3D Printing Technology

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***Abstract*- Once again we are facing a new decade and we have to wonder what the next dominant technology likely to change our way of life is the free energy device, our best is the technology called 3D printing which as the name implies is a technology that literally prints real 3D objects. It is used by the marketing industry to create models for marketing focus groups and pre-production sales demonstration.**

Originally developed at the Massachusetts Institute of Technology (MIT) in 1993, .3DP technology creates 3D physical prototypes by solidifying layers of deposited melted material using a heater. By definition 3D Printer is an extremely versatile and rapid process accommodating geometry of varying complexity in hundreds of different applications, and supporting many types of materials. 3D printer are developed to operate at unprecedented speeds, extremely low costs, and within a broad range of applications. 3D printers are used by almost leading manufacturers to produce early concept models and product prototypes .This paper describes the core technology and its related applications.

Keywords- barely noticeable, change the way of our industry, the next dominant technology, 3D printing, 3D objects

I. INTRODUCTION

3D printing or Additive manufacturing is a process of making a three-dimensional solid object of virtually any shape from a digital model. 3D printing is achieved using an *additive process*, where successive layers of material are laid down in different shapes. 3D printing is also considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling (*subtractive* processes).

The 3D printing technology is used for both prototyping and distributed manufacturing applications in architecture, construction(AEC),industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech (human tissue replacement), fashion, footwear, jewelry, eyewear, education, geographic information systems, food, and many other fields. 3D printing could become a mass market item because domestic 3D

printers can offset their capital costs by enabling consumers to avoid costs associated with purchasing common household objects.

II. 3D PRINTING – BASIC PRINCIPLES

Imagine a paper feed in your ink jet printer ever got stuck; you saw the same line being printed over and over as the drying ink built up. Same is the essence of the principle of 3D printing. In normal ink-jet printing, the 2D (two dimensional) printing program steers the printing nozzle from right to left and instructs for deposition of ink droplets to form a line of drawing or of text. When the paper advances the width of the line, the next pass of the nozzle deposits a slightly different pattern. Thus line by line the complete text or the drawing is formed. After the whole page has been printed, a new sheet of paper is inserted and a new text or a new drawing is printed. In 3D printing, after the first layer has been completed, either the vertical position of the nozzle is raised which is equal to the thickness of good quality paper, or the supporting table is lowered by an equivalent amount, and the process is repeated. In order to build an object the controlling drawing for each layer changes very slightly.

III. THERE ARE THREE BASIC METHODS OF 3D PRINTING

A. *FDM - Fused Deposition Moulding*

Also called FFF (Fast Filament Fabrication), is the simplest method wherein thermoplastic material gets deposited through heated nozzle steered by the design program. Invented in 1988 this technology uses primarily thermoplastic or polycarbonate materials supplied in spools of thread that are fed into the printing nozzle.

B. SLA - Stereo lithography

In this a thin layer of liquid photopolymer is laid as per the design and is solidified by an ultraviolet laser beam. The un-solidified resin is reused. It was invented in 1984 by Charles Hull. Photopolymer resins that are cured with ultraviolet radiation, such as ABS (Acrylo-nitrile butadiene styrene) are supplied as liquids.

C. *SLS - Selective Laser Sintering*

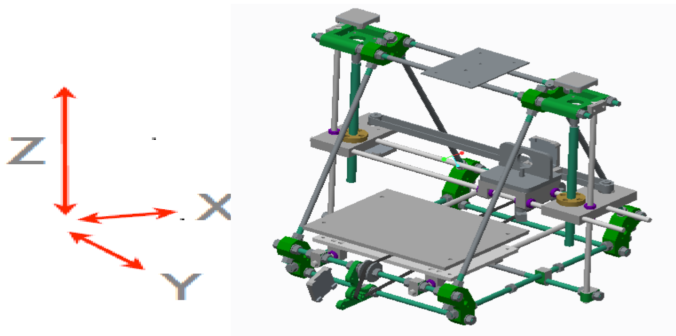
A thin layer of fine powder is deposited, then solidified (sintered) by a high energy pulsed laser beam. The unused powder serves as a support for the object being built, then is reused. It was invented in 1986 by Dr. Carl Deckard at the University of Texas. Fine powders of many metals, including titanium, gold, silver also glass and ceramics is used.

