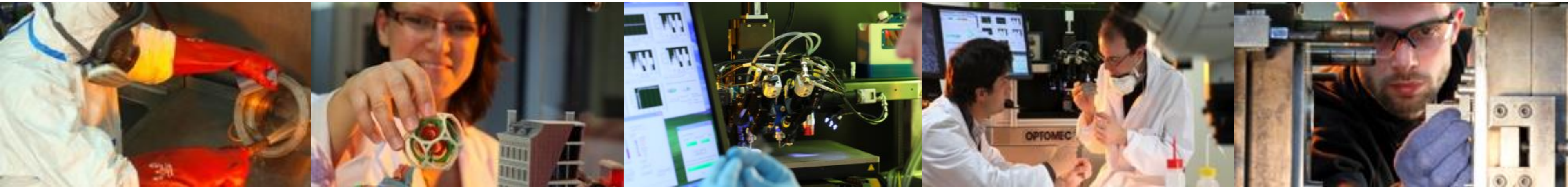


Quality of powders for AM

The INSIDE Metal AM project

Introduction

The INSIDE Metal AM project was started in 2018 in order to support the uptake of 3D printing with steel by the Belgian industry. Therefore, the aim was to be able to provide guidance along the entire process chain, starting from raw materials to finishing of the part. This was done through a combination of applied research and the realization of a number of industrial demonstrators. The project focused on three different AM technologies: Laser Powder Bed Fusion (L-PBF), Laser Metal Deposition (LMD) and Wire Arc Additive Manufacturing (WAAM). A number of different steels were used in the project: 316L, 17-4PH, H11, 2209 and S355. The topics covered by the project are materials selection and handling, the process-structure-property relationships and post-processing (including heat treatment and surface post-processing).

In this document, a brief overview is given of why the quality of powders is important, what the key characteristics are and how an efficient two-step testing procedure can be used to keep track of powder quality in your production flow.

This project received support from the Strategic Initiative Materials (SIM Flandres) and het Vlaams Agentschap voor Innoveren & Ondernemen (Vlaio).

Project partners: Sirris, CRM, BIL

Importance of Powder Quality

The importance of powder quality

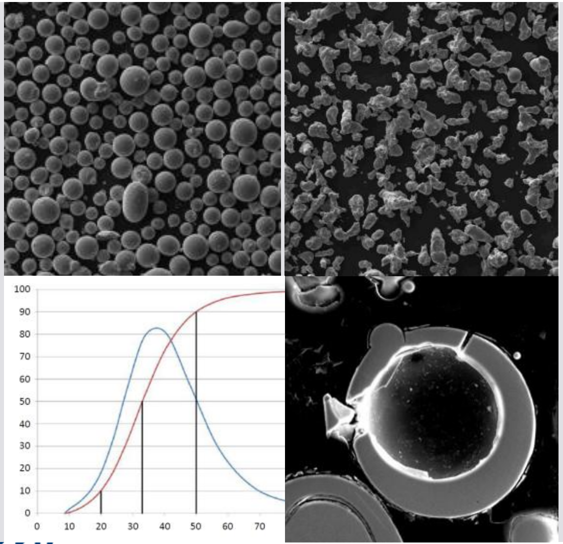
Powder transport, handling and recycling may cause drift in powder quality and properties by changing humidity levels, oxidation levels, particle shapes and particle size distributions. This has a direct impact on flowability and spreading of the powder and therefore also on part quality. But there can also be an indirect impact by resulting in increased part porosity and oxide inclusions. For 17-4PH it was observed that the average particle size increased after use, which had a positive effect on the flowability improved (shorter times in Hall Flow). However, for other powders (e.g. 316L), powder recycling was seen to reduce the flowability, even after mixing with virgin powder. For 17-4PH, it was further observed that using a powder batch sieved under air, resulted in a discoloration of the printed part. Mastery of the full chain of material handling is therefore mandatory to reach good quality on final part and powder properties. This includes printing, sieving, mixing, handling and storage.

