Rapid Prototyping and Tooling Method - A Review
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Abstract— This research focuses a new method of using data obtained from CT images combined with digital CAD and rapid prototyping model for the surgical planning of difficult corrective and this new application enables the surgeon to choose the proper configuration and location of internal fixation of plate on humerus bone in the field of orthopaedics. This paper presents the procedure for making model of humerus bone using rapid prototyping technologies [RPT]. Production of prototypes for medical modeling (orthopaedics) in general can be classified into two broad categories based on manufacturing process route and type of data available, i.e. designed data and scanned/digitized data. Designed data is data that is created according to a person's idea on computer aided design (CAD) system. For this type of data, the designer has total control to modify, adjust and manipulate his design ideas to serve the functional purpose of his design. Producing models with this type of data is very straightforward and no further data treatment is required. CAD solid model can be directly converted to STL format for use in subsequent rapid prototyping process. For this type of data, the user has limited capability to modify and manipulate the geometry and further processing is required before they can be readily used by rapid prototyping system. For example, further data treatment is needed for Scanned data from computed tomography (CT) and agnostic resonance imaging (MRI) scanners which capture soft and hard tissue information based on density threshold value. The undesired soft tissue data is removed before it is sent to rapid prototyping machine for fabrication.

Key words: Rapid Prototyping (RPT), Rapid Tooling (RT), Computer Tomography (CT), CAD

I. INTRODUCTION

Rapid Prototyping (RP) has become one of the fastest growing new technologies since its introduction in 1986. By means of this technology it is possible build prototypes and touches them in just a few hours, from a CAD file in which the geometry of the model is defined in 3D. These prototypes are used to visualize those complex shapes not easily seen or understood on conventional drawings. It gives to the designer the possibility of verifying the shapes of the product, validate if it fits into the assembly or if it complies with the desired functions. It cuts down the required time to design a product. This technology was covered an industrial applications to speed up the design and manufacturing process. But having a 3D touchable model of what you want to or even wish to build is something that can be useful in lots of fields. It has been used in medical application, arts (jewellery etc.), architecture and it is a potential tool for the mechanical field. In this paper, the design process methodology is described. It tries to be a guide of the logical procedure to introduce RP into a mechanical engineering design process and take the maximum benefit from it. Finally, the case studies illustrate the benefits of this technology applied to the mechanical field.

II. PROBLEM STATEMENT

To study the losses at the air duct junctions, Non-Iterative Method For Testing, Adjusting And Balancing Sizing And Balancing Of The Air Ducts, Natural Ventilation for Passive Cooling, Optimization Of Design Flow Rates.

III. OBJECTIVES

The objectives are as follows:
- To decrease development time.
- To decrease costly mistakes.
- Increasing number of variants of products.
- Decreasing delivery time.

