New product design using prototype manufacturing using CAD-CAM-CAE 3D printing and Analysis

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ABSTRACT

This research focuses a new method of using CAD software combined with rapid prototyping (RP) for mold design. CAD software and RP reduces the time required to generate the internal and external features of a tool by automating frequent or repetitive tasks, importing pre-configured standard components, and avoiding errors by following user-specified rules of mold design.

Injection molding has been a challenging process for many manufacturers and researchers to produce products meeting requirement at the lowest cost. The quality of molded part can be classified into four categories: part design, mold design, machine performance and process conditions. The development of unique technologies for high accuracy, high speed injection molding machine including a high rigidity, high speed driving mechanism and high dispersion, high speed plasticization mechanism through the structure analysis technology, flow analysis technology and control simulation technology. The each process variable can be categorized into one of five main types such as speed, pressure, time, Temperature and stroke. The cooling time period is depended on the general shape of the component, the wall thickness of the component, and type of material being processed. The cooling time can represent more than 70% of injection cycle. The cycle time can be reduced by reducing the cooling time. We also perform multiple optimization simultaneously minimizing cycle time, wasted materials, and pressure drop.

Keyword: *Injection Molding, Injection Mold Design Finite Element Analysis (FEM), Rapid Prototyping (RPT); Rapid tooling (RT); CAD software's, 3D printing*

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1. INTRODUCTION

Today's typical mold-design CAD package features programs or modules to build and view a full representation of the mold, which includes generating core and cavity from the part model, parting-line splits, optimization of parting surfaces, mold-base selection, and addition of shutoffs, cooling lines, runner systems, gates, slides, lifters, ejectors, columns, spacers, guides, nozzles, screws, and pins. Mold-design software may also contain or link up with on-line libraries of standard mold components. These parts can then be imported directly into a 3D solid or surface program. Mold CAD software suppliers have not only improved many of these mold-planning functions, but are bringing in a host of additional or enhanced capabilities, such as more graphic visualization tools, preliminary mold designs for "quick quoting," rapid modeling of EDM electrodes for special part features, and the ability to create and manipulate holes, pockets, cavities, or side actions. Constructors have been using 3D printing (or additive manufacturing) for as long as 20 years. The first commercial 3D printer was originated by Charles Hull around 1986 and his company 3D systems suggested it for sale. The machine he used employed stereo lithography. A laser is to stiffen polymer material where the laser touches.

1.1 PARAMETER CONSIDERATION FOR MOLD DESIGN

Molding conditions effects on the final properties of the material regardless of the part design. Two of the process conditions that have a substantial influence on the behavior of the polymer are the melt temperature and mold temperature. It is important to distinguish between these process conditions and the set point that use to exercise control over them. Melt temperature is the actual temperature of the polymer as it exits the nozzle and enters the mold. The barrel set points are different at the melt temp.
The mechanical work imparted to the material, the residence time, and the condition in determining the actual melt temperature.

The actual surface temperature of the mold cores and cavities and fluid passing through the channels in the mold are same. Mold temperature has perhaps a less obvious but often more profound effect on final properties.

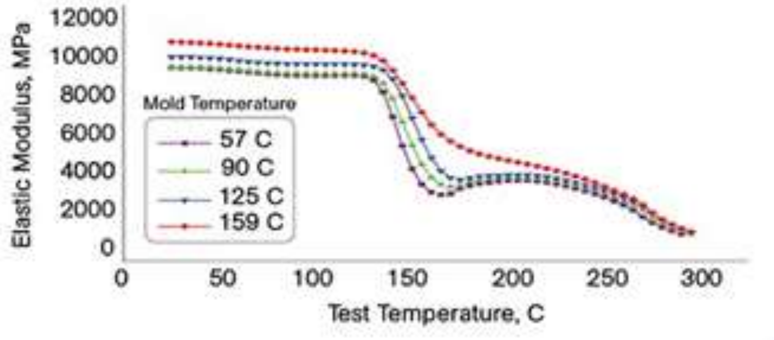


Fig1.1 Effect of Mold Temperature on Modulus Vs Temperature Behavior of PPA

1.2 TIME TO CRYSTALLIZE

In semi-crystalline materials, the ideal temperature of mould will be above the glass-transition temperature in order to give the polymer adequate time to crystallize. Figure 1 compares the behavior of high-temperature nylon (PPA) when molded at the proper mold temperature and at lower mold temperatures. The plot shows the modulus of the material as a function of temperature. As the mold temperature increases, the stiffness of the material at room temperature also increases.

