Impact of disintegrating agents on the wash-out process for 3D-printed aluminum green parts produced by slurry-based binder jetting

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In this study, we explore the use of polyethylene glycol 400 (PEG-400) as a disintegrating agent to enhance the wash-out process in slurry-based binder jetting of aluminum (Al) components. High densities of green bodies complicate the wash-out, but PEG-400 enables redispersion after binder curing. We conducted visual assessments and quantitative analyses of powder dissolution in an ultrasonic bath, examining the effects of varying PEG-400 concentrations on wash-out efficiency. Our findings indicate that PEG-400 significantly enhances wash-out effectiveness, paving the way for a cost-effective process suitable for intricate and complex aluminum products.

Methods

Slurry-based binder jetting process

The slurry-based binder jetting process chain (Figure 1) includes key steps as slurry mixing, binder jetting, binder curing, wash-out, and sintering, along with any necessary post-processing.

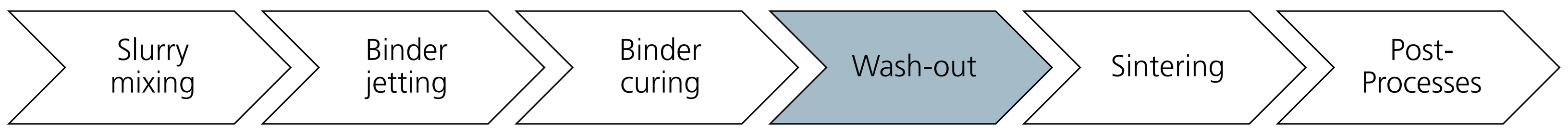


Figure 1: The slurry-based binder jetting process chain

This 3D printing method involves depositing layers of slurry onto a building platform. After drying to form solid particles, a binder is selectively jetted onto the dried layer to bond them (Figure 2). The printed part is then cured and washed to obtain green parts that are subsequently sintered.

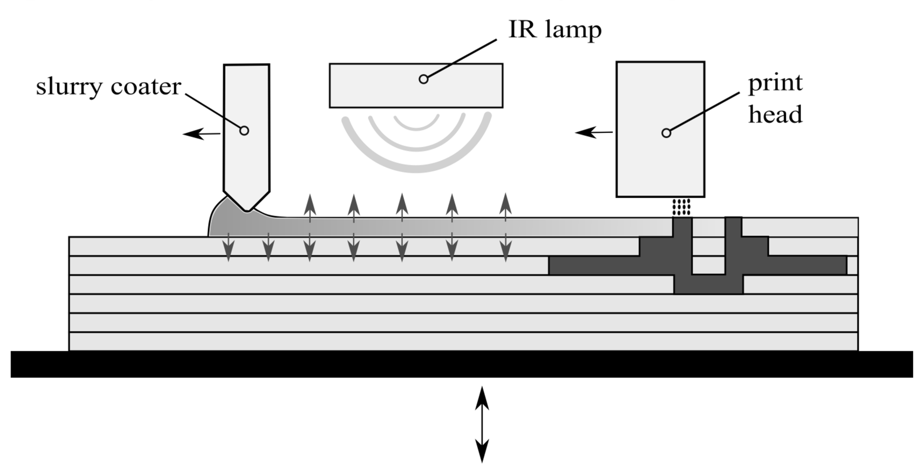


Figure 2: Schematic representation of the slurry-based binder jetting process [1]

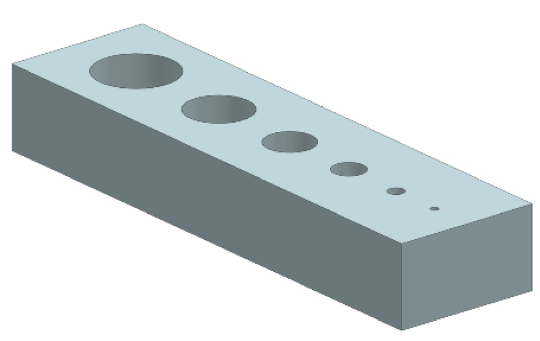
Slurry recipe

The aqueous Al-slurry for binder jetting consists of 72 wt.-% Al-powder (d_{50} = 5 µm), 27.5 wt.-% deionized water, 0.3 wt.-% dispersant, and 0.235 wt.-% rheology additive, serving as starting slurry A (see Table 1). Polyethylene glycol (PEG-400) was added based on porosity (43 %). The appropriate PEG-400 concentration for the Al powder cake is anticipated to be between 1 vol.-% to 9 vol.-% related to the porosity.

