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Design and Analysis of FDM based 3D Printer

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***Abstract*: Fused Deposition Modelling (FDM) is an Additive Manufacturing Technology for printing 3D objects layer wise. The main objective behind the research is to design and analyze a cheap 3D-printer using readily available materials and methods for fabrication which can be used to print objects confined within 200 x 200 x 200 (in mm) printing area. After a thorough market survey, we came to a conclusion that 3D Printers available in the Indian market cost around Rs. 50k to 60k due to difference in type of supporting material used. Firstly, we designed our 3D Printer model in 3D Modelling Software SOLIDWORKS and analyzed each part and selected readily available material appropriately so as to build a cost effective printer. Main objective of research is to develop a printer which is cost effective and to encourage manufacturers to adopt the method of 3D Printing.**

***Keywords*: Fusion deposition modelling, 3d Printing, additive manufacturing, extrusion nozzle heat bed.**

1. Introduction

3D printing (or additive manufacturing, AM) is one of various processes used to make a three-dimensional object. 3D-printing is an additive manufacturing process which uses layer by layer deposition of the printing material. Geometry and structural properties of a 3-D structure can be varied widely, and are produced from the electrical data source. A 3D printer is a type of industrial robot. 3D printing originally refers to processes that uses layer wise deposition of material onto a heated bed with printer heads. More recently the meaning has changed to encompassing wide variety of techniques such as sintering, FDM, STL etc.

A. How FDM Works

3D printers that uses FDM Technology build parts layer-by layer by heating and extruding thermoplastic filament on the platform.

The process includes following steps:

Pre-processing: The 3-D model is sliced into layers of pre-defined thickness and converted into a G-code with help of software packages like Cura and Netfabb.

Production: This process includes heating the PLA to a semi-molten state and deposition of it on the bed or previous layers along its predefined extrusion path. Where support is required, the 3D printer deposits a removable material that acts as support.

Post-processing: The user removes the support material by dissolving it in acetone and water, and the part is ready to use. FDM Benefits include

The technology is clean, easy to use and office-friendly. Complex geometries and shapes that would otherwise be difficult to fabricate become possible with FDM technology. Rapid prototyping methods uses iterative testing, and for very short runs, rapid manufacturing can be a relatively cheaper alternative. FDM uses the thermoplastics ABS, Polyalactide (PLA), Polycarbonate (PC), among others.

2. Design and analysis of 3D printer

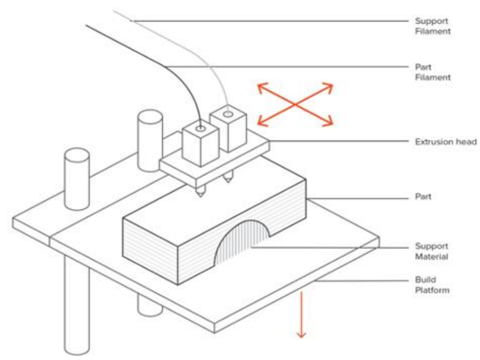


Fig. 1. Diagram showing FDM 3D- printer schematic

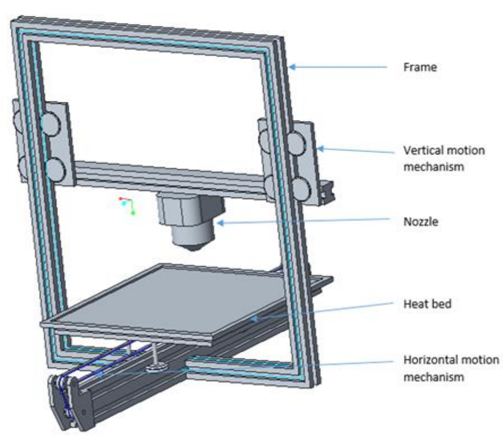


Fig. 2. FDM 3D- printer CAD model

3D printer uses a combination of components that operate simultaneously to provide the manufacturer with required output using the input digital file, the basic components are listed below:

A. Print Bed (Tray)

The flat surface where the filament is layered during printing is Print bed. It is used at required temperature as per the need of filament used for printing. The heat bed is used to maintain the temperature of the printed section for layering of the next layer.