IV. EXPERIMENTATION

A. Thierry Rayna a, Ludmila Striukova [1]

3D printing is a form of “additive” manufacturing where a three dimensional object is printed by adding layer after layer of particular material, which differ from the more usual “subtractive” forms of manufacturing. The first stage of 3D printing involves creating a digital model of the object to be printed. This is usually done with Computer-Assisted Design (CAD) modelling software or using dedicated online services provided by some of the 3D printing platforms. 3D scanners can also be used to automatically create a model of an existing object (just like 2D scanners are used to digitise photos, drawings or documents). When an object is printed, the 3D model of the object is discomposed into successive layers that are printed one at time. Nowadays, the most common material used for 3D printing is plastic (ABS, PLA, Nylon). While 3D printing technologies were, originally, intended exclusively for (heavy) industrial use, the constant decrease in cost has put them within reach of SMEs and individual entrepreneurs. With home 3D printers now being available for less than $1000 (the cheapest printer, the Buccaneer, costs $350), 3D printing is progressively becoming a technology any business, small or large, can afford and a number of companies have already started to integrate 3D printing into their business model. The first 3D printing technologies (stereolithography, selective laser sintering, fused deposition modelling, laminated object manufacturing) appeared in the late 1980s and began operational in the early 1990s. At the time, only plastics could be used. The level of details and quality of finish were rather low, which meant that only ‘rough’ looking objects could be printed. Printing was slow, expensive and restricted to small objects. Consequently, the first application of 3D printing technologies was rapid prototyping, 4 i.e., the ability to rapidly build plastic models of objects. In the second half of 1990s, the advent of 3D printers using heat resistant polymers and metal alloys triggered the second stage of adoption of 3D printing: rapid tooling. Manufacturing processes have always required customised tools: jigs and hardware and, more importantly,
moulds that are used for the ubiquitous injection moulding and die casting manufacturing. Such moulds have traditionally been built by machining (subtractive manufacturing) blocks of steel or aluminium, an expensive (a single mould can cost well above a few thousands of dollars) and lengthy (from a week to above a month, depending on the complexity of the part) process. In this context, mistakes can be quite costly and there is little flexibility in terms of improvement or upgrades of the manufactured objects. In contrast, 3D printing technologies enable to print moulds in a matter of hours, often for a fraction of the cost of traditional tooling (Hiemenz, 2013; Zonder and Sella, 2013), thereby leading to significant savings and opportunities (e.g., low volume production and frequent upgrades). In the late 2000s, the cost of 3D printing began to be low enough (and quality high enough) to start directly manufacturing final products with 3D printers. As noted in Gibson et al. (2010), “speed, quality, accuracy and material properties have developed to an extent that [3D Printed parts] can be made for final use. 5” This led to the third wave of adoption, generally referred to as Direct Digital Manufacturing (or DDM) or simply direct manufacturing, and which implies an entirely digital production process, with end-products directly manufactured using digital (CAD) models and 3D printers, without moulds, casts or machining. The fourth and final stage of adoption, home fabrication has just started. It involves consumers (or end-users) manufacturing objects themselves using 3D printing equipment they have at home. At the moment very few consumers own a 3D printer and those who do are mainly hobbyist and engineering students (Wholers, 2013). While the growth of ‘personal 3D printer’ (i.e., printers costing less than $5000) sales over the past few years has been very significant, with a yearly average growth of 346% between 2007 and 2011 and a yearly growth of 46% between 2011 and 2012 (Wholers, 2013), the sales of personal 3D printers still remain low (35,508 units sold in 2012) in comparison to other consumer electronics products.

Table 1: Adoption stages of 3D printing technologies and resulting involvement in production.

<table>
<thead>
<tr>
<th>Adoption stage</th>
<th>Started</th>
<th>Design</th>
<th>Tooling</th>
<th>Manufacturing</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>Rapid prototyping</td>
<td>Early</td>
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<td>Rapid tooling</td>
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<td>Direct manufacturing</td>
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<td>Home fabrication</td>
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The ability and the extent to which the firm is able to create and capture value is defined by its business model (Øiestad and Bugge, 2014). As noted in Baden-Fuller and Morgan (2010), business models are often hard to define, since they can serve at the same time as scale models, role models and ideal models. Likewise, business model construction often results from both a taxonomy and a typology. As noted in Makadok and Coff (2002), the term ‘value creation’ is often used incorrectly in place of ‘value capture’. While the two may occasionally coincide, this is not always the case and companies may well end-up capturing more (or less) value than what they actually created (Pitelis, 2009). Value creation requires increasing the consumers’ perceived worth of consuming a particular product (Priem, 2007). Once it has happened, consumers’ willingness to pay normally in their work they have concluded that the aim of this article was to investigate the impact of 3D printing technologies on business models and business model innovation. Because 3D printing technologies can be involved at different stages and to a different extent in the production process, four different cases, which correspond to the four progressive stages of adoption of 3D printing technologies, were considered: rapid prototyping, rapid tooling, direct manufacturing and home fabrication. As expected, rapid prototyping and rapid tooling were found to have a limited impact on business models, mainly because, placed within a ‘traditional’ manufacturing process, they merely speed up the process without changing it significantly. Although they may affect cost structures, their impact on value capture is unlikely to be significant. Yet, it was noted that the increasing affordability of 3D printers could, by bringing rapid prototyping to ‘the masses’, significantly increase competition. Yet, the article has shown that one of the key aspects of 3D printing technologies is that they enable to rapidly change and experiment with business models. Indeed, these technologies enable fully adaptive and ‘mobile’ (upstream or downstream, sideways, long or short) business models and bring the rapid prototyping paradigm to the world of business model innovation.

