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THERMAL ANALYSIS OF DESKTOP FUSED DEPOSITION MODELING (FDM) LIQUEFIERS

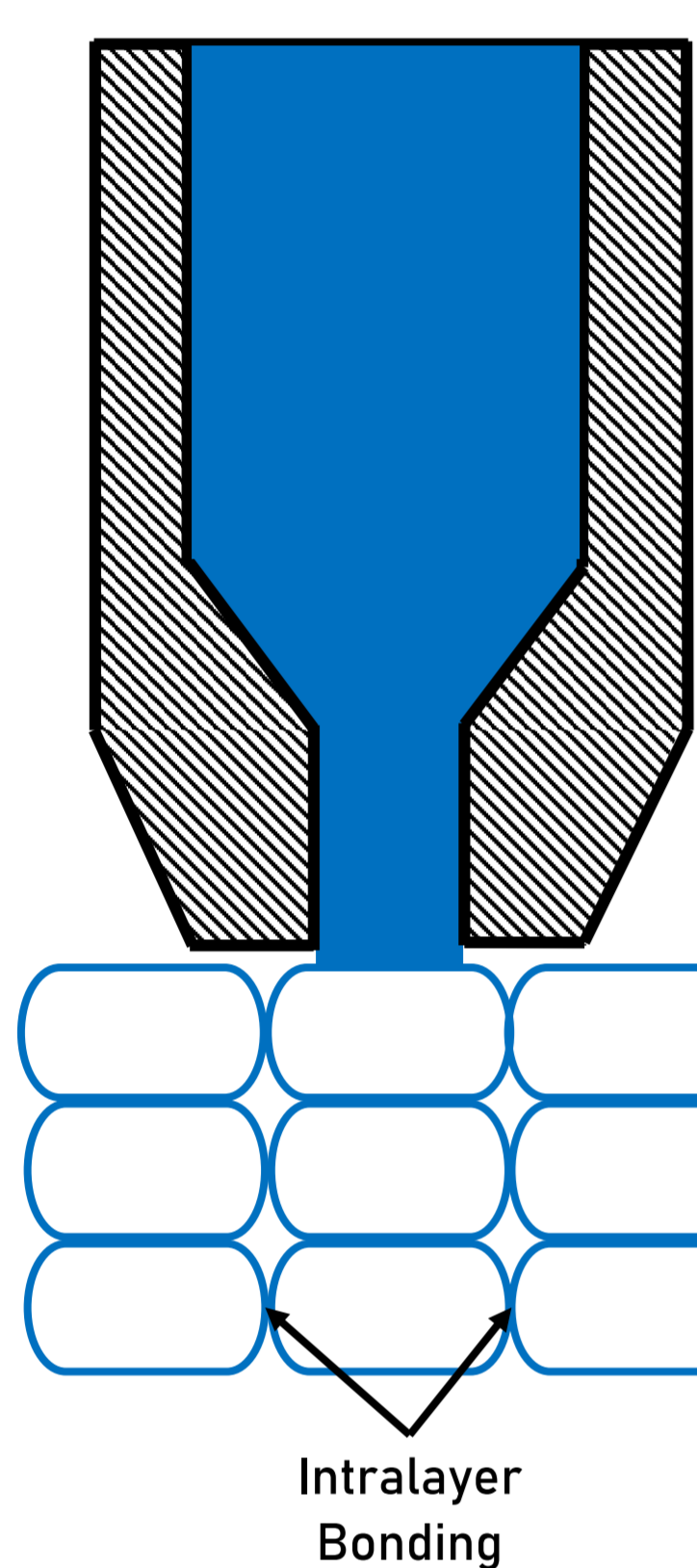
International Symposium on
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PRESM 2019 DA NANG, Vietnam

Mouhamadou Mansour Mbow, Philippe René Marin & Franck Pourroy

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:

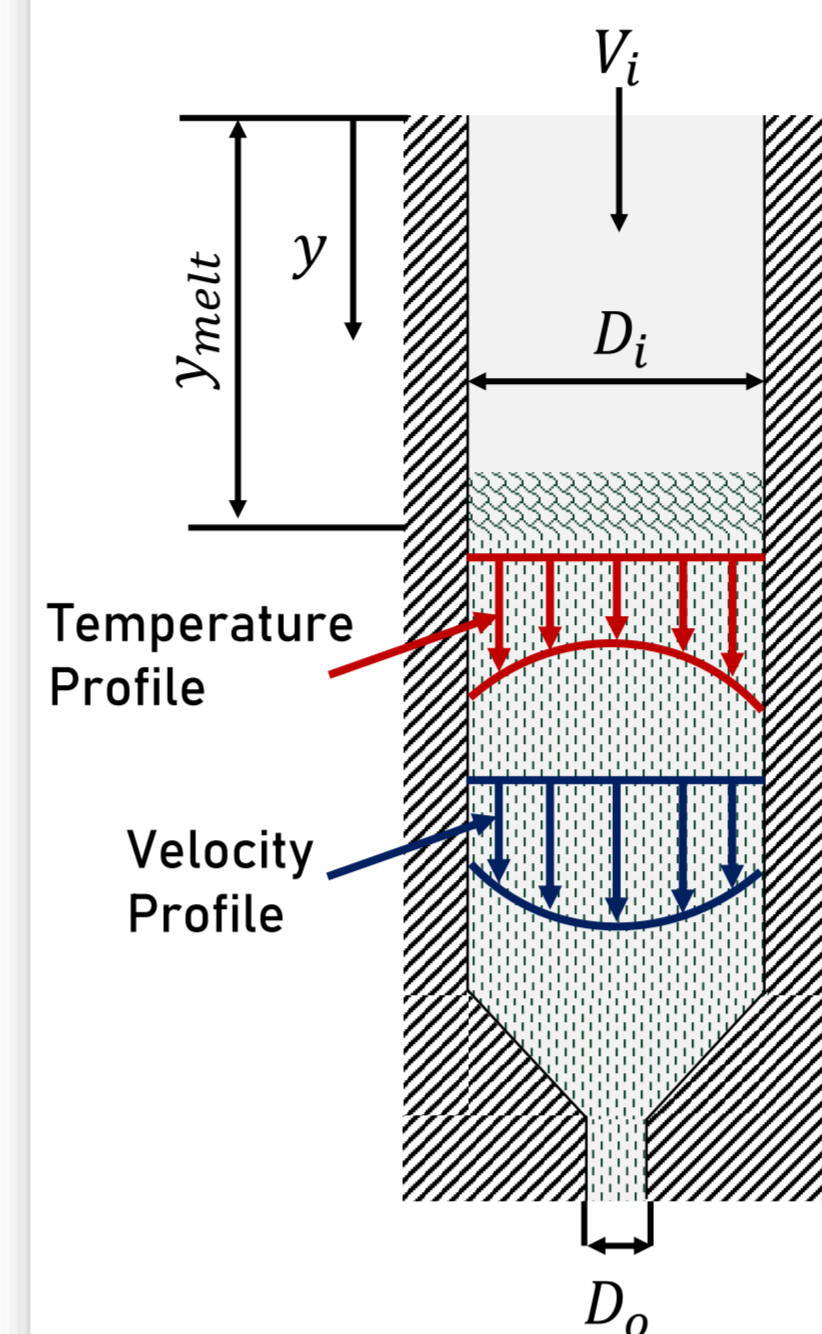
- The **Interlayer** and **Intralayer Bonding**, thus, the **Mechanical Strength**
- The Deposited Layer Dimensions (**Width**), thus, the **Geometrical Quality**

Objective:

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

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

Newton's law of cooling:

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

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

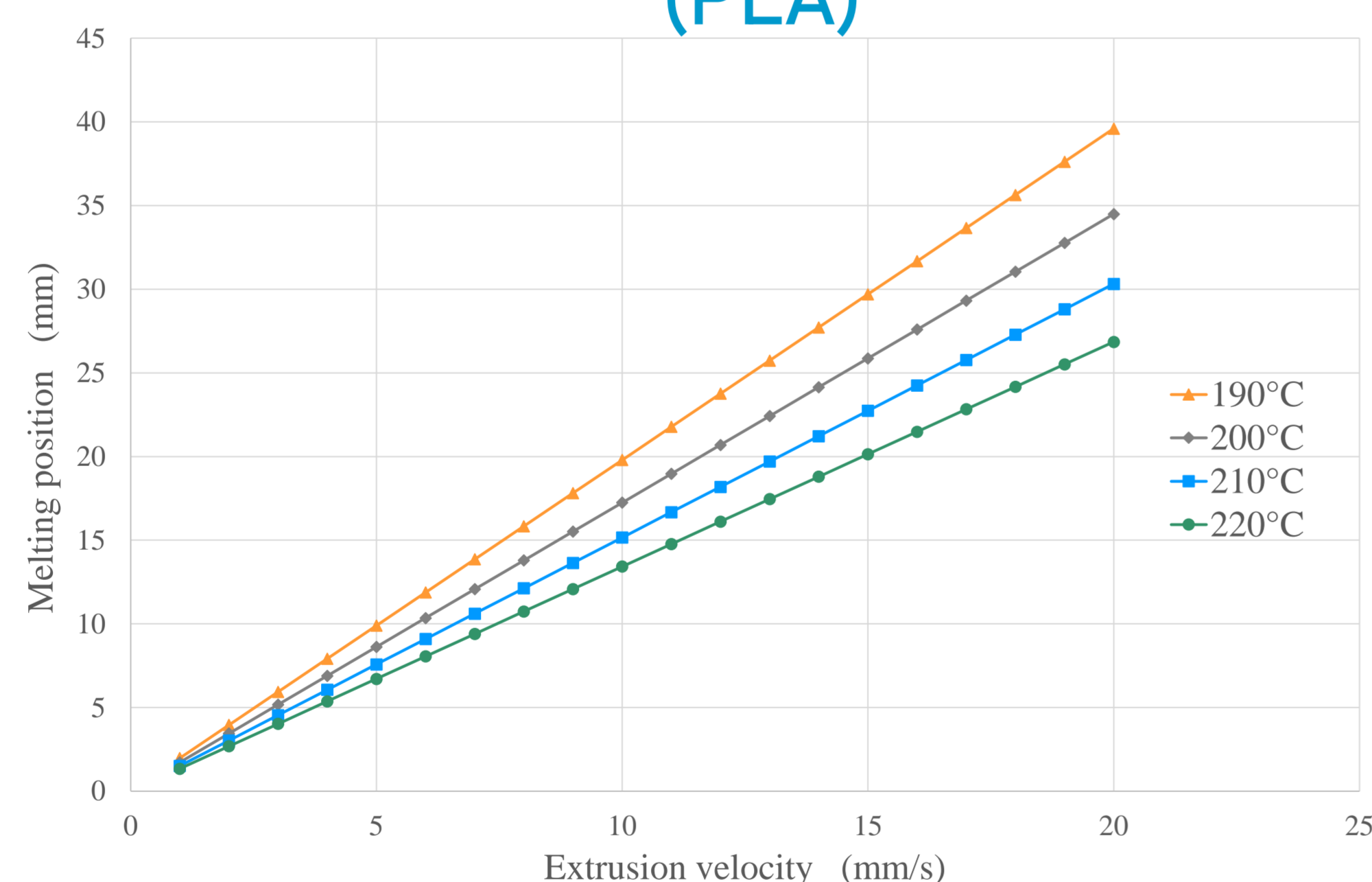
$$y_{melt} = V_i \left[\frac{M \rho C_p D_i^2}{16k} \frac{(T_{melt} - T_i)}{(T_w - T_i)} \right]^2 \quad \text{with} \quad M = \sqrt{\frac{4\pi\alpha}{D_i^2}}$$

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

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

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MELTING FRONT WITH RESPECT TO EXTRUSION VELOCITY (PLA)