B. Extruder

It is the component that ejects and supply the plastic filament (or any suitable filament) into the 'hot-end'. Extruders are typically fixed into the hot-end, pushing the filament inside a tube, into the hot-end by use of a simple two gear mechanism. Sometimes a dual extruder is used, when there is need to print two different materials simultaneously.

C. Hot-end

A hot-end consist of a temperature sensing device, heat source and an extrusion tip where plastic filament is fed through to deposit molten material. The size of slot hole varies typically from 0.2mm to 0.8mm. Smaller size hole increases the detailing of the produced print resulting in increased print time.

D. Filament

It is the material which is heated in order to print 3D solid object. It ejects from the nozzle in the form of semi-solid thermoplastic.

3. Analysis of printer

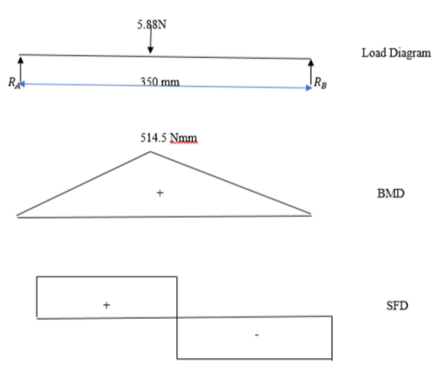
There are three types of motion of the extruder i.e., in X, Y, Z directions. Horizontal direction is X, Z directions while vertical motions is Y axis motion.

A. Design Calculation

1) Horizontal Frame (Static Load Analysis)

Analysis for horizontal rail for three position of extruder.

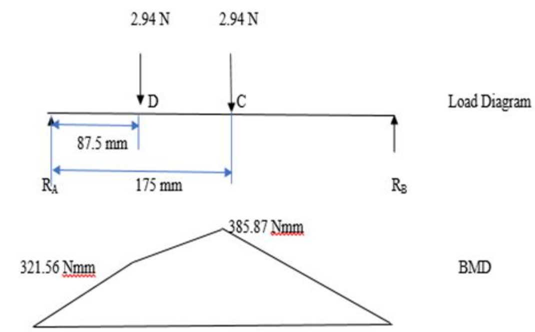
S. No.	Parameters	Value
1	Load due to weight of frame	W1 = 2.94N
2	Load due to extruder assembly	W2 = 2.94N



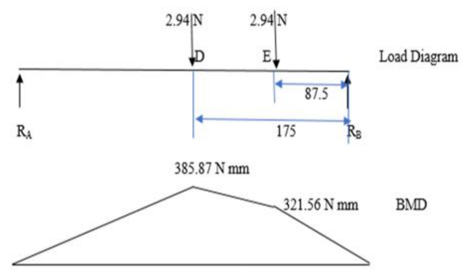
For center position of estruder:
Total weight acting = W1 + W2 = 5.88 N

$R_A = R_B$ = 2.94 N
BM_A = - (2.94 ×350) + (5.88 × 175)
= 0
BM_B=0
BM_c= (R_A × 175) = 514.5Nmm

For extruder at 87.5mm from the left side:



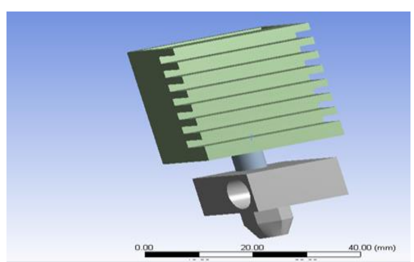
For extruder at 87.5mm from the right side:



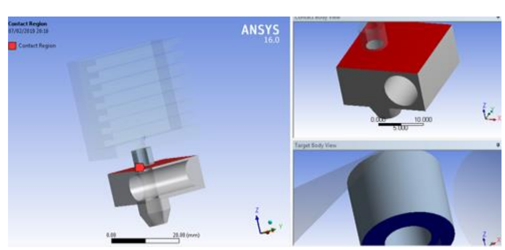
On calculating the bending moments we came to know that the maximum deflection occurs at the center position of extruder. So the design of the frame is done for the center position of extruder.