B. Mario Lusic, Simon Hausleidera, Rüdiger Hornfecka[2]

Considering the current trends for energy saving by using lightweight design, carbon fibre reinforced plastics (CFRP) present a possible solution. To produce individual, spatially curved CFRP components in a mass customised way, form-flexible moulds are advantageous. But, as indicated in Fig. 2, the design freedom within the CFRP panel depends on the pin’s size: the larger the pins, the fewer pins must be produced, assembled, maintained, and adjusted by actuators and thus the machine complexity decreases, but the creative flexibility with regard to the design elements that can be mapped within the CFRP panel is restricted.
Fig. 2: The pin size limits the design freedom within CFRP panels.

An alternative approach is assembling miniature attachments on the elastic IPL as introduced in [3]; this is useful in order to be able to manufacture such needed filigree designed panels while still using pin-type moulds with small pin densities. Fig. 3 illustrates an example of miniature attachment geometries, which make possible, e.g., a diameter within the CFRP component that is smaller than the diameter given by the pins (a), an undercut (b), and a nearly right angle(c) for moulding, but retain the pin size and number of the present pin-type mould. The entire CFRP manufacturing process can look like this: firstly, adjusting the existing pin-type mould as near as possible to the CFRP geometry (1/3); secondly, building and placing the corresponding miniature attachment(s) on the IPL (2/3); and thirdly, laminating the CFRP on the shape which is now mapped by the surface of the IPL, including the miniature attachments placed on the IPL (3/3).

Fig. 3: Extending manufacturing limits of already available pin-type moulds by assembling miniature attachments on the IPL.

However, such miniature attachments must fulfil several conditions, which are usual characteristics of pin-type moulds, in order to be attached. The IPL may be uneven after the pin adjustment due to mapping the spatially curved CFRP panels. Furthermore, the IPL may have dimples spread on its entire surface which is due to firmly fixing the IPL on the pins. This can happen, e.g., by applying a vacuum under the IPL but within the space or vacuum chamber where the pins are placed (see Fig. 4) or other types of fixing which result from different kinds of fasteners. In addition, the capacity for non-destructive (dis)assembling is required since the same IPL may be used for subsequent different panel geometries.

Therefore, new flexible and non-destructive disassembly-enabled attachment designs of additive manufactured MA are needed. In their work they have concluded that, in general, the design concepts could be developed and categorised with respect to existing design parameters of pin-type moulds for CFRP laminating, such as different IPL materials, thicker/thinner IPLs, larger/smaller pins and dimples, different pin geometries (e.g. triangle or squares), etc. Finally, if the creative design process is continued, entirely new solutions are imaginable, such as: fixing by magnetic force flow to the pins if these have favourable magnetic properties, attaching via rasterised assembly insert positions within the IPL, adhesive joints, etc.

C. Dheeraj Nimawat, Mahaveer Meghvanshi [3]

Figure 1 shows the process where researches can differentiate perfectly the necessary steps to obtain the model. The process is divided in four stages: First stage: it is based on designer’s idea. As we know that any project begins with an idea, a sketch made by the designer by hand or by means of a design software, or with a scale model made by hand of any material. The two important aspects of this stage are the idea (which is in the designer’s mind) and the initial given information for the accomplishment of the project, as main dimensions, surrounding constraints or others. Second stage: - It is based on modelling in the computer. It is the logical step, to work with the computer, by means of bidimensional CAD software; researches will make the necessary section, sketches and all details for the correct understanding of the original idea. It is not really necessary to start always with a 2D model, but it is quite helpful in making 3D CAD models during the creation of the solid model.
An mechanical component that is impeller casting development. The pattern (Figure 5) was reverse engineered using Renishaw Cyclone Laser scanner for getting the Cloud of points (CoPs) (Figure 6). Firstly, CAD model (Figure 7) was generated using Image ware surface software. STL format of the CAD data was used for generating FDM pattern with plastic material (Figure 8).