In determining the impact performance of ABS, an amorphous polymer typically selected for its toughness. As the mold temperature is varied and adjacent from 218 to 271c It may be surprising to some that the impact resistance ranges from less than 2 N-m (1.4 ft-lb) to almost 50 N-m (36.5 ft-lb) simply as the result of these process changes.

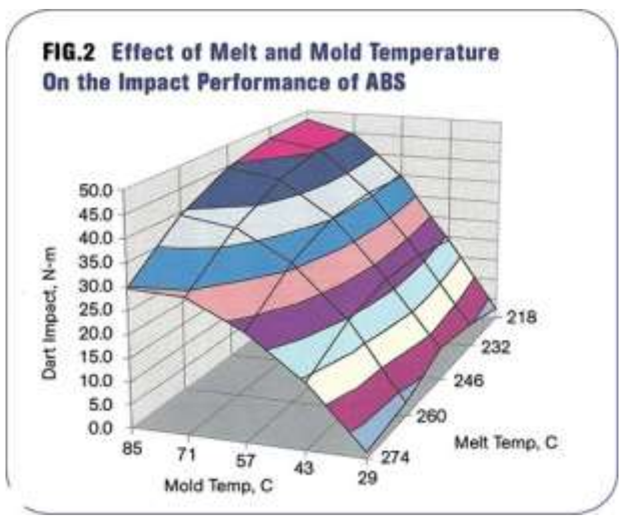


Fig1.2 Effect of Melt and Mold Temperature on Impact Performance of ABS

The mold temperature is the dominant factor; however, the best results are obtained when higher mold temperatures are combined with lower melt temperatures. The ideal range of processing conditions, as well as those conditions that should be avoided, are very apparent in this plot.

1.3 **INDEPENDENT VS. INTEGRATED**

Mold making CAD software comes from a variety of sources. There are independent packages from companies Mold and Die Design Solutions. In truth, they do not run on their own, but as an add-on to other vendors' CAD packages. A mold-design module may be part of a CAD package designed firstly for part design. Mold-design modules are also part of software packages whose main focus is on CAM for machining.

Tying the mold-design software to part design CAM can help reduce errors in understanding the design or manufacturing intent, avoids data-translation issues, and can allow for more rapid adjustments to revisions.

Integrating is used to create part design, CAM software specifically for plastics molds. If designer are using the same software, it creates a same data features. When there is a change to the product, it also changes the mold plan. Integrated can lost time in data translation and reprogramming. So having an integrated solution and working within the same data structure is important

2. General Principle

2.1 Modeling

3D printable models may be created with a computer aided design(CAD)package.3D scanning is a process of analyzing and collecting digital data on the shape and appearance of real object base on these data three dimensional models of the scanned object can then be produce. The 3D model software is used, to be converted to either a .STL or a .OBJ format.

2.2 *Printing*

Before printing a 3D model from an STL file, it must first be examined for "manifold errors", this step being called the "fixup". STL's that have been produced from a model obtained through 3D scanning often many small errors in them that need to be fixed. Examples of software that can be used to fix these errors are net fabb and Mesh mixer, or even Cura, or Slic3r.

2.3 Finishing

The printer produced resolution is applicable for many applications, printing or slightly oversized version of the desired object in the standard resolution and then and removing material with higher resolution subtractive process can achieve greater precision. Some printable polymer allows the surface finish to be smooth and improved using chemical vapor process. The entire metal 3D printer involves cutting the metal component off of the metal subtract after deposition.

Fig.2.1-3D Sample of the product

3. NEW PRODUCT DEVELOPMENT (ALUMINUM EXTRUSION COVER)

If **A**t first after finalizing the concept we started creating the 3D model in **Unigraphics Nx6.** It took us around 3 hours. After this activity we created the drawing of the model for cross checking purpose. Then we used this model for **3D Printing** Purpose. After receiving the prototype we used it for.