2) Heat analysis of the extruder:

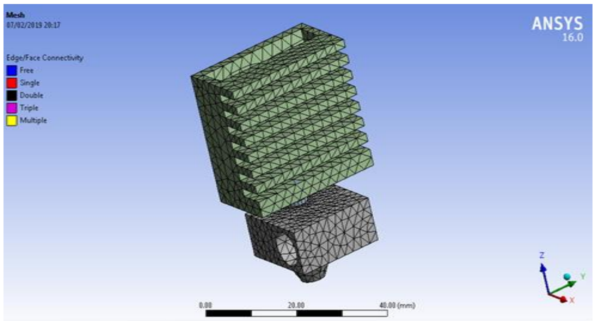
- *CAD assembly (Nozzle, pipe and Heat Sink)*



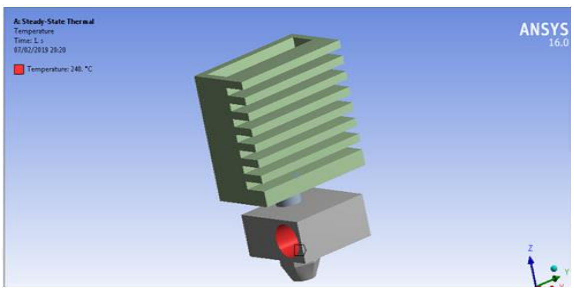
- Creating Contact region between the assembly parts



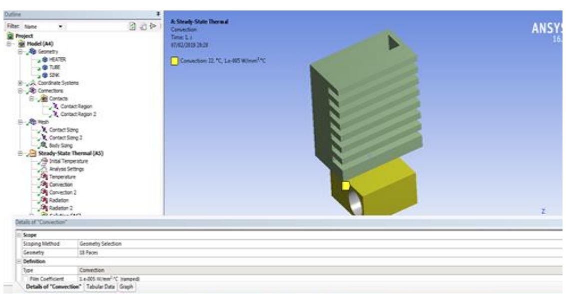
- Creating mesh of total body and Contact surface



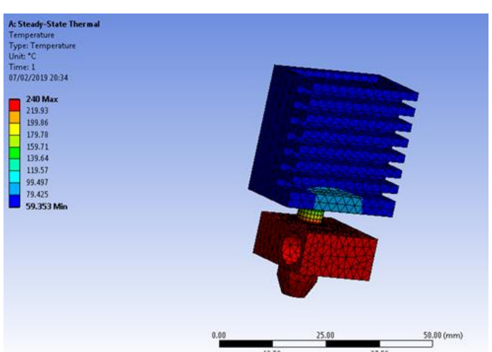
- Temperature increased to 240 C due to heating rod in the nozzle.



- Convection of Brass (Nozzle). Input (film coefficient)- 105 W/C-m^2



- Resultant FEA for assembly at 240C



The extruder head was designed and analyzed to ensure a better heat concentration only in the area of the nozzle, avoiding as much as possible dissipation of heat to the aluminum frame or to the environment. Furthermore, lowering temperature of the ABS material pas-sage, improves the sliding of the material, because it is heated only in the area of extrusion, where it is needed.

4. Conclusion

3D printing is rapidly evolving and there are many who wish to access and understand the plethora of diverse and specialized information that accompanies this new phenomenon, and because of this, this work has been designed to enlighten users on one of the many aspects of 3D printing as well as giving the reader a general overview of the related subjects. From the 3D printing and the additional contributing equipment and software, both central and peripheral, which need to be reviewed and scrutinized, this work concentrates specifically on CAD software's modelling capabilities, by example; and its essential ability to create good G-code to enable the models to be 3D printed successfully.

Abbreviations

STL: stereo lithography
CAD: Computer aided designing
ABS: Acrylonitrile butadiene styrene
BMD: Bending moment diagram
SFD: Shear force diagram
BM: Bending moment

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