Assessing the impact of moisture on powder based additive manufacturing processes

Lefebvre, Louis-Philippe; Timercan, Anatolie

Assessing the Impact of Moisture on Powder Based Additive Manufacturing Processes

Louis-Philippe Lefebvre, Anatolie Timercan

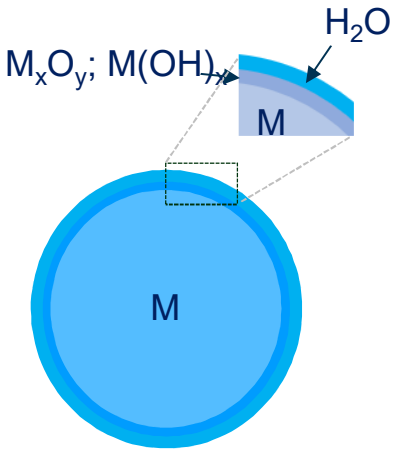
Context: Standardization

ASTM CoE supported projects to generate the knowledge and data to develop standards and fill standardisation gap.

- ✓ **F3606−22:** Additive Manufacturing -- Feedstock Materials -- Guide for Testing Moisture Content in Powder Feedstock
  - Method to measure moisture
- ➢ **WK83145**: Additive Manufacturing - Feedstock Materials- Assessing the effect of moisture (ASTM Subcommittee: F42.01, filed August 12th, 2022)
  - Methodology to assess the sensitivity of the material and process to monitor moisture and approach to determine maximum allowance

Water adsorption on AM metallic powders

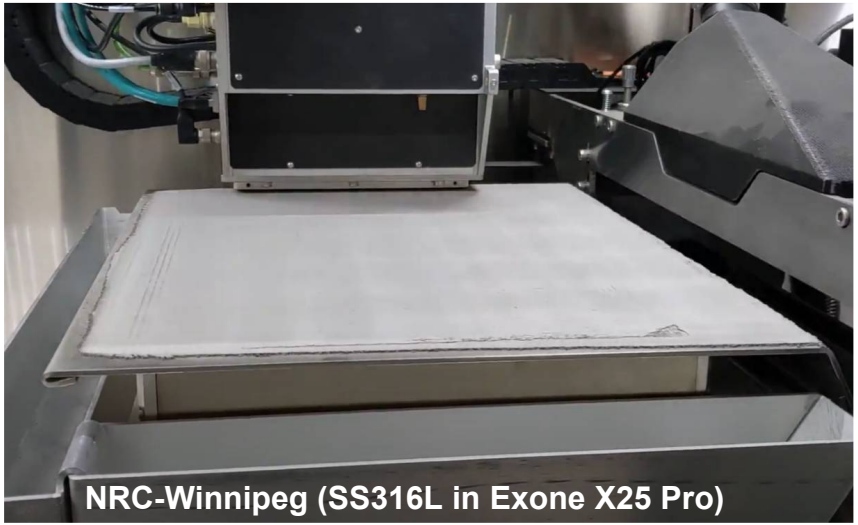
- Production
- Shipping
- Storage
- Handling
- Processing
  - Printing
  - Curing
  - Recycling…



- Interparticle adhesion
- Composition (%O, %H)
- Powder recycling/life cycle
- Cost

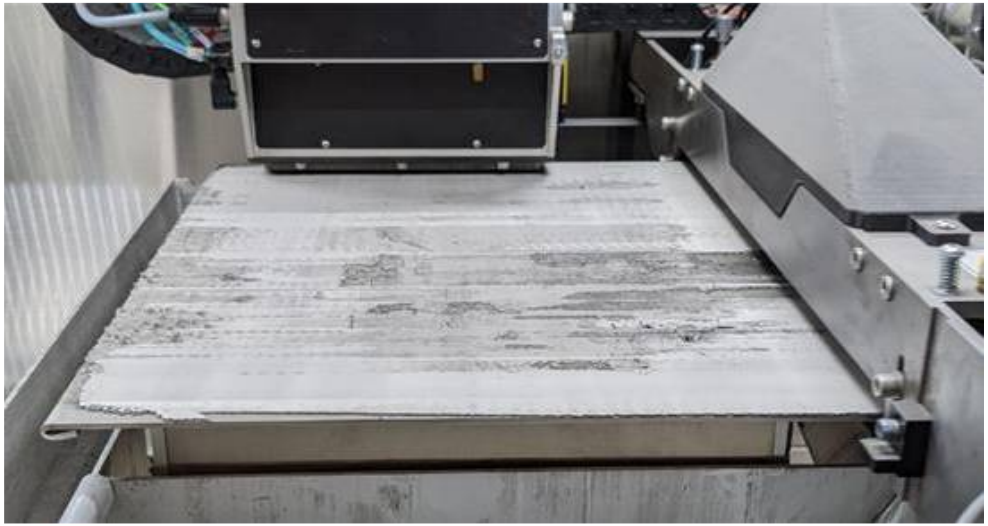
Effect of moisture on AM process

Dry



NRC-Winnipeg (SS316L in Exone X25 Pro)

Humid



Impact

- Fabrication process: Reliability
- Final part quality: Composition, properties
- Cost: Powder aging, QA, productivity