IV. HOW DOES 3D PRINTING DIFFER FROM RAPID PROTOTYPING?

Rapid prototyping refers to a broad category of processes used to build models layer by layer from computer-generated STL data. Two common forms of rapid prototyping are stereo lithography (SLA) and selective laser sintering (SLS).

In the process, filaments of plastic modelling material and soluble support material is fed from auto-loading carriers in the material bay up to the extrusion head. There, the material is heated to a semi-liquid state, forced through dual extrusion tips and precisely deposited onto the modelling base in extremely fine layers. The print head moves in Z coordinate, and the modelling base moves in the X-Y-axis as the model and its support material are built from the bottom to up, layer by layer. After the build is complete, the support material is removed, and the model is ready to use. 3D Printing technology is often faster and less expensive than other rapid prototyping methods and is especially valuable when creating concept and working models early in a design process. The small size of 3D printers enables them to function as office equipment that stays within department. By comparison, large rapid prototyping systems often need to be centrally located and run by a dedicated staff of experts.

V. HOW DOES 3D PRINTING WORK?



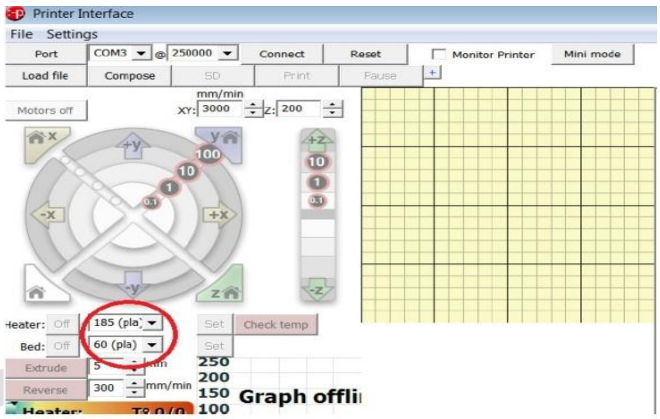
(Fig1.1)

The printing head is lifted layer by layer at a time in the Z axis. The table is controlled in the X-Y axes. The home position (0,0,0) of 3D Printer can be selected as per requirement. The plastic filament (thread) is feed into a heated extruder (like when you pull the trigger on a hot glue gun). The plastic melts and comes out of the extruder head nozzle which is 0.4mm in diameter. Being molten, it melts the surface of the material it touches to bond and build a new layer.

The fundamental purpose of a 3D printer is to quickly transform an idea into a physical object. That idea is usually first embodied in a 3D computer model created in 3D CAD software like Solid Works, Auto desk Inventor or Pro/ENGINEER.

All of these software tools export 3D models as files in standard formats for 3D printing, including .STL, .WRL (VRML), .PLY, .3DSand .ZPR. The exported file is a mesh or series of triangles oriented in space that enclose a 3D volume. This mesh must be "water tight". With the file now in a printable format, you open pronterface software on your PC. Using pronterface, you can scale up or scale down the file you wish to print, orient the part in the build chamber, and direct the 3D printer to print multiple versions of the part in the same build (with or without variations).Then Pronterface slices the 3D model file into hundreds of digital cross-sections, or layers. Each 0.004 inch (0.1 mm) slice corresponds to a layer of the model to be fabricated in the 3D Printer. When ready to start the print job, you click "3D Print." This sends the digital layer files to the 3D Printer, and the model begins printing immediately. The 3D Printer prints each layer, one a top another, as the physical part is constructed within the build area of the machine. Once the final layer is laid the printing is said to be complete. Then the physical object can be removed.

A. Pronterface software workbench



(Fig1.2)

B. CAD Software

CAD software exports files in standard formats for 3D printing.

(Fig.1.3)

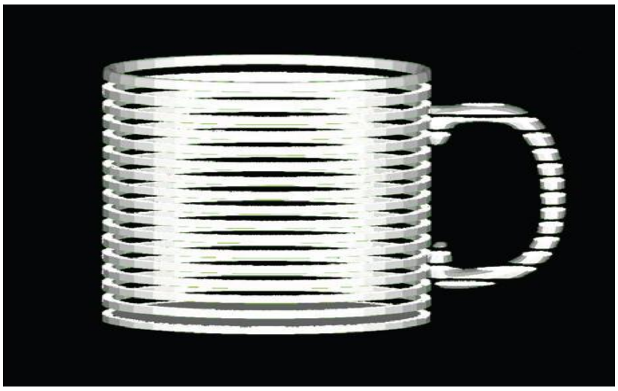
C. *Mesh*

The exported file is a mesh that encloses a 3D volume.