![Image](https://via.placeholder.com/150)

The STL file was sent over Internet to an RP facility with an FDM machine. This FDM pattern was used for Aluminum sand casting (Figure 2.1.5). In their work they have concluded that, The use of Rapid Prototyping technologies is essential in any design fields. Although it was conceived as an medical application, arts, architecture applications, the mechanical field can also take benefit from this technology. It gives the mechanical engineer, the possibility to visualize those complex shapes not easily seen or understood on connectional drawings, and touch them to verify the shape. It can be used to in early design stages to build a conceptual model or in later stages when details are needed. Complex shapes can be obtained using surface and solid modeling CAD software, and then build the physical model. In a few hours the model can be built easily, in a similar way as a 2D drawing is plotted. In a short time, rapid prototyping will become a technology that will be used routinely by many design engineers in conjunction with the traditional existing ways of creating scale models of mechanical parts.

D. Mr. D. Chandramohan, Dr. K. Marimuthu[4]
Methodology of Rapid Prototyping
- CAD solid model
- ‘.STL’ file
- Slicing the file
- Final build file
- Fabrication of part
- Post processing

These technologies are still in their developing stage. Due to the economic and material constraints it has to cover a long way, before it can be fully commercialized. The major problems in the current systems include part accuracy, mechanical performance and limited material variety.

1) Part Accuracy
The main errors in developing CAD to get accurate prototype are: mathematical, process and material related.

2) Mathematical Related
It includes fact approximation of the part surface in the standard input to the prototyping system, limited layer resolution along the Z- direction, such as stair steps and accuracy of vertical dimension.

A 5 axis CNC technique milling machine is developed to eliminate the steps in newly developed Rapid prototyping. These machines also maintain the accuracy of vertical dimension by away the excess material.

3) Process related
These include the error in the shape along X-Y and Z axis. This mainly depends on the accuracy of prototyping machine and operator experience.

4) Material Related
Material related error occurs due to shrinkage and distortion. Sometimes the shrinkage is not identical along X, Y and Z-axis. So, during solidification stress may be developed in different sections.

This effect can be minimized by selecting appropriate manufacturing control parameters, exploring new materials with relative small shrinkage and stress relief methods.

For SLA system, 3D systems uses star –weave method to limit distorting by curing more resin in the vat, hatching inside cross sectional area on each layer.

5) Various Prototyping Processes

![Image](https://via.placeholder.com/150)

- Stereolithography (SLA)
- Laminated Object Manufacturing (LOM)
- Selective Laser Sintering (SLS)
- Fused Deposition Modeling (FDM)
- Solid Ground Curing (SGC)
- 3D-Printing (3DP)

In their work they have concluded that, RP technologies are definitely widely spread in different fields of medicine and show a great potential in medical applications. Various uses of RP within surgical planning, simulation, training, production of models of hard tissue, prosthesis and implants, biomechanics, tissue engineering and many other cases open up a new chapter in medicine. Due to RP technologies doctors and especially surgeons are privileged to do some things which previous generations could only have imagined. However this is just a little step ahead. There are many unsolved medical problems and many expectations from RP in this field. Development in speed, cost, accuracy, materials (especially biomaterials) and tight collaboration between surgeons and engineers is necessary and so are constant improvements from RP vendors. This will help RP technologies to give their maximum in such an important field like medicine.

V. CONCLUSION
This paper provides an overview of RP technology in brief and emphasizes on their ability to shorten the product design and development process. Classification of RP processes and details of few important processes is given. The description of various stages of data preparation and model building has been presented. An attempt has been made to include some important factors to be considered before starting part deposition for proper utilization of potentials of RP processes.
Finally, the rise of rapid prototyping has spurred progress in traditional subtractive methods as well. Advances in computerized path planning, numeric control, and machine dynamics are increasing the speed and accuracy of machining. Modern CNC machining centers can have spindle speeds of up to 100,000 RPM, with correspondingly fast feed rates. Such high material removal rates translate into short build times. For certain applications, particularly metals, machining will continue to be a useful manufacturing process. Rapid prototyping will not make machining obsolete, but rather complement it.

REFERENCES
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