Mitigating Discoloration in PA11 SLS

Experimental DoE and Novel Simulation Approaches

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GRUNDFOS

1. BACKGROUND

- **Developed in 1986**, SLS is a key additive manufacturing (AM) and powder bed fusion (PBF) technology.
- **Part quality is highly sensitive** to laser power, oxygen content, powder quality and thermal profile.
- Printing parameters affect **mechanical**, **dimensional**, and **physical** properties.
- **PA11 SLS parts tend to yellow** at factory settings, which is undesired.
- **Predictive models** can reduce waste, energy use, time and enable in situ monitoring.

2. OBJECTIVES

1 Investigate

how energy denisty and build placement affect discoloration (yellowness), mechanical and dimensional properties.

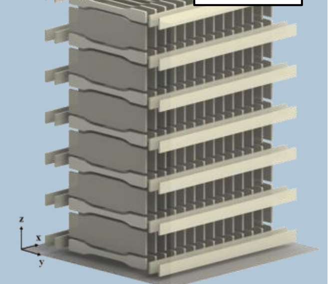
2 Develop

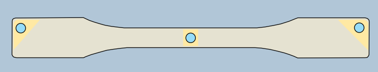
a statistical model based on experimental data and a numerical model to predict degradation-related discoloration.

3. METHOD

1 Print

- Design of Experiments (DoE) with three levels.
- High printing time, build height and nesting density.





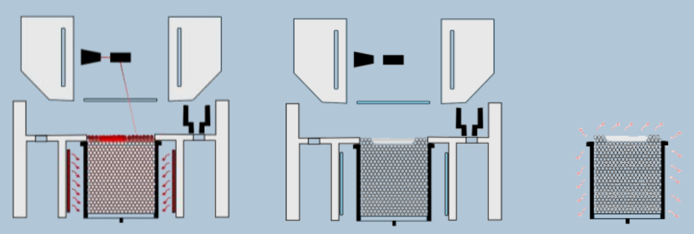
Measure 2

- Color (CIELAB)
- Ultimate Tensile Strength (UTS [MPA])
- Elongation at break (EAB [%])
- Length and thickness [mm]
- Custom degradation metric:

$$\Delta D_{100} = 100 - (L^* - b^*)$$

3 Develop models

Printing | **Controlled cooling** | **Ambient cooling**

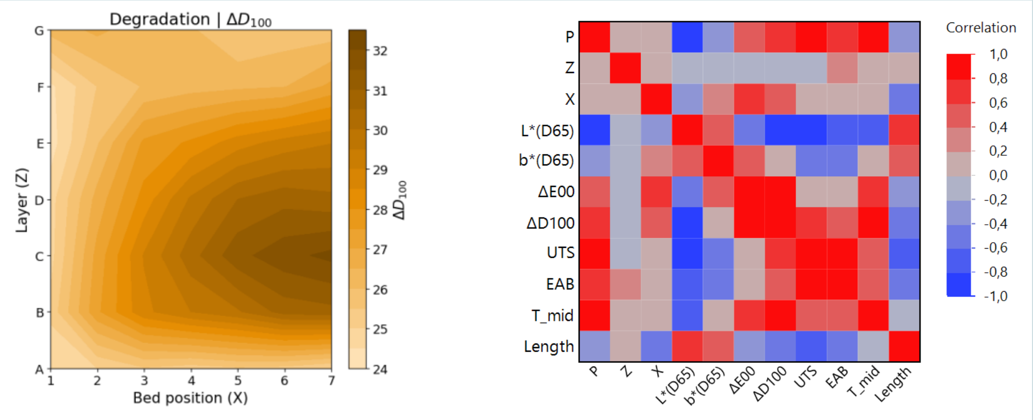


- PA11 material properties from DSC.
- Continuous model with layer-by-layer process made in COMSOL.
- Controlled cooling assumed as linear fit from the initial sink temperatures to the removal temperature of 100 °C.
- Degradation was modelled using the Arrhenius equation.

4. RESULTS

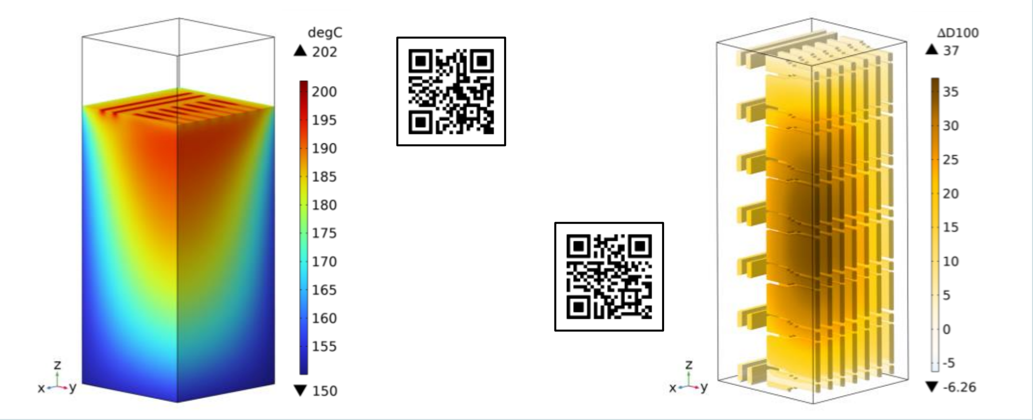
Experimental & statistical

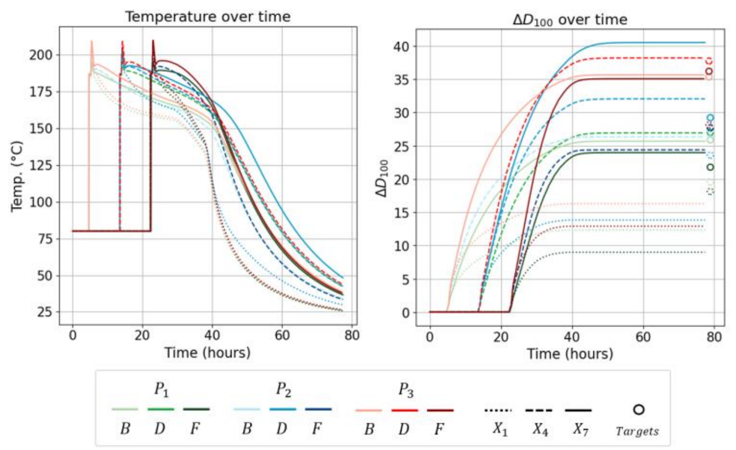
- Degradation highest in the center of the build chamber.
- Strong correlation between the energy density attributed by the laser power (P) and the CIELAB colors, UTS, EAB and thickness of the parts.



Numerical

- Arrhenius parameters globally optimized with COMSOL heat-transfer temperature profiles show excellent agreement with the measured color data when the boundaries are excluded.





- The model was validated on a large component, an impeller, and showed strong agreement with the expected visual trends.
- Moreover, the greatest degradation occurs in regions with the highest end-time temperatures.

5. CONCLUSION

- Component placement and energy density is shown to both influence discoloration likely due to thermo-oxidative degradation.
- The most visually appealing color was achieved at the mid-range energy density of 0.34 J/mm3.
- A strong correlation is observed between discoloration, UTS and thickness.
- The numerical model's thermal history and thereby resulting degradation prediction fairly represents measurements when the boundaries are excluded.

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