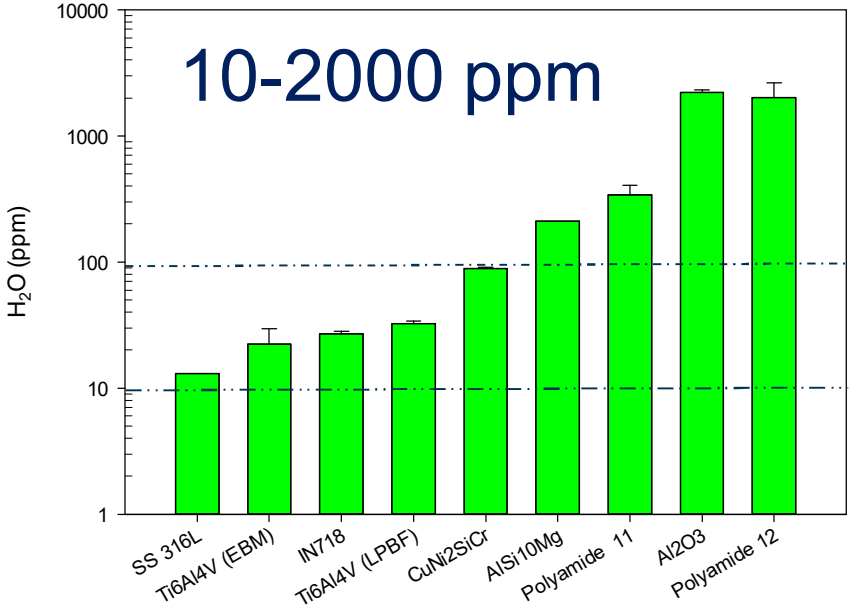
- Difficulty to assess:
  - Not all materials and systems have the same sensitivity
  - Complex, multivariable (affected by surface composition, particle size and shape, surface area, density, processing conditions…)

- Need to develop procedures to assess the impact of moisture
  - Must rely on data

Moisture in as-received powders

Karl Fischer

- Metal and ceramic @ 250°C
- PA @ 120°C



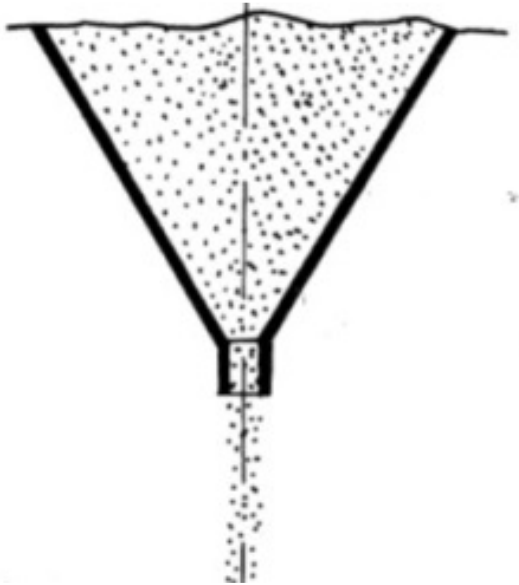
Detection limit of measurement methods

- Loss on drying (LOD)
- Coulometric titration methods (e.g. Karl Fischer)
- Relative humidity sensor

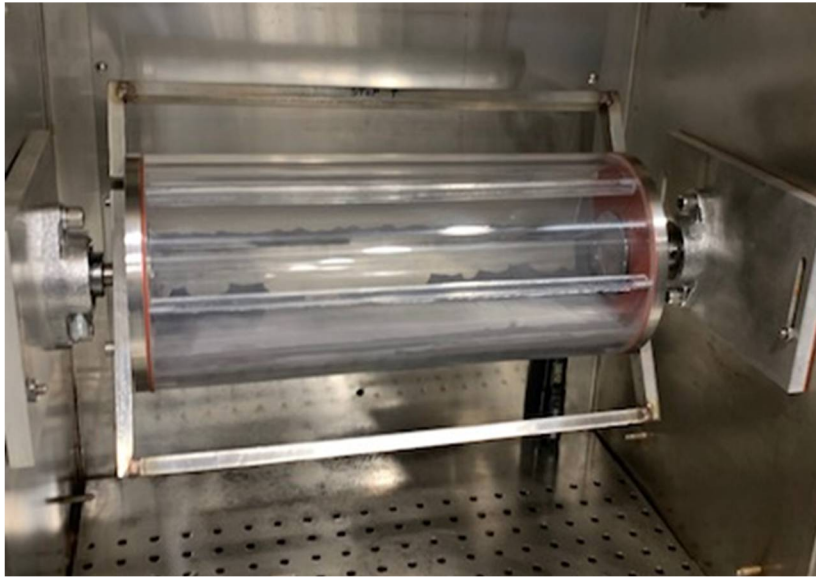
Louis-Philippe Lefebvre, Pelle Mellin, Mylène Trublet, AnnikaTalus, Olivier Rigo, *Moisture in AM powders*, in the Proceeding of the AMPM2022: Additive Manufacturing with Powder Metallurgy Conference, June 12-15, 2022, Portland, Oregon, USA, 209-220.

