Glass Transition of ABS in 3D Printing

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Overview

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  - Material Properties
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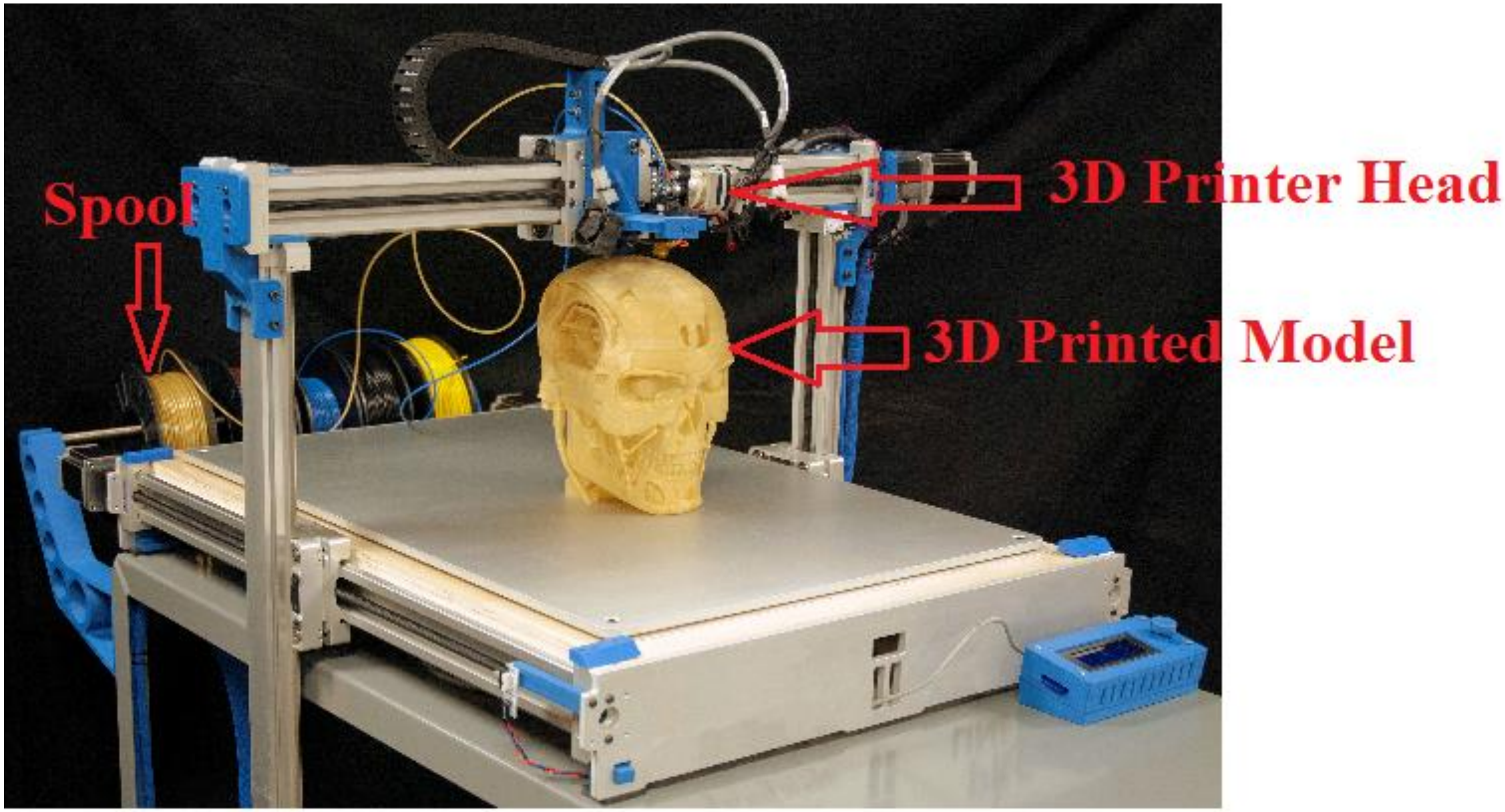
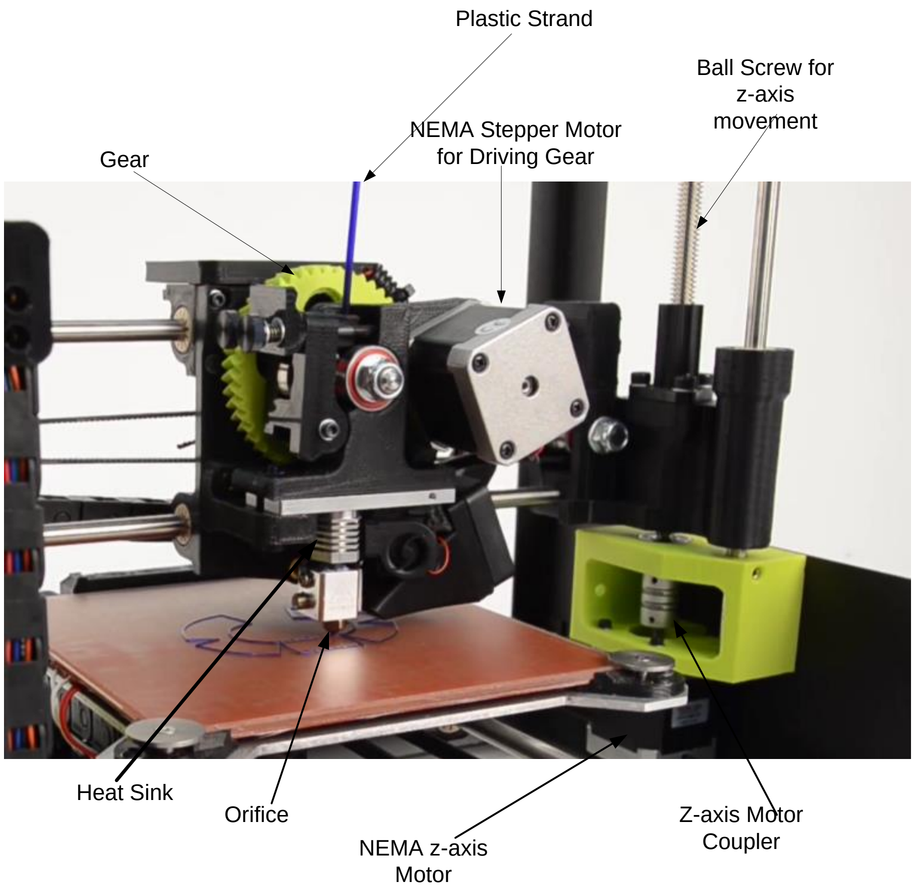
3D Printer