In summary, some of the major impacts on part quality are:

- Impact on flowability of powder (through particle shape, particle size distribution, humidity) and thereby an impact on spreading of the powder in powder bed printing or possible blockage of hoppers and nozzles in LMD.
- Chemical composition of the powder
- Introduction of porosity (through moisture or H2 absorbed on powders, or direct inclusion of gas porosity from gas bubbles in the powder itself)
- Introduction of oxide inclusions (by oxidation of the powder itself)

The importance of powder quality

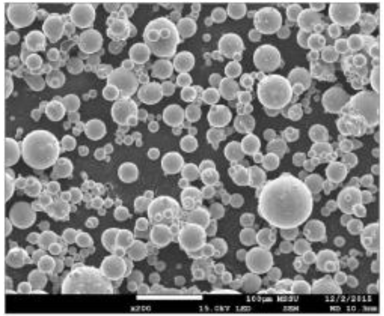
Powder quality features

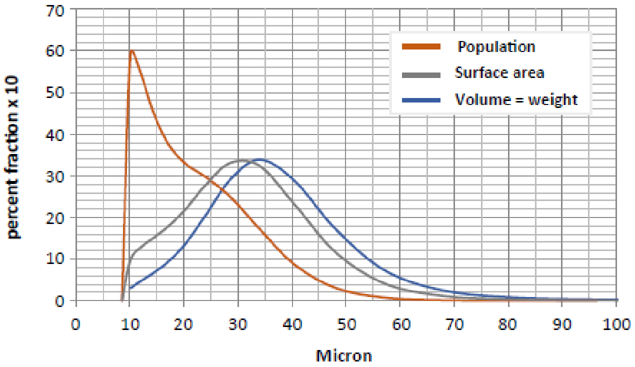


- ✓ Particle size and distribution
- ✓ Shape
- ✓ Flowability
- ✓ Entrapped gas

The importance of powder quality

- Particle shape: round, spherical particles needed for good flowability, more critical for powder bed processes as compared to blown powder methods
- Particle size distribution
  - Direct influence on flowability
  - The fine particles can have a significant effect on the AM process.
    - melt quickly in SLM -> good. BUT: can evaporate, creating smoke or porosity.
    - a small amount of fines can act as ball bearings improved flow
    - large amounts of fines increase particle cohesion deteriorated flow
  - Size depends on the technology
    - 10-50µm for laser powder bed techniques
    - 50-150µm for electron beam & laser metal deposition





Source: An introduction to metal powders for AM: Manufacturing processes and properties, Metal AM Magazine, Summer 2018

The importance of powder quality

- Flowability
  - A good flowability and high powder density are required
  - Tap density vs. Apparent density
    - Hausner ratio = tap density/apparent density
    - Hall Flow Rate - Hall Flow Rate meter: extensive use and historical database. On the other hand, it is subject to operator variability and has limited ‘resolution’, it also doesn’t say anything about spreadability, i.e. not adapted to what AM needs.
    - Shear cell Rheometer
    - Rotating drum
- Chemical composition
  - Powder vs. printed part: there can be changes in the part composition due to preferential evaporation or interaction with the build environment (remaining oxide, absorption of N, etc.; elements such as Cr and Al are sensitive to preferential evaporation)
  - Low concentrations off N, O en H can have a large impact on part characteristics (<0.1wt%)

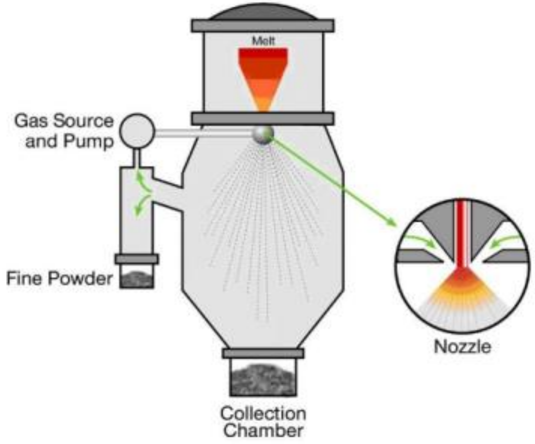
Source: http://www.dahometerinstrument.com

Source: An introduction to metal powders for AM: Manufacturing processes and properties, Metal AM Magazine, Summer 2018