Exposure to moisture

Funnel flow/Fluidisation

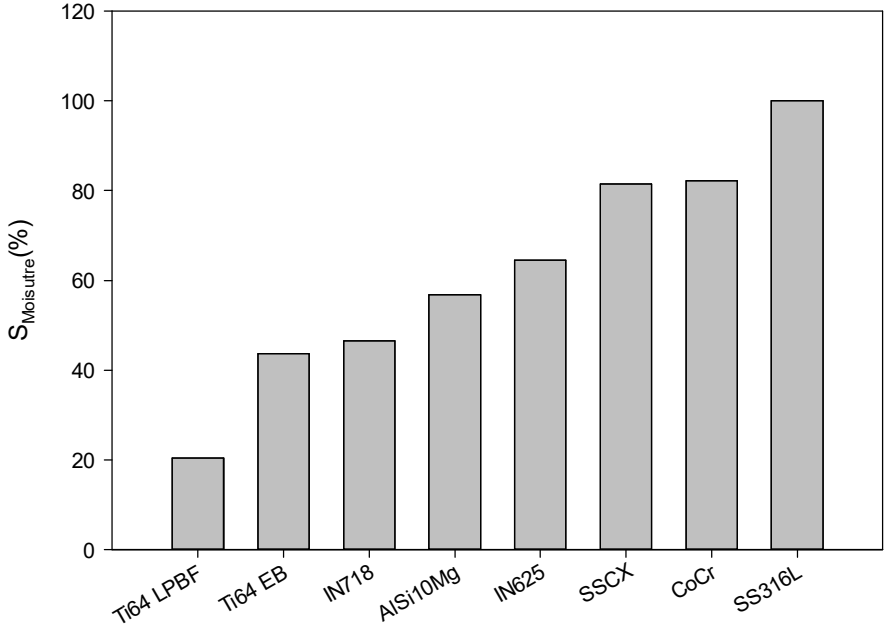


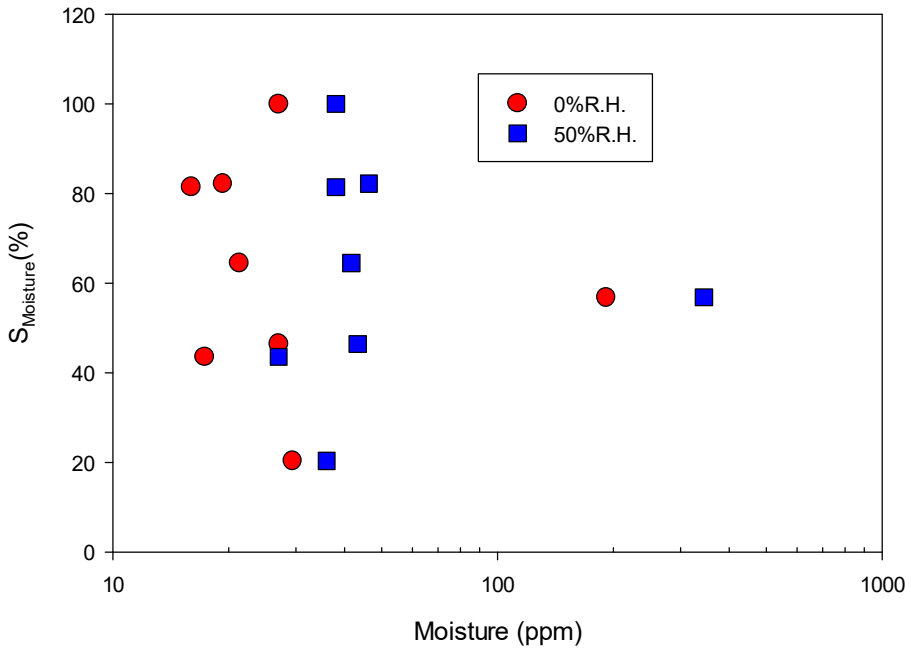
Mixer in an incubator: 70%R.H./24°C



Sensitivity to moisture adsorption 0-50%R.H.

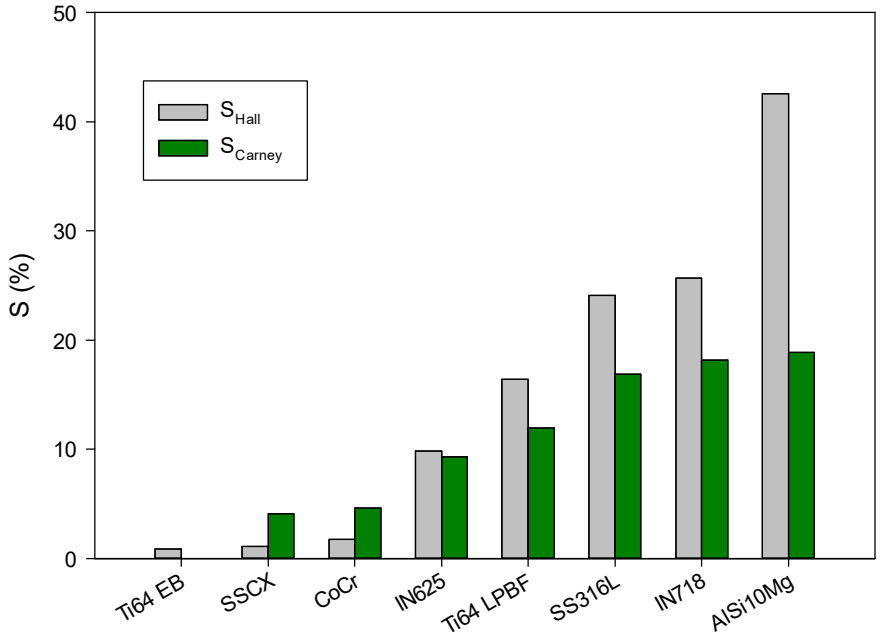
$$S_{H_2O}(0-50\%RH) = 100 * \frac{H_2O_{50} - H_2O_0}{0.5 * H_2O_{50} + 0.5 * H_2O_0}$$





Sensitivity of funnel flowability 0-50%R.H.