3D Printer View

Closer View of 3D Printer Head

Lulzbot 3D Printer Head



Numerical Modeling of 3D Printer Head with COMSOL Multiphysics 5.2

Modeling Assumptions:

1. 2D axisymmetric heat transfer model
2. Molten ABS flows continuously through a narrow nozzle
3. To obtain accurate results, the melt flow fields in combination with the heat transfer and glass (secondary) transition are considered.
4. The model includes the transition from glassy solid to rubbery melt, both in terms of sensible heat along with other physical properties.
5. The model assumes a steady state and continuous process.

Table-II Thermal parameters of ABS used in the COMSOL simulation.

Description	Data Used
Processing temperature	378[K]
Temperature transition zone half width	75[K]
Heat of glass transition	207[kJ/kg]
Heat capacity at constant pressure, glassy state	1200 [J/(kg.K]
Heat capacity at constant pressure, rubbery state	1797.6
Ambient temperature	300 [K]
Melt inlet temperature	378 [K]
Casting speed	1.0 [mm/s]
Heat transfer coefficient, ABS	2000 [W/(m^2.K]
Heat transfer coefficient, air	10 [W/(m^2.K)]
Surface emissivity	0.95

Table-III Thermal parameters of ABS used in the COMSOL simulation.

Glassy ABS	Value	Unit
Thermal conductivity	0.3	W/(m.K)
Density	1050	kg/m^3
Ratio of specific heats	1	1
Rubbery ABS	**Value**	**Unit**
Thermal conductivity	0.2	W/(m.K)
Density	1050	kg/m^3
Ratio of specific heats	1	1

3D Plot Shows the Velocity Magnitude Obtained by Revolution of 2D Axisymmetric Data Set

