Weld formation during material extrusion additive manufacturing[1]

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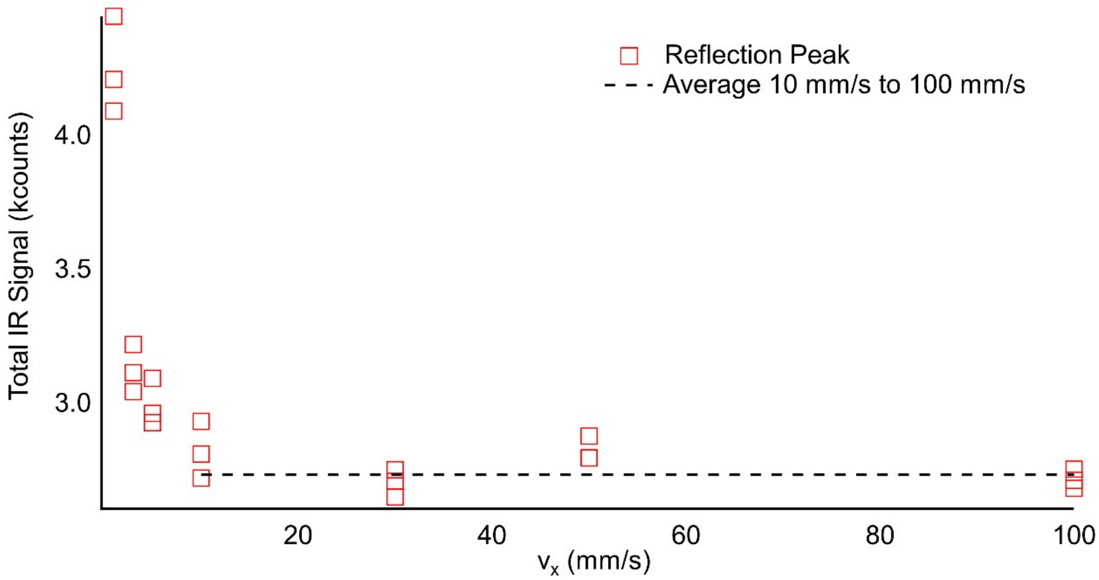
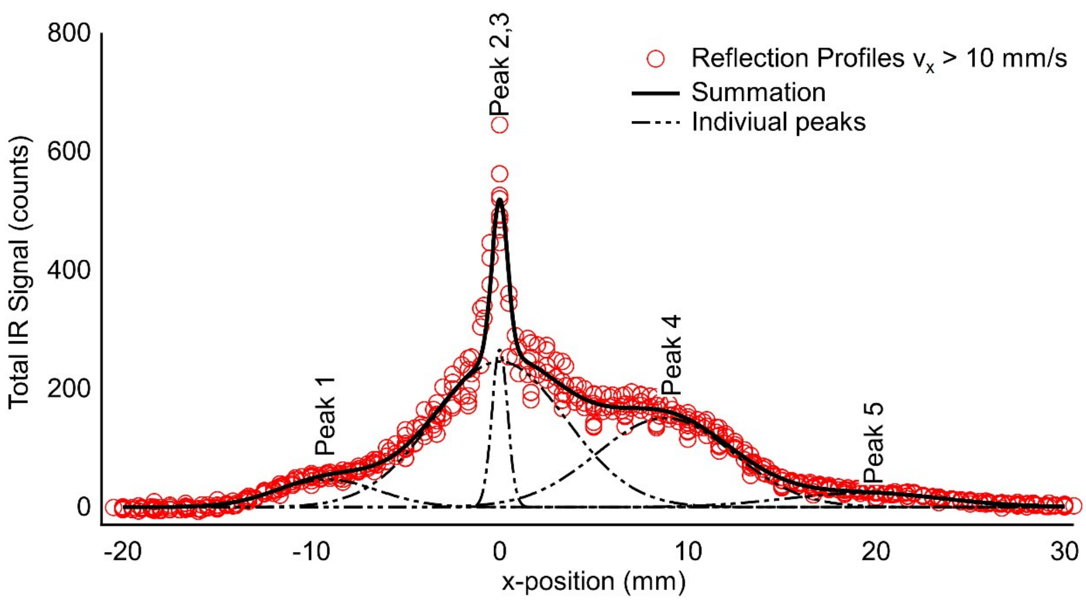
Reflection Corrections for $v_x \leq 10$ mm/s

The previously published IR thermography protocol was modified for the regime of print speeds at and below 10 mm/s. At such rates, radiant heat transfer from the heated nozzle begins to contribute to the overall thermal history. In SI Figure 1, the peak of the reflection peak signal should be independent of v_x, however, the total IR signal begins increasing below $v_x = 10$ mm/s. This extra heat appears in both the emission and reflection signals and thus a different approach to the reflection correction is required. Instead of simply subtracting the reflection signal at the same print speed, the reflections from the higher print speeds, >10 mm/s, are plotted in the spatial domain and fit with a summation of 5 Gaussian peaks. The Gaussian peaks match the features of the extruder nozzle which contribute to the reflected intensity. The fit is then subtracted from the total IR signal. This method preserves the radiant heat transferred from the nozzle while allowing for the removal of the reflection signal, which would be feed rate independent.