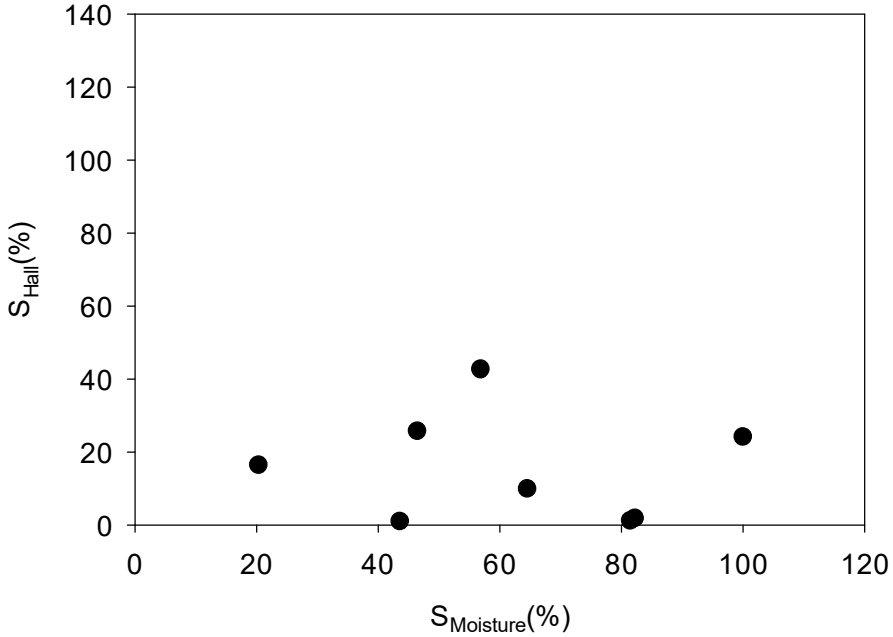
$$S_{Hall}(0-50\%RH) = 100 * \frac{Hall_{50} - Hall_0}{0.5 * Hall_{50} + 0.5 * Hall_0}$$

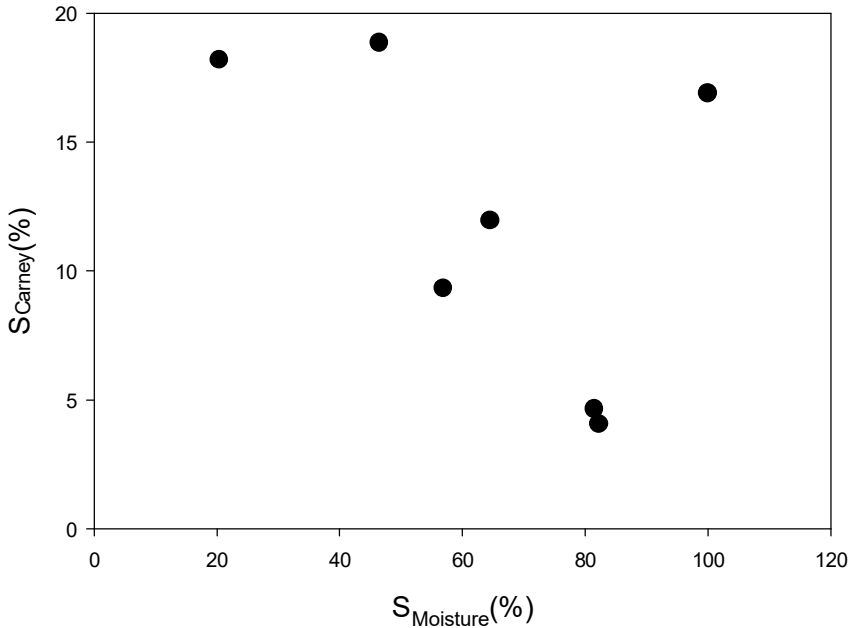


Sensitivity
Funnel flowability vs moisture

No correlation between the sensitivity of powder to moisture adsorption and funnel flow

- Sensitivity of the flowability is affected by many other factors (density, size, shape, composition…)



