or manufacture a part for which there are no CAD data, or for which the data have become obsolete or loss.
5) Inspection and/or Quality Control-Comparing a fabricated part to its CAD description or to a standard item.
6) Some bad features of a product need to be eliminated e.g., excessive wear might indicate where a product should be improved.
7) Strengthening the good features of a product based on long-term usage.
8) Analysing the good and bad features of competitor's products.
9) Exploring new avenues to improve product performance and features.
10) Creating 3-D data from an individual, model or sculpture to create, scale or reproduce artwork.
11) Creating 3-D data from a model or sculpture for animation in games and movies.
12) Architectural and construction documentation and measurement.
13) Fitting clothing or footwear to individuals and determining the anthropometry of a population.

14) Generating data to create dental or surgical prosthetics, tissue engineered body parts, or for surgical planning.
15) Documentation and reproduction of crime scenes.

III. APPLICATION OF REVERSE ENGINEERING

Following are the applications of reverse engineering [1]:

1) Design a new component. The design of new part comes from an existing real part model.
2) Reproduction of an existing component. Some parts exist for which no design/manufacturing documentation exists but its copy can be obtained by reverse engineering approach.
3) Recovery of a damaged or broken component. If the surface of a part to be measured is damaged or worn away, the reconstructed CAD model may not be precise compared with the true surface of the part.
4) Development of model precision. The engineer can finish a product concept design based on the requirements of function and aesthetics and then use some soft materials, such as wood or plaster etc. to fabricate models.
5) Observation of a numerical data. Scanning the part and reconstructing a 3D-CAD model by the reverse engineering approach, the designer can compare this model with the first model.

Some important applications in film industry, security, accident assessment, product design/rapid prototyping, quality control, fashion, restoration, medicine, simulation etc.

IV. PROCESS OF REVERSE ENGINEERING

The goal of reverse engineering an object is to successfully generate a 3D CAD model of an object that can be used for future modelling of parts where there exists no CAD model. There has been a mandatory need for 3D reconstruction of scenes and objects by the manufacturing industry, medical industry, military branches and research facilities. Manufacturing industry utilizes reverse engineering for its fast rapid prototyping abilities and accuracy associated with the production of new parts. This fast prototyping is done through the use of CAD model designs for inspection purposes. Military branches also utilize revere engineering to perform inspection task that are associated with safety. For generating clean, smooth 3D models which are free of noise and holes requires a strong, robust image acquisition system that can acquire data with a high level of accuracy in a sufficient time frame [3]. There are several building blocks or steps, which determine the process of building a complete 3D model from range and intensity data. These steps, listed in Figure 3 show the format of how range image data is acquired, transformed and generated. This flow chart can be characterized as a generic basic principle for reverse engineering. The steps shown often overlap during the process of each step.

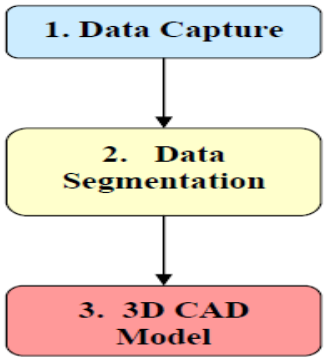

Figure 3 Flowchart for basic transformation phases of RE [3]

There are many different approaches to acquiring 3D data of objects of various structural shapes. Acquisition can be based on collecting the z-axis data using linear data, laser radar laser scanning techniques, point detectors or other approaches. These systems incorporate the computer power to manage process and analyze the data acquired. Traditional processes for reverse engineering of objects and structures from 3D datasets have been initial data (e.g. triangulated models) and parametric surface (e.g. quadratic surface) driven [4]. These approaches have been successful for simple parts, but have resulted in reconstructions that have errors when dealing with more complex structures. Typical errors arise from noisy data or missing data from the surface of the part. Other errors can also consist of incorrect relative positions of the object. Industries are looking for a

method to improve upon these errors and migrated toward a fast efficient way of modelling parts for inspection purposes. Traditional practices use CMMs, which are coordinate measuring machines that have a touch probe to model the surface for inspection. In data segmentation, pre-processing acquired data (data segmentation) and data post-processing (data integration) will be done. After the all scanned data available, the point data that lie on the boundary of the object only is available. These may be random cloud of points or in some order. If it is available in some order, if in the case of CT scans, this order must be exploited. For obtaining solid model from the point data by using an appropriate software and finally 3D model is created by relative reverse engineering software like Geomagic Design X, Geomagic Studio etc.

V. CONCLUSION

Developments in rapid prototyping and tooling technologies are helping to shorten dramatically the time taken to generate physical representations from CAD models, current Reverse Engineering Technologies are helping to reduce time to create electronic CAD models from existing physical representations. Advantage from utilizing the Reverse Engineering techniques in manufacturing process, especially in the case when worn or broken parts, for which there are no drawings, must be replaced and there is no source of supply. In this contest, Reverse engineering is absolutely required because allows digitising the part geometry to be utilised in CAD/CAE/CAM. Reverse engineering is often required to replace worn or broken parts in which documentation of mechanical components such as drawings, specifications and engineering analyses are lost. As a result application of reverse engineering approaches to gaining speed the product realization process is currently gaining momentum and largely decreases manufacture costs.

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