(Fig.1.4)

D. Dividing into slices

Pronterface software slices the 3D model file into hundreds of digital cross-sections, each corresponding to a layer of the model to be printed.



(Fig.1.4 a)

E. Finished Model

Each layer is printed one atop the other until the model is complete.

(Fig.1.4 b)

VI. MATERIALS USED

Although there is wide range of filament types, a 3D printer can handle ABS and PLA plastic are by far most popular. These two plastic are readily available in a staggering amount of colours, even glow in the dark

(Fig.1.5)

A. PLA

It is a thermoplastic derived from natural sources and has excellent print qualities. It flows at a relatively low temperature, starting at 185^0c to190^0c and does not required heated build platform. Objects made out of PLA are rigid and more brittle than ABS. PLA is also preferred over ABS when used in areas with poor ventilation due to its relatively non-offensive smell.

B. ABS

It is a synthetic thermoplastic commonly used in the automotive industry and also has excellent print qualities. It flows at temperature starting at 195^0c to 200^0c, but can be extruded at higher temperature than PLA due to its chemical stability, but required heated build platform. Objects made out of ABS are rigid and tend to bend before braking, unlike PLA. Lastly proper ventilation is must due to the offensive fumes generated when printing ABS.

VII. ADVANTAGES

A. 3D printers are easy to use

The straightforward user interface and simple part-making process make 3D printers accessible to everyone involved in product design. The materials used are non-toxic, completely safe, and do not require specialized operating environments such as a lab or a shop. Users can operate 3D printer right in an office rather than in a designated space with specialized requirements. The reliable technology allows its 3D printers to run unattended during the printing process, reducing user interaction to the simple setup and part removal steps, which generally take less than one hour.

B. *Speed*

3D Printers are the fastest.5-10x faster than other RP technology. A part can be printed at rate of 25mm vertical per hour. In today’s competitive global market speed in product development has become a critical factor for success.

C. Affordability

3D printer sets the standard for affordability in 3D printing. Because 3D printers leverage standard inkjet printing technology, they are more reliable and affordable. The application of modular design techniques to the printer’s electronics, printing, and maintenance components makes the printers efficient to maintain with minimum downtime, further reducing costs. The approach results in material usage costs that are a fraction of other rapid prototyping technologies.

VIII. DESIGN

A. Lead screw

- Now torque required for lifting load T=2.5(5.5)*tan(11.309+9.84) /2 = <u>2.658Nmm</u>

- Now torque required to lower load T=2.2(5.5)*tan(11.309-9.84)/2= 0.175Nmm
- $\Phi > \alpha$, As 11.3 > 9.84 ; The screw is self locking.
- η = 44.8%
- The transverse shear stress in screw, $\tau_s = W/(\pi d_c t *z)$ = 2.5/(π*3*2.5*z). Let z =3. Thus τ_s =2.5/(π*3*2.5*3)= 0.0354 N/mm^2

  Thus the design is safe as $\tau_s < \tau_{max}$.
- The transverse shear stress in nut,$\tau_n = W/(\pi dt z)$=2.5/(π*12*2.5*3)=8.84x10^{-3}N/mm^2

  Thus nut is also safe in design.
- Bearing pressure, $S_b = 4W/[\pi(d^2-d_c^2)*z]$= 4*2.5/[π(12^2-9^2)*3]=0.0168 N/mm^2

  As the bearing pressure is less than permissible bearing pressure the design is safe.

B. Shaft

From vertical bending moment diagram,

- M_c = 5*250 = 1250 N/mm (at centre of shaft)

Thus, 118.8 = 16(1.5*1250)/(π* d^3) Hence d = 4.315mm.

- Selecting standard size as 8mm.

C. Coupling

- Outer diameter of hub, d_h = 2d= 10mm
- Length of hub or effective length of key, l_h= 1.5d= 7.5mm
- Pitch circle diameter of pins, D =3d = 15mm
- Thickness of output flange, t= 0.5d= 2.5mm
- Thickness of protective rim, t_1 = 0.25d= 1.25mm
- Diameter of pin, d_1= 0.5d/(N)$^{1/2}$ = 0.5*5/(6)$^{1/2}$= 1.02mm
- Outer diameter of bush is given by M_t= (D_b^2*D*N)/2= 5.573mm
- Effective length of bush, l_b= D_b=5.573mm

D. Dimensions of key

- Length of key, l= l_h= 7.5mm
- Breadth of key, b = 2mm
- Height of key, h= 2mm

E. Checking for shear

- Shear stress on key, τ = 2* M_t/(dbl) = 2*1398/(5*2*7.5) = 37.28 N/mm^2

As the shear stress developed is less than the permissible stress key is safe in shear.