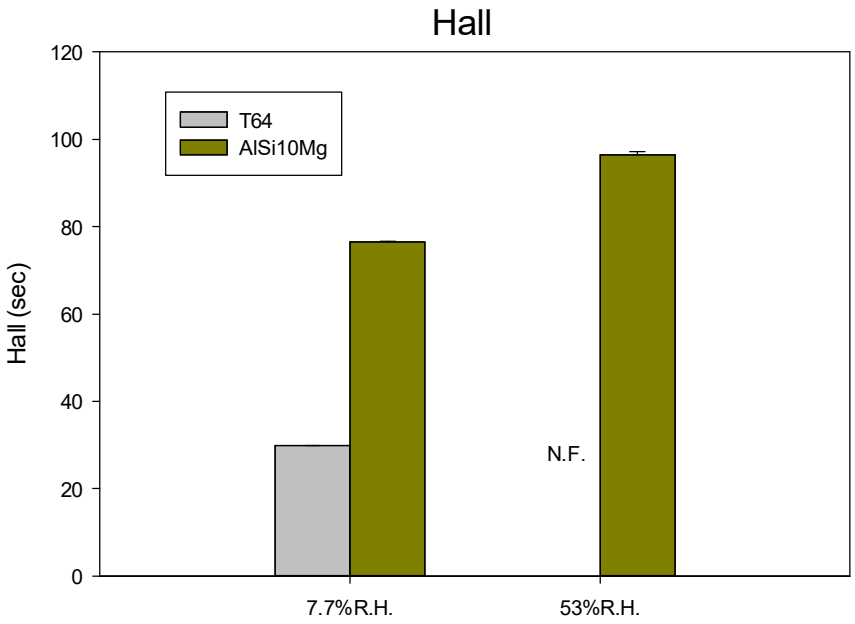


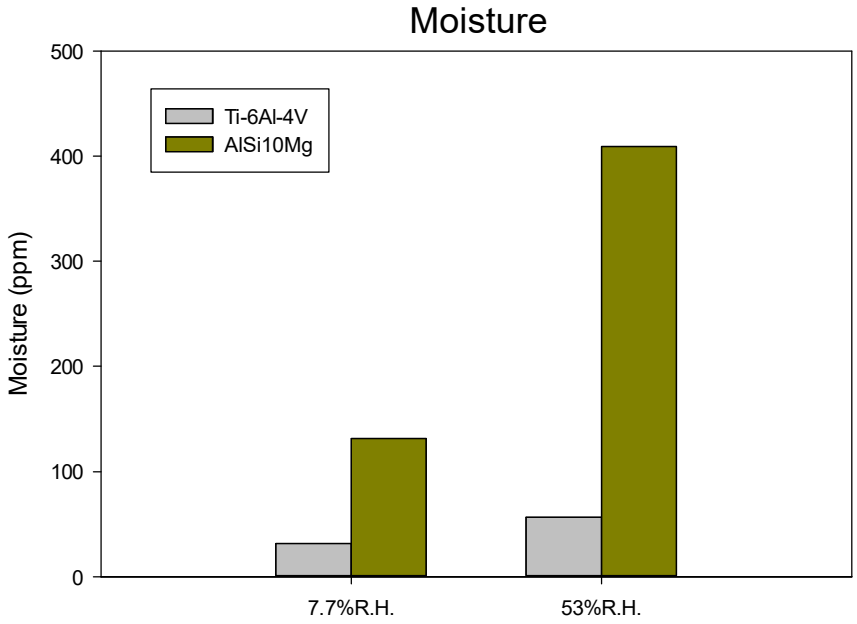
Printing

Printing coupons and artefacts and evaluate the composition, microstructure and properties of the printed materials:

- Printer: Truprint 1000
- Powders: **AlSi10Mg, Ti6Al4V**
- Conditioning:
  - As received
  - ~ 50%R.H. (5 flow through a funnel)
  - ~70%R.H. (5 flow through a funnel)
  - ~70%R.H. (one week in a mixer)

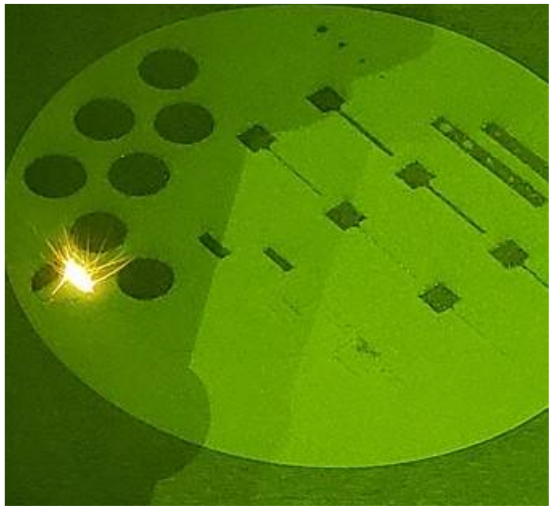
Sensitivity to moisture

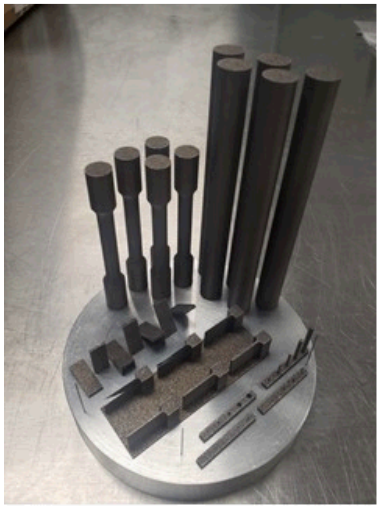


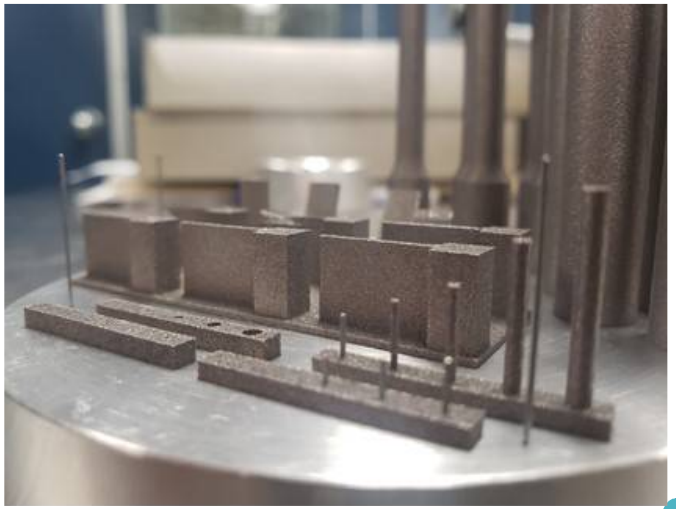


General observations

- No significant differences observed during the printing of the parts
  - Uniform layer, no sign of line defects or waves
- No apparent differences in the printed components