SI Figure 1 Reflection peak total IR signal counts for samples printed at T_{ext} = 230 °C and various v_x. Dashed line marks the average value for 10 mm/s ≤ v_x ≤ 100 mm/s. For v_x < 10 mm/s the total IR signal increases.

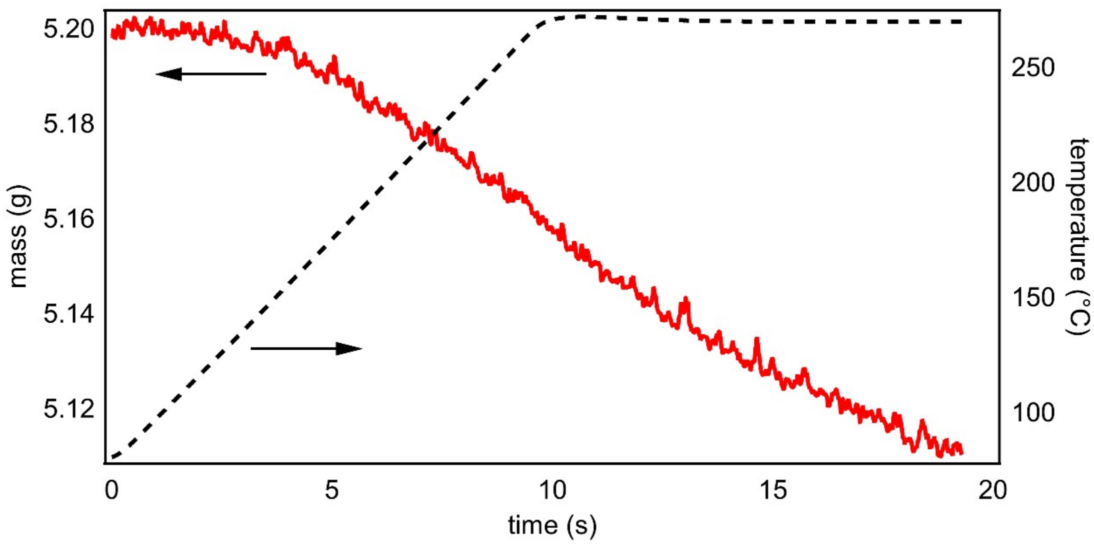


SI Figure 2. Reflection profiles from print speeds (v_x) at 30 mm/s and greater. All profiles were fit with the summation of 5 Gaussian peaks. The fit prolife was used to correct the reflection intensity for print speeds of 10 mm/s and slower.

Thermal Gravimetric Analysis (TGA)

Thermal gravimetric analysis was used to support degradation at elevated temperatures. Approximately 5 mg of ABS filament was placed in at TGA, held at 80 °C under N_2 for 600 s, then ramped at 0.33 °C/s up to 270 °C after which the oven gas was switched to a standard air mixture. Mass loss is evident in SI Figure 3, occurring during the ramp up prior to switching the oven gas and continuing after the switch.

Although the mass loss rate is quite low, the loss is occurring at the surface which is the critical area for adhesion between layers.



SI Figure 3. Thermal gravimetric analysis of ABS during ramp up to 270 °C and isothermal at 270 °C in air atmosphere.

Thermal Profiles

Included with the electronic supplemental information (ESI) is a zip file, thermal profiles.zip, containing data sets for all the thermal profiles used in this study. The filenames indicate the material (MAT), extrusion temperature (T_{ext}), x-velocity (v_x), and a unique file identification number (###) using the following format MAT_T_{ext}_v_x_###.txt. Each text file contains four tab delimited columns with the first line denoting the column information.

Column 1: Relative time in seconds

Column 2: Temperature of layer 9 in degrees Celsius

Column 3: Temperature of layer 8 in degrees Celsius

Column 4: Temperature of layer 7 in degrees Celsius

The relative time range is constrained to -0.5 s < t < 15 s and the temperatures for layer 9 at t < 0 s are set to "NaN" as the layer does not exist until t = 0 s.