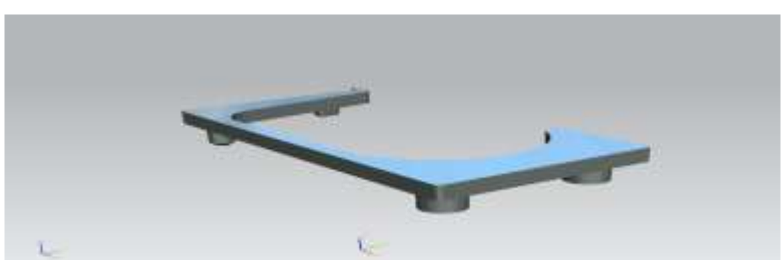


Fig.3.1 CAD Model

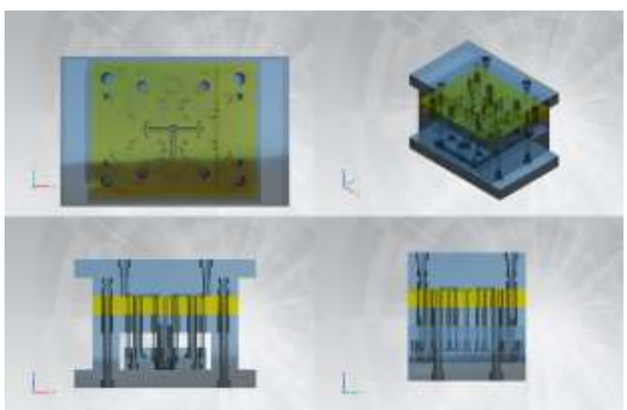
3.1 Material used

Acrylonitrile-Butadiene-Styrene (ABS) is one of the most widely used and versatile thermoplastics.
The three monomers are added together in specific proportions as15-35% acrylonitrile, 5-30% butadiene and 40-60% styrene. A small change in even one of the monomers can create drastic changes in the mechanical and physical properties of ABS

Fig 3.1.1 ABS physical/mechanical properties as a function of monomer content

3.2 PLASTIC INJECTION MOLDING

Molding is a manufacturing technique for making parts from plastic material. The molten plastic is injected at high pressure into a mold, which is the inverse of the desired shape. The mould is made by a mold maker from metal, usually either steel or aluminum, and processed by using precision-machined to form the features of the desired part. Injection molding is very widely used for manufacturing a variety of parts, from the simple shape of smallest component to entire complex body panels of cars. It is the most common method of production
A use of Molding is to get molds Tool Used to Get a Number of Plastic Components of Identical Dimension.



3.2.1- Product Mould Design-4 Cavity Mould

4. RAPID PROTOTYPING PROCESS

Rapid prototyping is ancient technique used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

The main enabling technology behind time compression engineering is 3-D computer-aided design modeling. Development time can reduce if part design and manufacturing are carried out frequently. This can also allow engineers to be creative by providing more time for design iterations.

Rapid prototyping models are widely used in many industrial sectors. Initially conceived for design approval and part verification, rapid prototyping now meets the needs of a wide range of applications, from building test prototypes with material properties close to those of production parts, to fabricating models for art and medical or surgical uses.

4.1 THE BASIC PROCESS

Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are:

1. Create a CAD model of the design
2. Converts the CAD model to STL format
3. Slice the STL file into thin cross-sectional layers
4. Constructs the model one layer at another.
5. Clean and finish the model

4.1.1 CAD Model designing:

First, the object is to do part modeling using a Computer-Aided Design (CAD) software package. Solid modelers, such as PRO/ENGINEER, tend to represent 3-D objects more accurately than wire-frame modelers such as AutoCAD, and will therefore yield better results. The designer uses a pre-existing CAD file to create part design for prototyping purpose. This process is identical for all the RP build techniques".

4.1.2 Conversion to STL Format:

CAD packages are used at number of different algorithms to represent solid objects. Firstly, the STL (stereo lithography, the first RP technique) formats are being used as the standard of the rapid prototyping industry. In second step convert the CAD file is into STL format. This format represents a three-dimensional surface as an assembly of planar triangles, "like the facets of cut jewel." The file contains the co-ordinates of the number of the vertices and the direction of the outward normal of each triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation, but at the cost of bigger files size. Bulky files may require more time to pre-process and build, so it is necessary to balance accuracy with manageability to produce a useful STL file. The *.stl format is standard this process is identical for all of the RP build techniques.