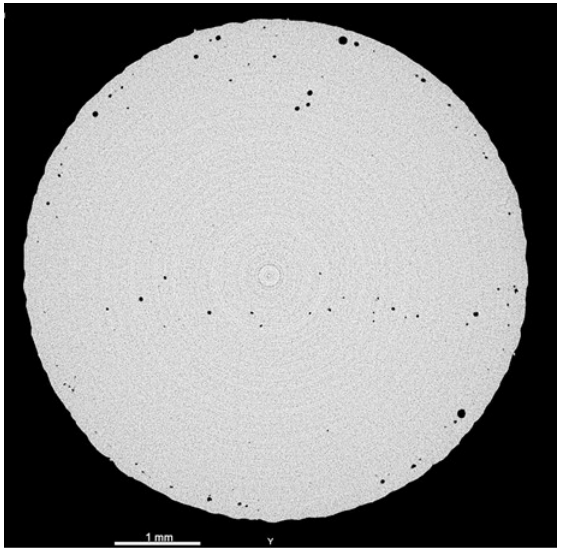






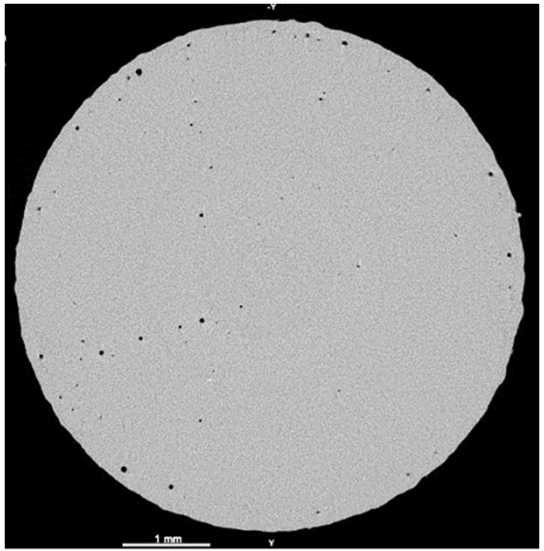
µCT (after thermal treatment)

As received



Porosity (3D): 0.27%

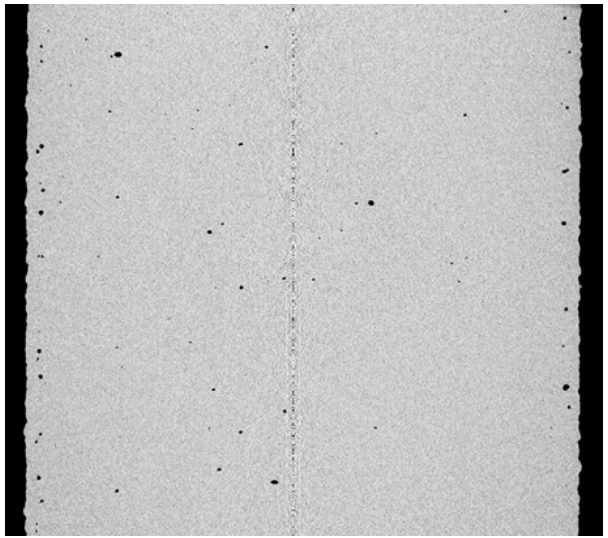
74% R.H.



Porosity (3D): 0.15%

μCT (after thermal treatment)

As received



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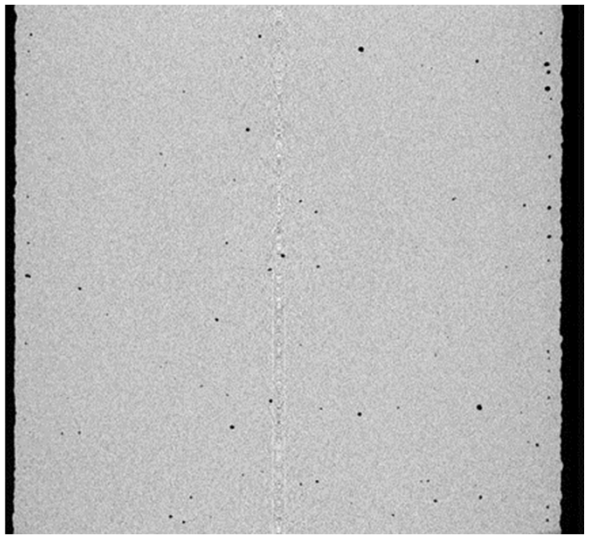
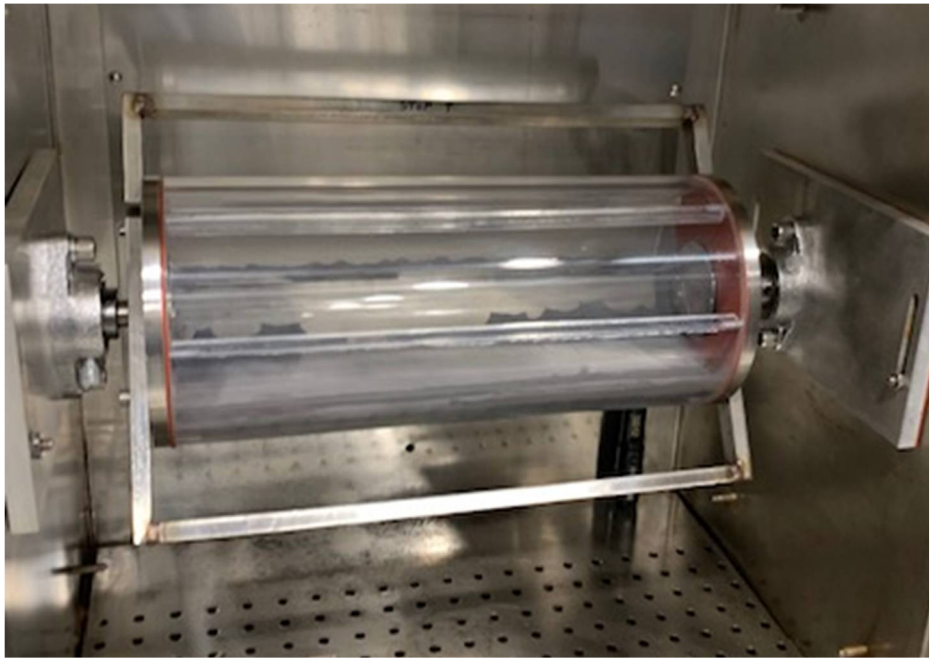