Production methods for AM powders

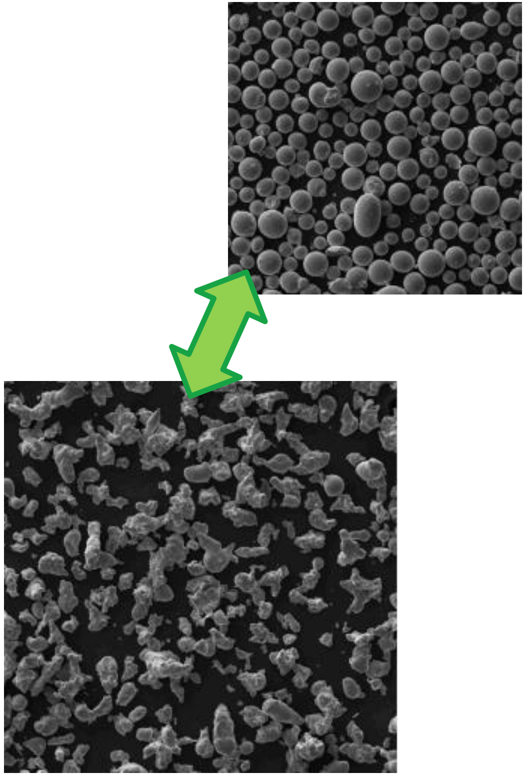
The production method can have a direct influence on part quality.

- **Gas atomisation**
  - Most used method
  - Importance of atmosphere (N2 can be absorbed by powder and have an influence on part properties, for example as shown in 17-4PH steel)
  - Spherical powders
  - Melt material (open, vacum or inert atmosphere)
  - Molten metal stream is broken in droplets by high pressure gas
  - Batches in the range of 5kg to 3000kg
  - Particle size: 0-500µm
  - Good balance price/quality
  - Very flexible in terms of composition



Production methods for AM powders

- Induction Melted Bar Atomisation
  - Comparable to gas atomisation
  - Melt by induction melting of bar material
  - Typically used for reactive alloys (like Ti-alloys)
  - Expensive and limited choice of materials
- Plasma Atomisation
  - Comparable to gas atomisation
  - Wire molten by plasma torch
  - Limited to alloys availble as wire
- Water Atomisation
  - Largest production volume
  - Irregular shape and rough surface
  - Not suited for most AM processes
- Plasma Rotating Electrode Process



Maintaining powder quality

sirris

driving industry by technology

Maintaining powder quality

To maintain high part quality, the powder quality also needs to be controlled. This includes:

- Protection and storage of powders during production, distribution, use and recycling.
- Quality checks during production, distribution, use and recycling.
- ‘Tracing’ of powders
    - Blends
    - Recycling/mixing