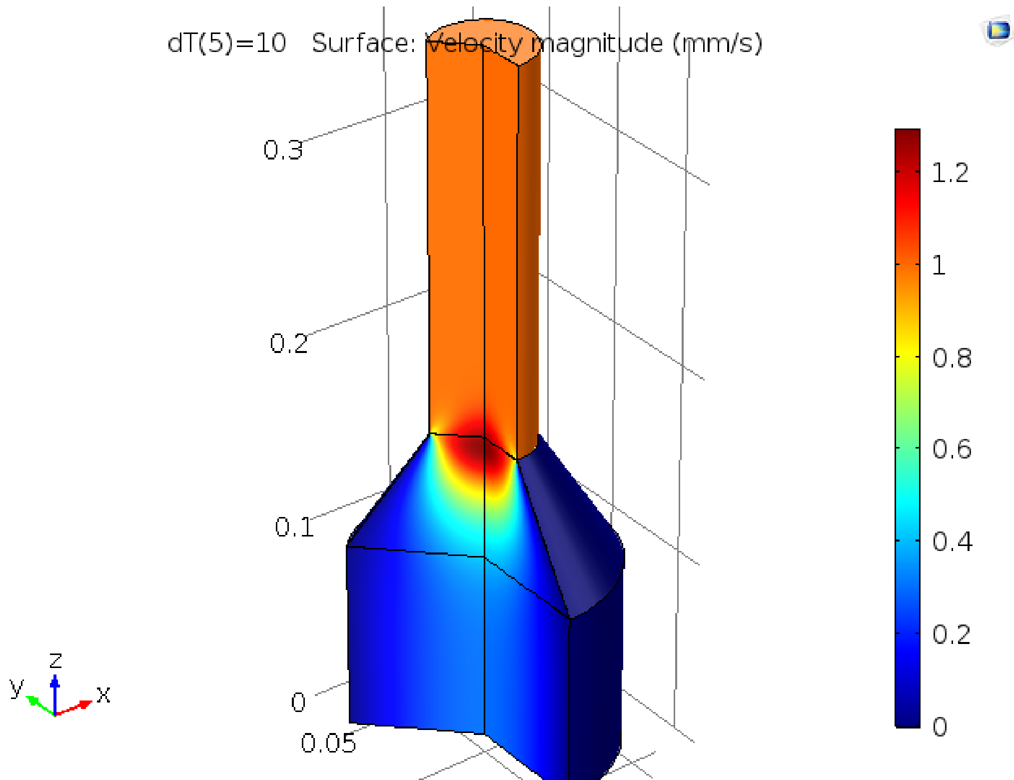


Fig. 5 3D plot shows the velocity magnitude obtained by a revolution of the 2D axisymmetric data set.

2D Surface Velocity Magnitude (mm/s) as Streamlines of Total Heat Flux

Animation Heat Flux

Animation Inkjet

Glass Transition Change in ABS

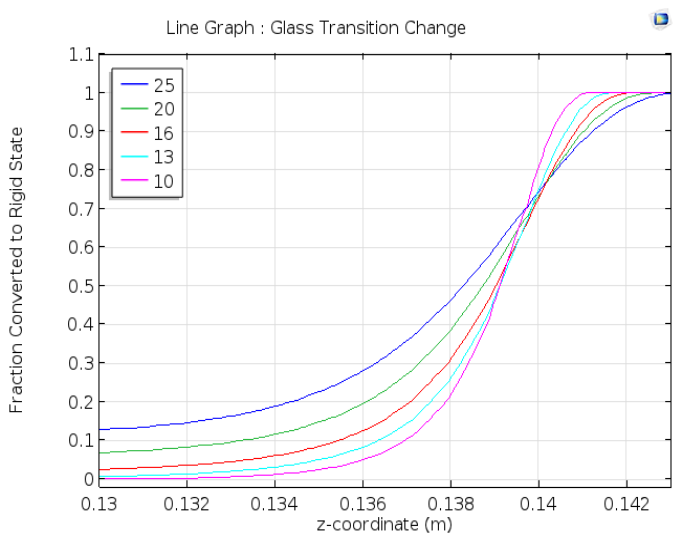


Fig. 7 The fraction of liquid rubbery state along the centerline for all values of ΔT. For smaller values of ΔT, the glass transition is steeper.

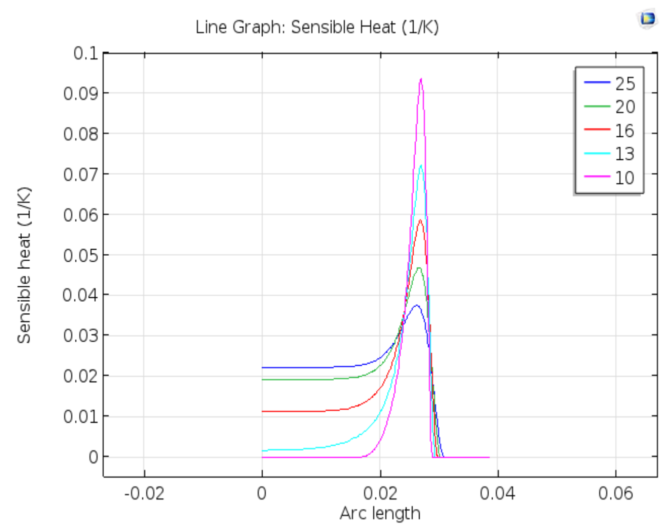


Fig. 8 As ΔT gets smaller, in particular $\Delta T = 10\,K$, the curve is not entirely smooth. As a result, to model with reduced ΔT increments one must to increase the mesh resolution.

Results & Discussions

The **glass-transition temperature** T_g of a material characterizes the range of temperatures over which the glass transition occurs.

The **glass–liquid transition** or **glass transition** for short is the reversible transition in amorphous materials from a hard and relatively brittle "glassy" state into a molten or rubber like state, as the temperature is increased.

However, it is always lower than the melting temperature, T_m, of the crystalline state of the material, if one exists.

Hard plastics like ABS, PS and PMMA (polymethyl-methacrylate) are used well below their glass transition temperatures, that is in their glassy state. Their T_g values are well above room temperature, both at around 100-105 °C (212- °F).

Despite the massive change in the physical properties of a material through its glass transition, the transition is not itself a phase transition of any kind.

However, the question of whether some phase transition *underlies* the glass transition is a matter of continuing research.

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Conclusions

- Modeling and simulation of 3D printer head using COMSOL software tools may predict the die design that gives the best properties for the 3D model.

- Die design may control the heat flux to give the fastest cure rate to make the model strong in least amount of time.

- The effects of fillers and their influence on cure rate and end use properties can be predicted.

- Intelligent 3D head is being implemented by IRays Teknology Ltd.

Questions?

Thank you !!!