4.1.3 Slice the STL File:

After converting STL file format a pre-processing program prepares the STL file to be built. Several programs are available, and most allow the user to adjust the size, location and orientation of the model. Build orientation is important for several reasons. First, properties of rapid prototypes vary from one co-ordinate direction to another. Sometime prototypes are usually weaker and less accurate in the z (vertical) direction than in the x-y plane. A part design model orientation is to determine the amount of time required to build the model partially. By placing the short dimension in the z direction can reduces the number of layers, so it shortening builds time. Depending on the build technique the pre-processing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm thick. The program can be generating an auxiliary structure to support the part model design during the build. Supports For overhangs, internal cavities, and thin-walled sections supports are useful

4.1.4 Layer By Layer Construction:

Last but not the least step is the actual construction of the part. Using many types of techniques rapid prototyping machines build one layer at a time from polymers, paper, or powdered metal.

4.1.5 Clean and Finish:

The final step is post-processing. This involves removing the prototype from the machine and detaching any supports. Photosensitive materials have to be cured before use. Prototypes required cleaning and surface treatment frequently. Other properties such as Sanding, sealing, and/or painting the model will improve its appearance and durability.

4.2 FUSED DEPOSITION MODELING

In these techniques, filaments of heated thermoplastic are extruded from a tip that moves in the x-y plane. Like a baker decorating a cake, the controlled extrusion head deposits very thin beads of material onto the build platform to form the first layer. The platform is maintained at a lower temperature, so that thermoplastic quickly hardens. After the platform lowers, the extrusion head deposits a second layer upon the first. Supports are built along the way, fastened to the part either with a second, weaker material or with a performed junction.

Stratasys, of Eden Prairie, MN makes a variety of FDM machines ranging from fast concept modelers to slower, high-precision machines. Materials include ABS (standard and medical grade), elastomer (96 durometer), polycarbonate, polyphenolsulfone, and investment casting wax

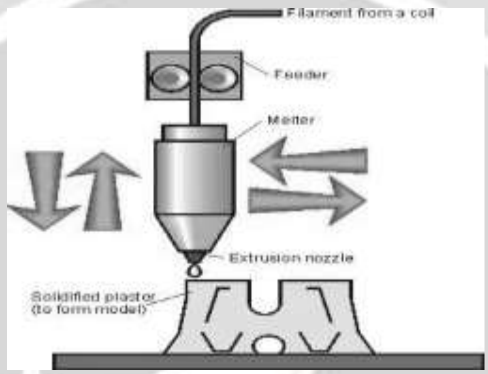


Fig 4.2.1- Fused Desposition Modeling

5 ANALYSIS (CAE)

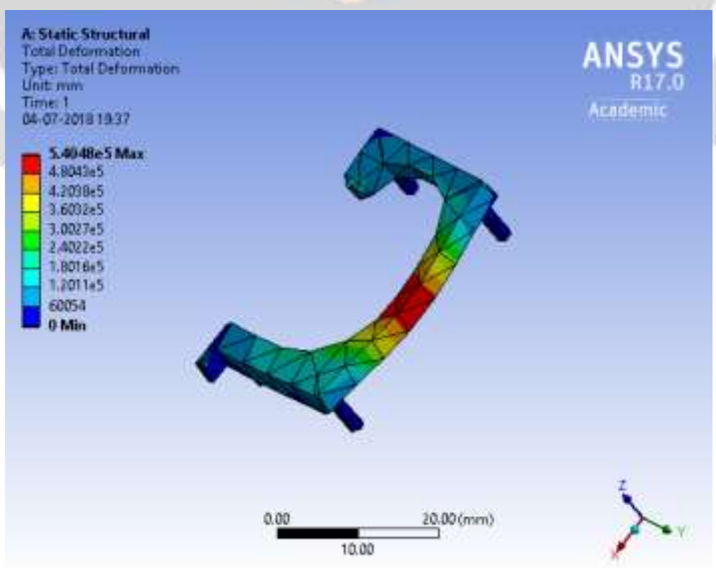


Fig.5.1-Total Deformation analysis of the product

Study name	Stress Analysis of Product
Analysis type	Static
Mesh Type:	Solid Mesh
Thermal Effect:	Input Temperature
Zero strain temperature	298.0
Units	Kelvin

Table No.5.1.2-Study Properties

Unit system:	SI
Length/Displacement	m
Temperature	Kelvin
Angular velocity	rad/s
Stress/Pressure	N/m^2

Table No-5.1.2 Units

No.	Body Name	Material	Mass	Volume
1	Cover	PC High Viscosity	0.166641 kg	0.000140035 m^3

Material name:	ABS
Material Source:	Library files
Material Library Name:	cosmos materials
Material Model Type:	Linear Elastic Isotropic

