



HAL
open science

Thermal Analysis of Desktop Fused Deposition Modeling (FDM) Liquefiers

Mouhamadou Mansour Mbow, Philippe René Marin, Franck Pourroy

► **To cite this version:**

Mouhamadou Mansour Mbow, Philippe René Marin, Franck Pourroy. Thermal Analysis of Desktop Fused Deposition Modeling (FDM) Liquefiers. International Symposium on PRecision Engineering and Sustainable Manufacturing. PRESM 2019, Jul 2019, Da Nang, Vietnam. hal-02542029

HAL Id: hal-02542029

<https://hal.science/hal-02542029>

Submitted on 14 Apr 2020

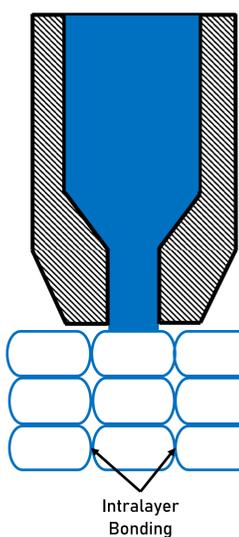
HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

OVERVIEW

- FDM is one of the most used Additive Manufacturing Systems
- Despite its technical development in the last few years, the FDM products still exhibit some geometrical and mechanical issues
- A better process understanding is required

Here, the effect of processing parameters on extruded material temperature is studied



The Temperature Influences:

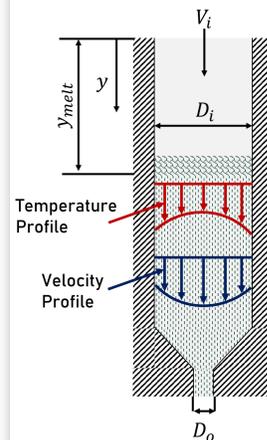
- The **Interlayer** and **Intralayer Bonding**, thus, the **Mechanical Strength**
- The Deposited Layer Dimensions (**Width**), thus, the **Geometrical Quality**

Objective:

Establishment of Mathematical models for temperature estimation regarding the adjustable process parameters i.e. target temperature and extrusion rate

1

ANALYTICAL ANALYSIS



Physical and Mathematical considerations

Fourier's Law:

$$\frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial T}{\partial r} \right) = \frac{1}{\alpha} \frac{\partial T}{\partial t}$$

Hyperbolic Temperature: $T(r) = C_1 \left(1 - \frac{r^2}{R_i^2} \right) + T_w$

Parabolic Velocity: $u(r) = \frac{1}{\mu} \left(\frac{dp}{dy} \right) R_i^2 \left[1 - \left(\frac{r}{R_i} \right)^2 \right]$

Newton's law of cooling:

$$h = \frac{q_w''}{T_w - T_m}$$

Material **MELTING FRONT** (y_{melt}) with respect of extrusion temperature velocity

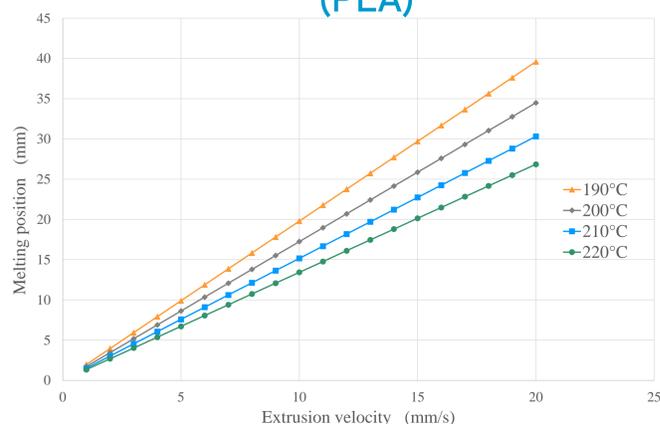
$$y_{melt} = V_i \left[\frac{M \rho C_p D_i^2}{16k} \frac{(T_{melt} - T_i)}{(T_w - T_i)} \right]^2 \quad \text{with} \quad M = \sqrt{\frac{4\pi\alpha}{D_i^2}}$$

Material **TEMPERATURE AT ANY POSITION** with respect of extrusion temperature velocity

$$T_{mat} = T_w - (T_w - T_{melt}) \exp \left[- \frac{24k}{\rho D_i^2 V_i C_p} (y - y_{melt}) \right]$$

2

MELTING FRONT WITH RESPECT TO EXTRUSION VELOCITY (PLA)

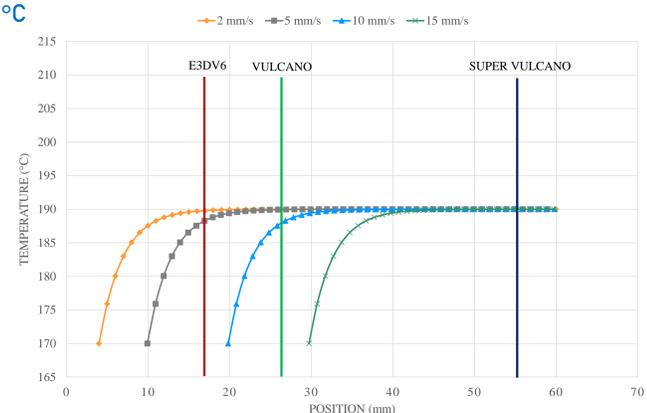


CONCLUSIONS

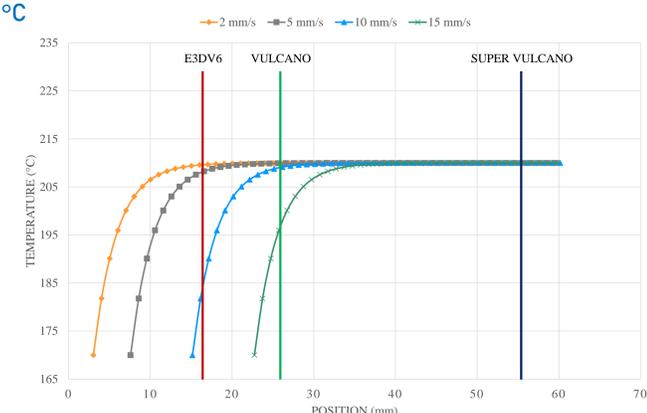
- The material **temperature** is found to be greatly depending on the adjustable processing parameters such as the target temperature and the extrusion velocity
- For a given target temperature, every liquefier configuration has its limit velocity for extrusion, for example at **210 °C**, a **SUPER VULCANO** could print at 15 mm/s while, an **E3DV6** could not because the target temperature can't be reached
- A better process control is required to fit the **extruded material characteristics** with the process variables
- FDM machines with higher performances allowing to print at higher velocities could be designed using these extensive models.

MATERIAL (PLA) TEMPERATURE WITH RESPECT TO POSITION FROM THE ENTRY

Target: 190 °C



Target: 210 °C



3