F. Checking for crushing stress

- Crushing stress, σ_c = 4 M_t/(dhl)=4*1398/(5*2*7.5)=74.56 N/mm^2

As the crushing stress is also less than permissible stress key is safe in crushing.

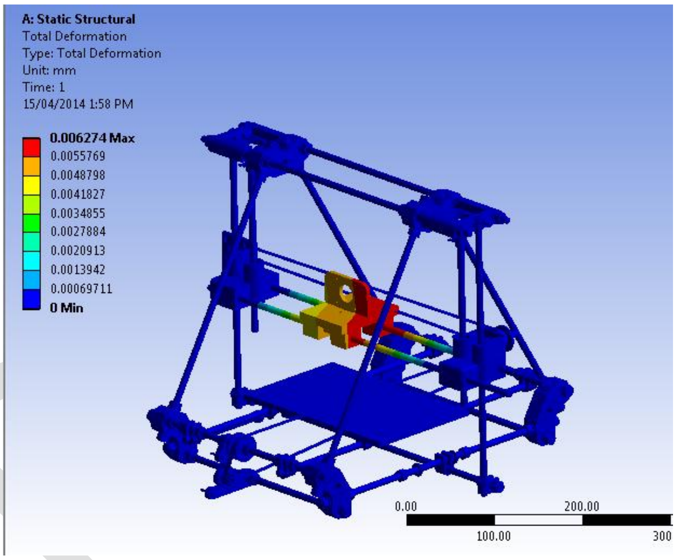
G. Timed belt and pulley

- Pitch code 24 MXL
- Belt pitch in mm = 2.03
- Standard widths in mm = 10

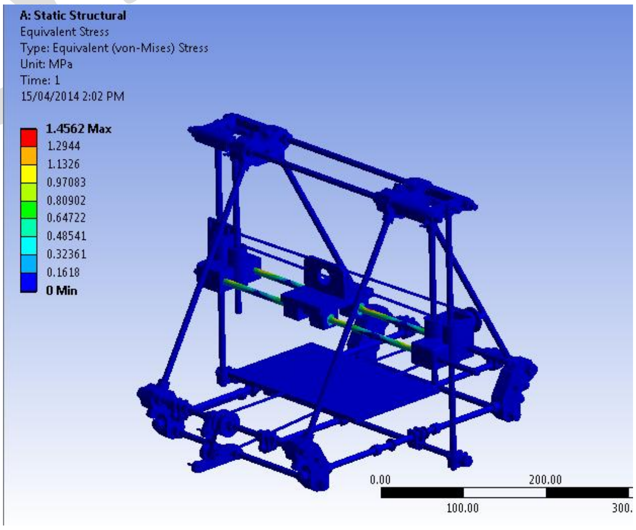
IX. ANALYSIS

The overall analysis of the structure is safe.

- *Deformation*



- *Stresses*



X. APPLICATIONS

***A.* Industry**

Fast prototyping of new designs for testing small quantity production runs, example: spare parts for obsolete models. Fabricating moulds quickly at low cost.

B. Entertainment

Producing sets and various objects for stage, film and TV. Custom built toys in small quantities.

C. *Art*

Producing three dimensional objects that would otherwise be almost impossible, including unusual jewellery.

D. Architecture

Making models directly from drawings.

E. Research

Building models that are easily modified for testing.

F. Medicine

Developing tissues and structures from individual's own cells.

CONCLUSION

3D Printing is the method of converting virtual 3D models into physical model. After the arrival of 3D Printing futurist predicted that we'd soon see them in every home. In future consumers will probably make what they want at home with their own 3D Printers. If some want a latest fashion toy. They will buy the 3D file instead of the product. One day we may have 3D Printer that use nanotechnology to create products by depositing them atom by atom. Simple machinery has been created at the atomic scale such as small wheels, transistors and "walking DNA". These could be the precursors to more advanced custom manufacturing system.

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