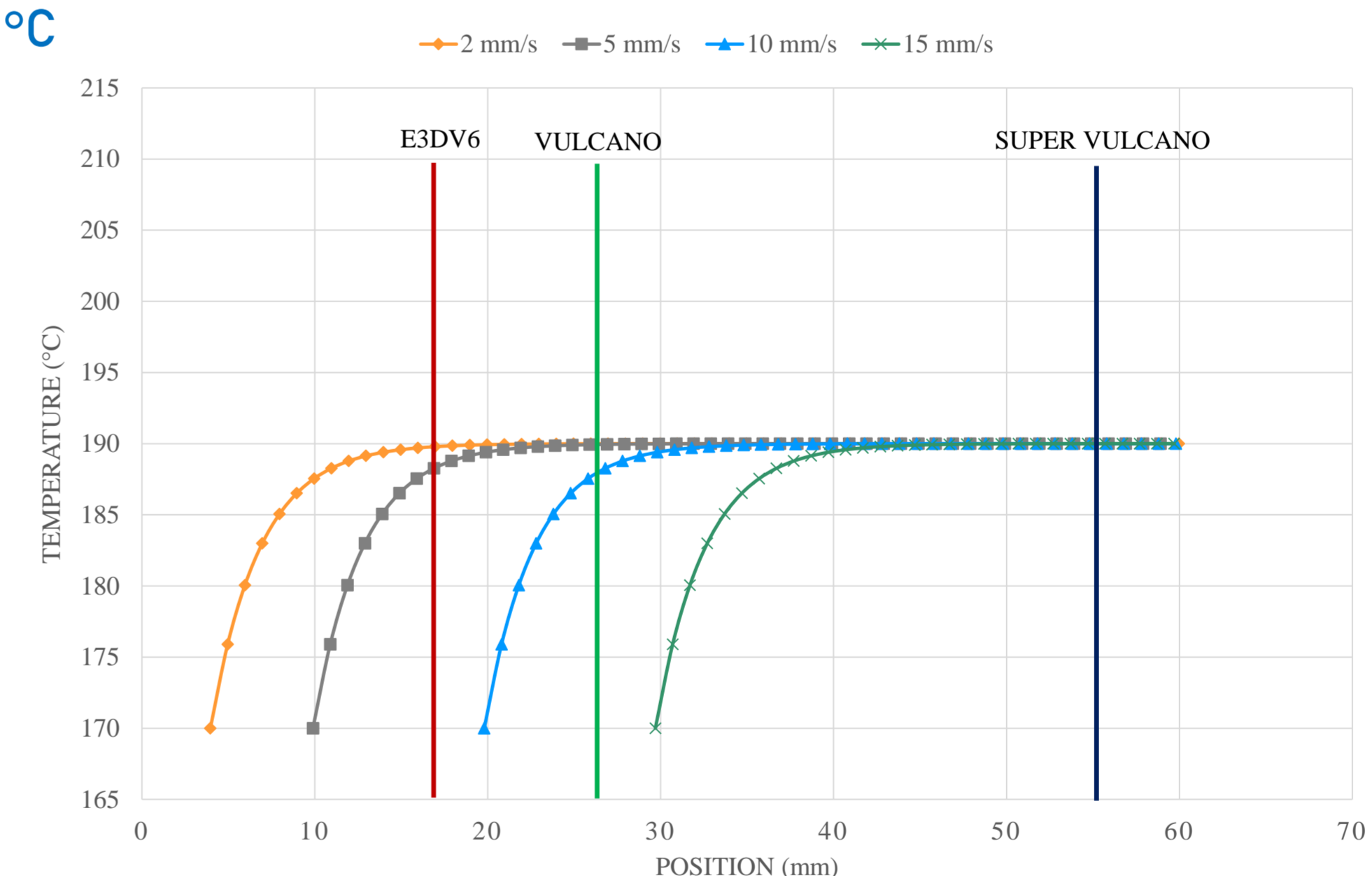


CONCLUSIONS

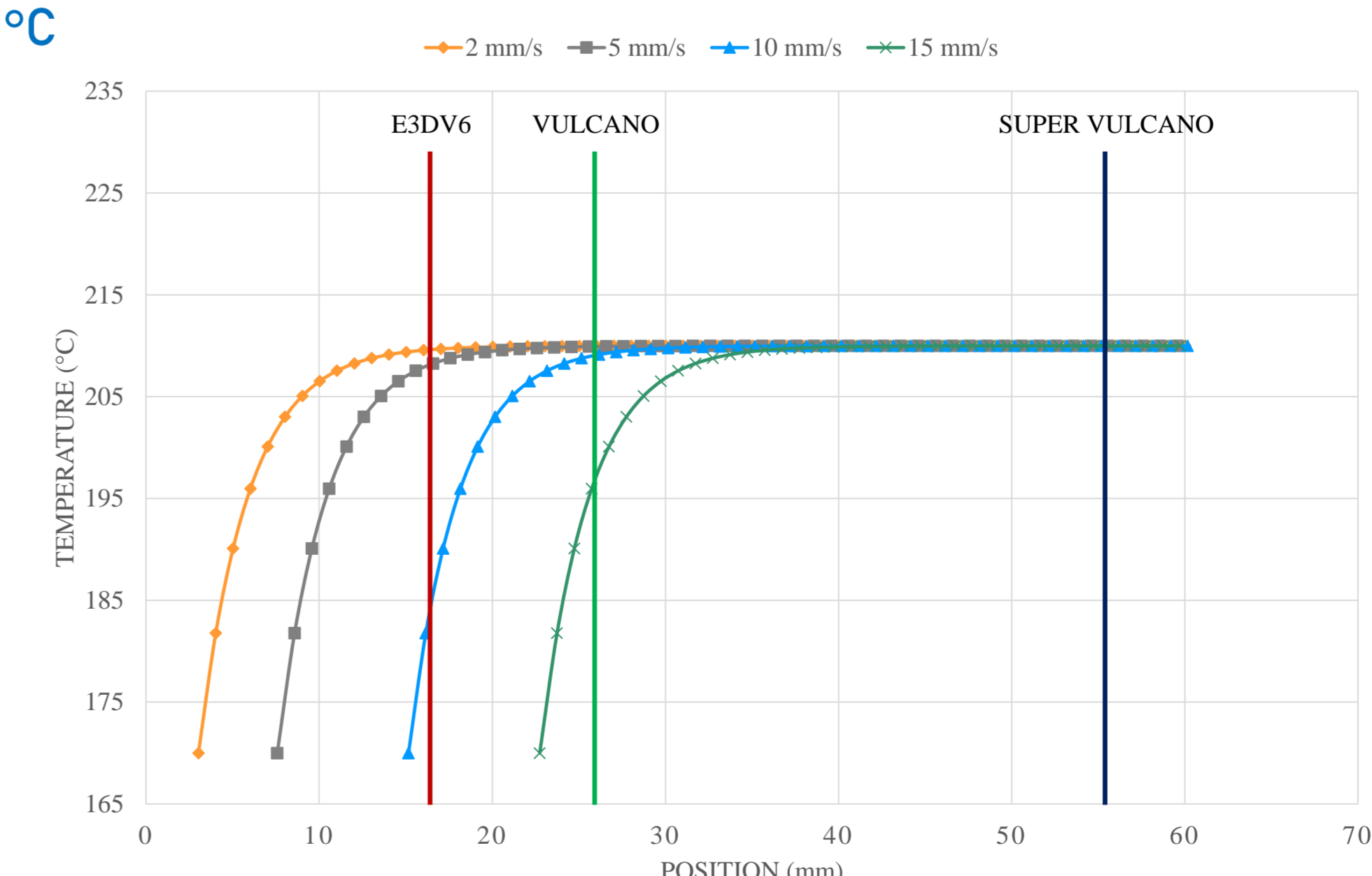
- The material **temperature** is found to be greatly depending on the adjustable processing parameters such as the target temperature and the extrusion velocity
- For a given target temperature, every liquefier configuration has its limit velocity for extrusion, for example at **210 °C**, a **SUPER 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



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