Wash-out process

After printing and curing, blocks containing the printed green parts (Figure 2) were cut from the surrounding powder cake for individual washing. The green parts were immersed in a 25 °C ultrasonic bath for wash-out. Specimens were placed centrally and inspected visually after 15, 45, and 90 minutes.

Figure 3: CAD model of the printed specimens with the dimensions of 33 mm × 9 mm × 5 mm (l × w × h) featuring through-holes with diameters of 5 mm, 4 mm, 2 mm, 1 mm, and 0.5 mm



Results

Initial experiments identified the PEG-400 concentration for the wash-out process as 5 vol.-%, yielding the best results. Samples without PEG-400 showed no visible holes after 90 minutes of wash-out in an ultrasonic bath, while those with 1 vol.-% and 3 vol.-% PEG-400 exhibited some improvement. The specimens made from slurry with 5 vol.-% PEG-400 showed three clear holes after 90 minutes. Increasing PEG-400 to 7 vol.-% and 9 vol.-% did not enhance wash-out results, and lower concentrations also resulted in fewer visible holes. The findings suggest that 5 vol.-% PEG-400 is appropriate for effective wash-out, minimizing adverse effects on sintering. Figure 5 shows washed gyroid structures that can serve as aluminum heat sinks after sintering.

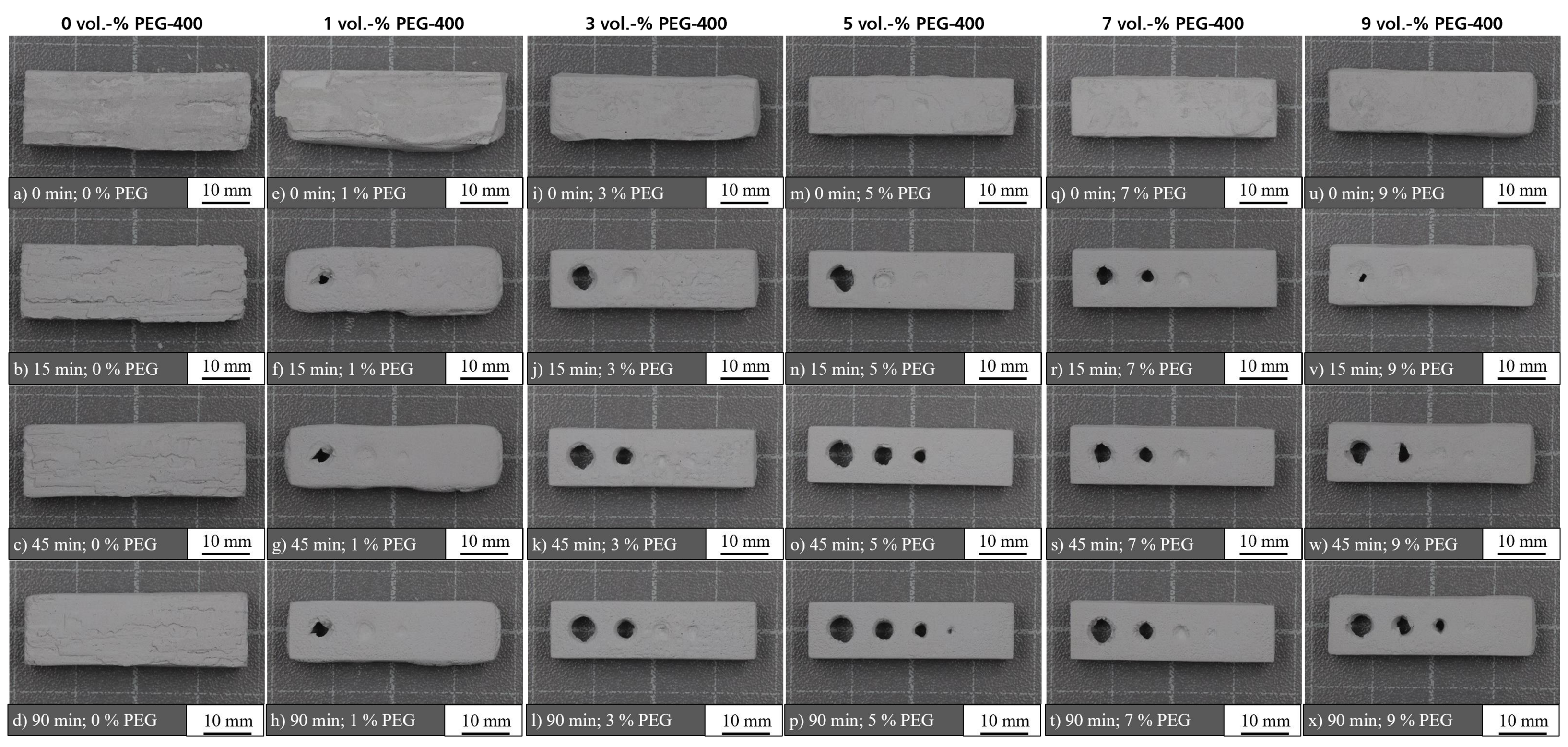