Table No-5.1.3 Material Properties

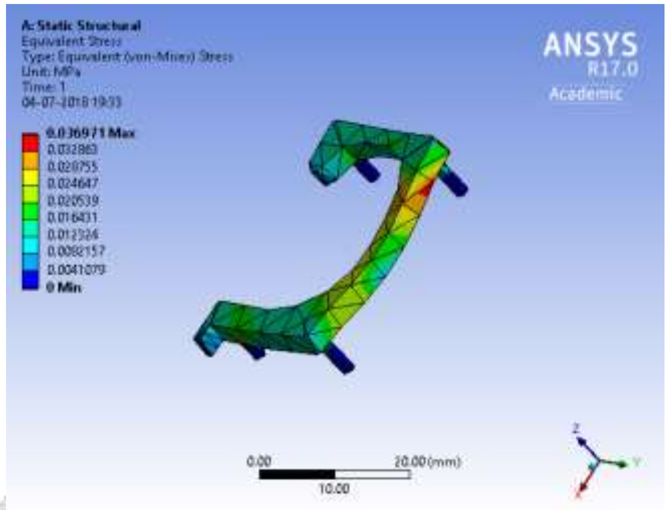


Fig.5.1.2- Equivalent Stress

6. OPTIMIZING CONFLICTING GOALS

A thermoplastic molding challenge is cycle time is considered when it is as cooling time vs. distortion. These goals are conflicting: Shorter cooling time makes for a hotter part at mold open and likely leads to greater shrinkage outside of the mold (where there is no mold to hold it in shape), which results in a distorted part. A longer cooling time allows the part to cool more inside the mold, where it's constrained (mostly), holding the part in place until it has higher strength. It shrinks less outside the mold and typically has less distortion. The objective is to find a way to reduce the part temperature at ejection and *also* reduce the cooling time in the mold.

The new, automatic approach is quite different. The software operator sets up the initial design, which includes objectives. Variables and constraints. The software automatically produces each future variant (simulated design) by changing the process and/or geometry in milliseconds, generates the mesh, queues it up for calculation, runs the simulation, and plots the results of the objectives. The results of all variants are plotted in a single chart so the operator can easily determine which of the variants produce the results that most closely meet their objectives. Two very common problems molders encounter are determining the best gate location and the fastest possible cycle time. But there are other objectives too, all involving part quality. Parts must meet dimensional, aesthetic and mechanical requirements. With autonomous optimization, multiple objectives are used one by one to ensure molders don't end up with undesirable outcomes, such as finding the lowest pressure to fill a cavity but also finding that it creates weak weld lines, or determining the route to the least amount of trapped air but finding that it requires the highest melt pressure.

7. Future Developments

Rapid prototyping is starting to change the way companies design and build products. On the horizon, though, are several developments that will help to revolutionize manufacturing.

One such improvement is increased speed. "Rapid" prototyping machines are still slow by some standards. By using faster computers, more complex control systems, and improved materials, RP manufacturers are dramatically reducing build time. Continued reductions in build time will make rapid manufacturing economical for a wider variety of products.

Another future development is improved curacy and surface finish. Improvements in laser optics and motor control should increase accuracy in all three directions. In addition, RP companies are developing new polymers that will be less prone to curing and temperature-induced war page.

The introduction of non-polymeric materials, including metals, ceramics, and composites, represents another much anticipated development. These materials would allow RP users to produce functional parts. Today's plastic prototypes work well for visualization and fits tests, but there often too weak for function testing. More rugged materials would yield prototypes that could be subjected to actual service conditions. In addition, metal and composite materials will greatly expand the range of products that can be made by rapid manufacturing. The field of rapid prototyping is just over ten years old. In spite of this, significant progress has been made in widening the use of this technology and in the development of new processes and materials. To achieve long-term growth in this field and realize its full potential, a number of challenges remain. These challenges could be grouped under the following categories.

8. CONCLUSION

Rapid prototyping process indicates the possibility of its application in various fields. It can be concluded that RP printing technology is the most fascinating for mold design, especially in the development of plastic mold design technologies are definitely widely spread in different fields and show a great potential. Applications of CAD software and rapid prototyping combine improves efficiency, saves time and man, machine and material.We have designed the product using CAD software, done the prototype using the 3D printing process.Thus our project aims at the awareness of advances of the new age technology of CAD/CAM/CAE & 3D printing Process

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