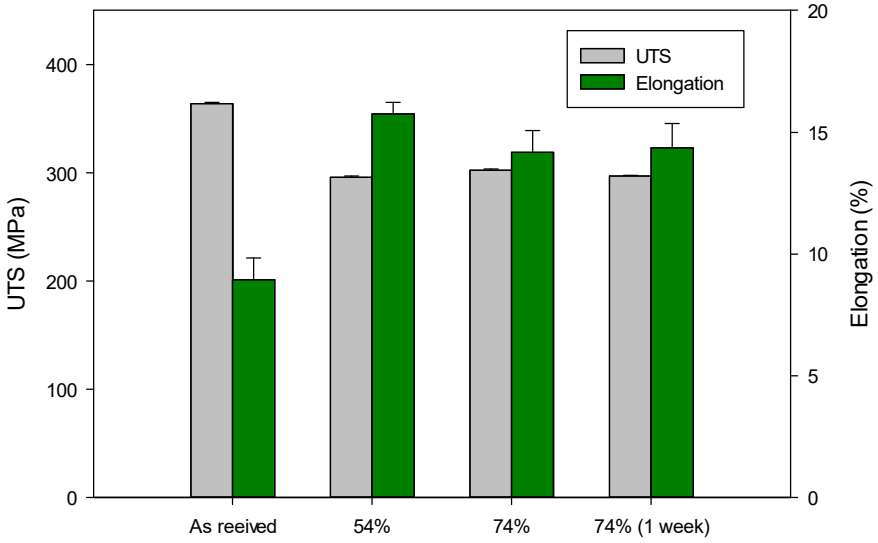
Porosity (3D): 0.15%

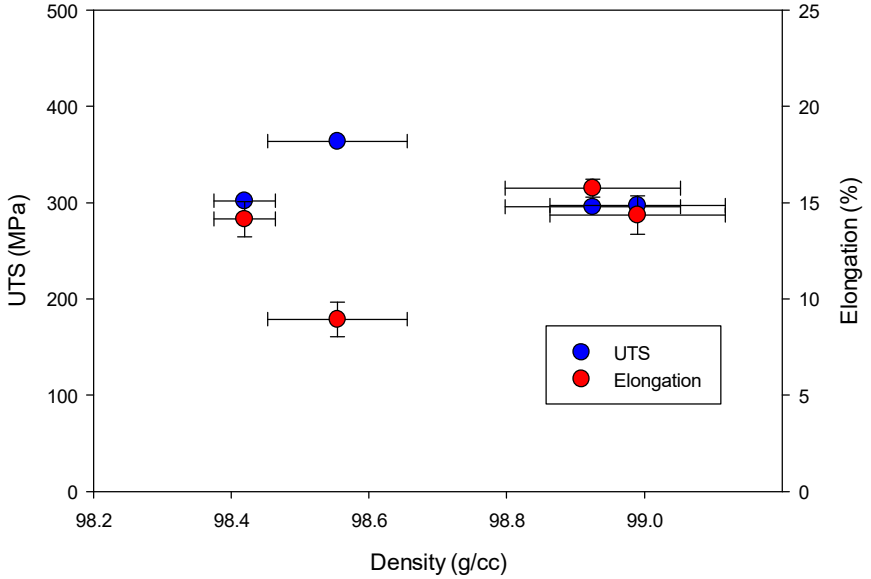
Long term exposure

- 1 week at 74%R.H. and 24°C

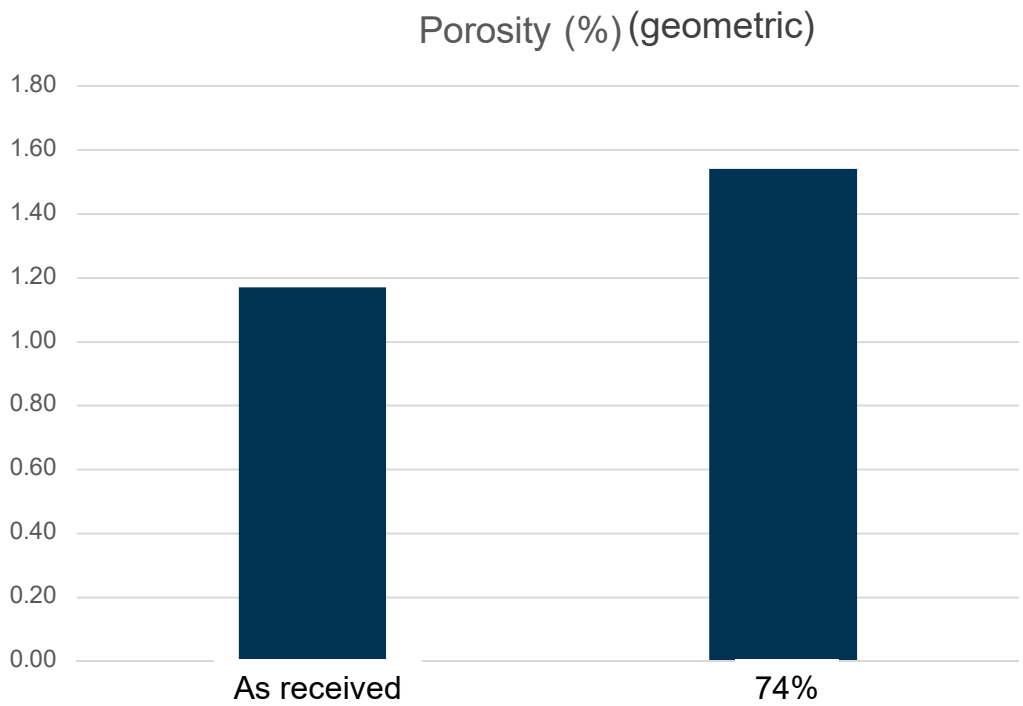


Mechanical testing



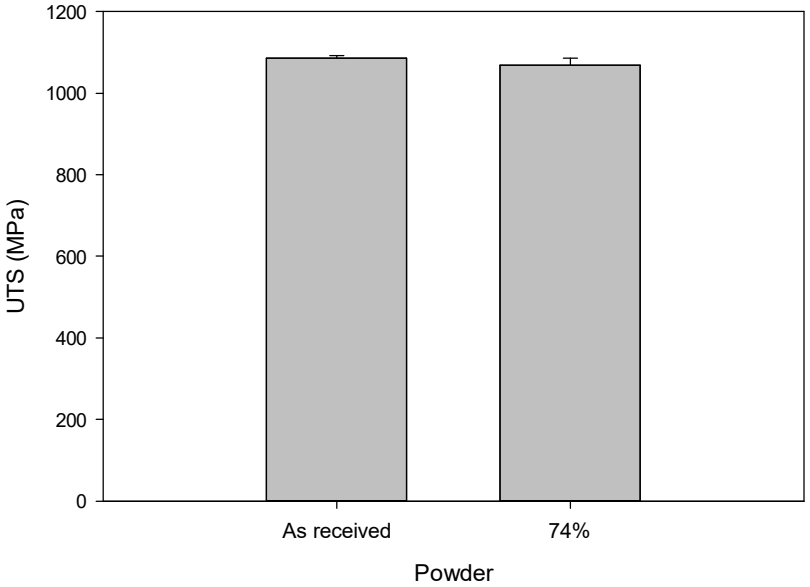


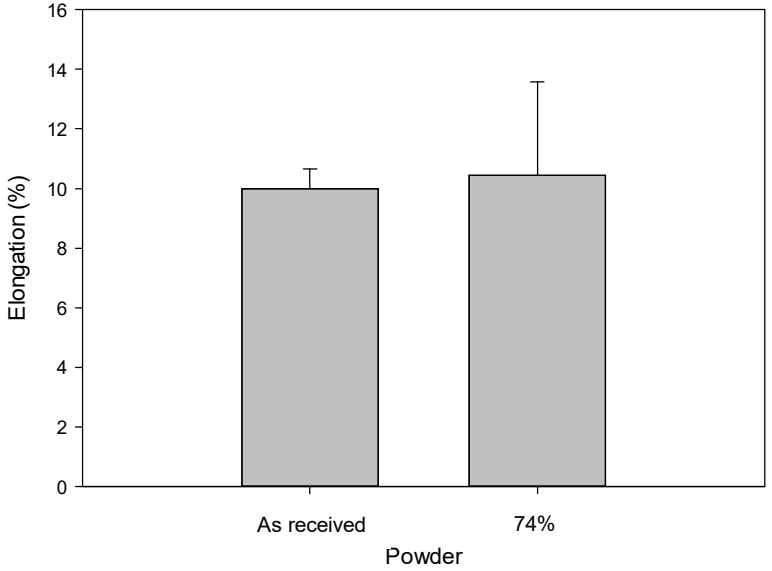
Ti-6Al-4V



3 x 1 week

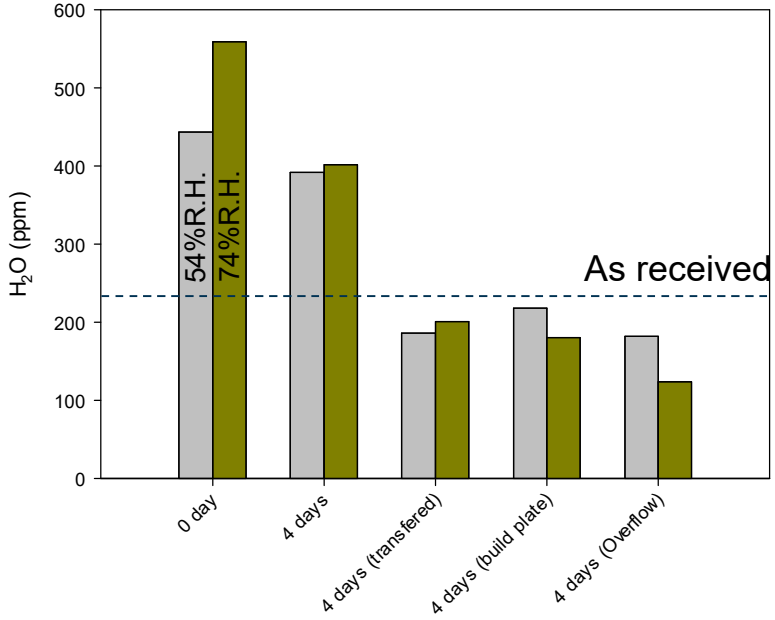
Ti-6Al-4V


1200
1000
800
600
400
200
0
UTS (MPa)
As received
74%
Powder


16
14
12
10
8
6
4
2
0
Elongation (%)
As received
74%
Powder

Evolution of the moisture Before and after printing

- Significant differences after exposure but differences vanished with time and after printing
- Desorption of moisture in the machine when exposed to dry argon and reaction of moisture with the surface of the powder
  - Values lower than in the as-received powder after printing



Observations

- Water adsorption/desorption is rapid and depends on the powder (composition, surface chemistry and particle size distribution).
  - Water content may evolve with time
- Water adsorption may affect the flowability
  - No correlation between the sensitivity and the amount in the as-received powder
  - No correlation between the variability of the flow rate and moisture content

Observations

- For the powders and print conditions investigated, the amount of moisture adsorbed has limited effect of the formation of porosity and mechanical properties (UTS, elongation).
  - Effect on other powders and print conditions need to be validated

WK83145: Additive Manufacturing - Feedstock Materials- Assessing the effect of moisture

- Filed August 12th, 2022
- Sponsoring Subcommittee: F42.01
- Practice
  - Methodology to assess the sensitivity of the material and process to monitor moisture and approach to determine maximum allowance
- Draft ready for balloting

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