3D PRINTING: SOLVENT TRANSPORT IN A POWDER BED

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Mass Transfer Characterization

The mass transfer phenomena of focus is diffusion. The Arnold Cell Diffusion model was used to characterize the mass transport of solvent, with the assumption that the diffusion path length changes a small amount over a long period of time, Eq. 1. Using this model, the pathlength, $Z$, was measured over time, $t$. The solvent diffusion coefficient ($D_{AB}$) was estimated to be 0.02 cm$^2$/s ± 0.01 cm$^2$/s using the slope.

$$t = t_0 = \frac{P_k \cdot Y_{im}}{C \cdot M_0 \cdot D_{AB} \cdot (Y_{im} - Y_{an}) \cdot \left(\frac{Z^2 - Z_0^2}{2}\right)}$$

Equation 1: Arnold Diffusion Equation

Solvent Transport Model

The solvent transport model was generated assuming the transport within the powder bed can be modeled as a semi-infinite medium with a constant source and transient sink by using the error function.

$$C_s = \left(1 - \text{erf} \left(\frac{Z}{2 \sqrt{D_{AB} \cdot t}}\right)\right) \cdot (C_{an} - C_{AB})$$

Equation 2: Semi-Infinite Medium Transient Diffusion Equation

The error function equation was used to determine the change in concentration as a function of position in order to estimate the flux, Eq. 2. The flux equation, Eq. 3, was integrated as a function of time in order to estimate the mass of solvent at position $z$, Eq. 4.

$$N_A = -D_{AB} \cdot \frac{dC_A}{dz}$$

Equation 3: Flux equation using the diffusion coefficient and the change in concentration as a function of position

$$m_{\Delta t} = S \cdot C_s \left(\frac{2 \cdot D_{AB} \cdot t}{3 \sqrt{\pi}} \cdot \sqrt{D_{AB} \cdot t} \cdot \left(\sqrt{D_{AB} \cdot t} - 2\pi^2\right) - \frac{2\pi^2}{\sqrt{\pi}} \cdot \frac{z}{\sqrt{D_{AB} \cdot t}}\right)$$

Equation 4: The resulting equation models the mass transport of solvent as a function of time

Figure 2: Microscopic scale picture of solvent within the powder pores.

Figure 3: The mass of solvent removed over time at 140°C when loaded with 6.7 grams of solvent.

Figure 4: After plotting the Arnold Model pathlength vs time from Eq. 1, the Diffusion Coefficient, $D_{AB}$, was able to be estimated from the slope to be 0.01 cm$^2$/s.

Figure 5: The mass of solvent removed over time at 140°C when loaded with 6.4 grams of solvent.

Figure 6: After plotting the Arnold Model pathlength vs time from Eq. 1, the Diffusion Coefficient, $D_{AB}$, was able to be estimated from the slope to be 0.02 cm$^2$/s.

Figure 7: The time required for 6.4 g of solvent to be completely removed at a designated position away from the part, $z$, at diffusion coefficients of 0.01, 0.02, and 0.04 cm$^2$/s.

Future Work

- Conduct experiments using solvent that does not contain water
- Compare model results to physical experimentation
- Work with HP research team to enhance model and apply to current 3D printing process

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References