Figure 4: Wash-out process of green bodies at varying PEG-400 concentrations (0 vol.-%, 1 vol.-%, 3 vol.-%, 5 vol.-%, 7 vol.-%, and 9 vol.-%) over time (0 min, 15 min, 45 min, and 90 min). The panel with 5 vol.-% PEG-400 (pictures m through p) demonstrate the best wash-out results, showing 4 free through holes after 90 min (picture e).

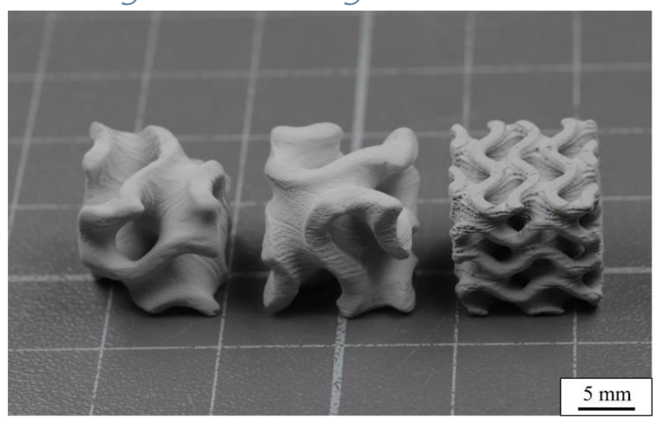


Figure 5: Demonstrators in the form of gyroids; from left to right: gyroid with a wall thickness of 1.5 mm; gyroid with a wall thickness of 2 mm; gyroid with a wall thickness of 1 mm.

Takeaway

- The ideal PEG-400 concentration for effective wash-out of green bodies in slurry-based binder jetting is 5 vol.-%, as it yields the best results compared to other concentrations examined.
- Successful wash-out of complex structures can be achieved using the slurry recipe with 5 vol.-% PEG-400.
- Future research will focus on enhancing wash-out quality, exploring the impact of additives on sintering, and assessing the effects of ultrasonic treatment on surface quality.

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[1] P. Erhard, A. Seidel, J. Vogt, W. Volk, D. Günther, Evaluation and optimisation of a slurry-based layer casting process in additive manufacturing using multiphase simulations and spatial reconstruction, Prod. Eng. Res. Devel. 16 (2022) 43–54. https://doi.org/10.1007/s11740-021-01078-8.

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