Maintaining powder quality

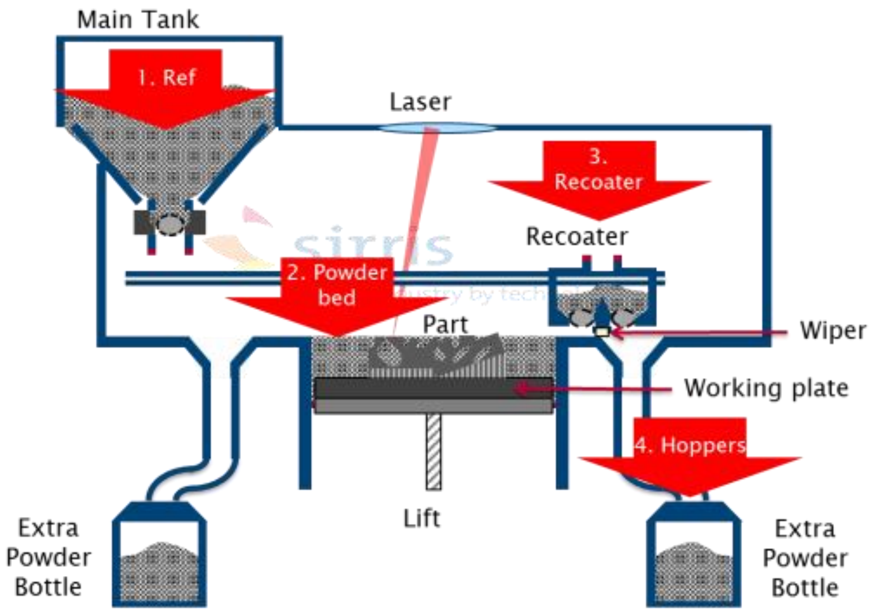
Focus on powder bed processes

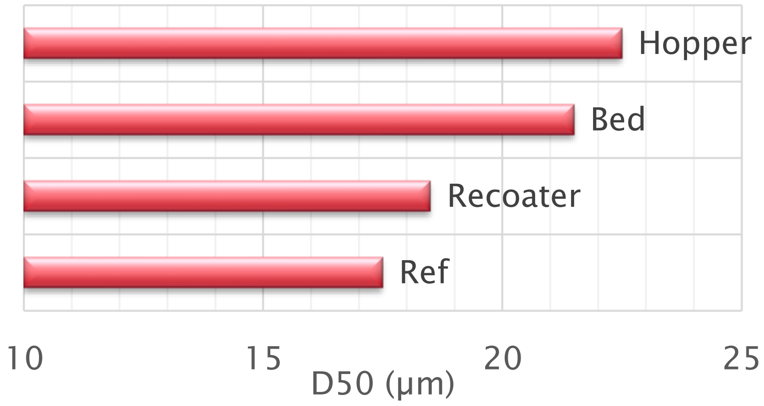
- Powder manipulation
    - avoid contact with air
    - always sieving under argon, and at least ones before sending to machine (avoids mistakes during storage, and make sure there are no remaining big parts in the powder from previous print)
- Removing powder from machine
    - Where possible, vacuum cleaner integrated in the machine, so don't need to open the machine
    - Sieving unit integrated in the machine, or use a brush and metallic blade to collect the powder. Many machines can be accessed as a glove box. In this case, keep the brush/blade in the machine, allowing to manually put the powder in a bottle through the overflow without opening the machine.
- Bottle/container with powder should always contain a protective atmosphere.
    - Can fill containers, etc. in a glove box
    - Valves can be used to connect bottles to sieving, these exist as closed systems flushed with a protective gas
- Powders can be store in special closets with a protective atmosphere (can also be used for fire protection)

Maintaining powder quality

Recycling of powder

- The printing process has an influence on particle size distribution
- Different distributions were found at different locations in the process



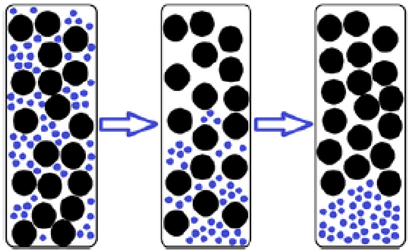


Maintaining powder quality

Recycling of powder

- The printing process has an influence on particle size distribution
- Different distributions were found at different locations in the process

- Powder segregation has been observed in the main tank, resulting in a risk on powder drift during the process



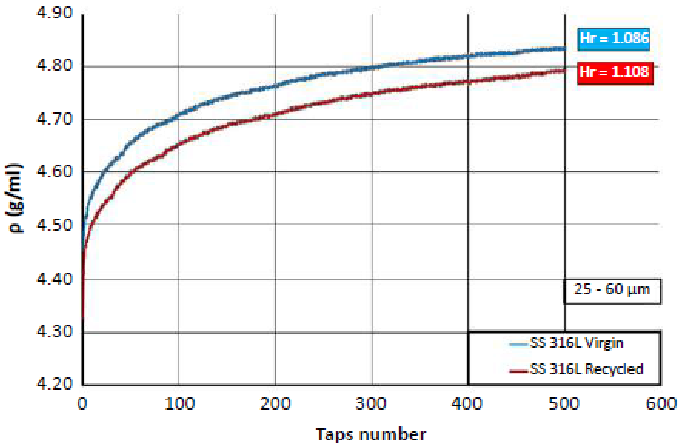
Important to mix powders from various locations.

As the size distribution depends on the sampling location, a good sampling procedure is required to determine the correct particle size distribution.

Maintaining powder quality

Recycling of powder

- Flowability of recycled powder can change, even after sieving or mixing with virgin powder (pick-up of contamination, spatters, etc.)



Source: An introduction to metal powders for AM: Manufacturing processes and properties, Metal AM Magazine, Summer 2018

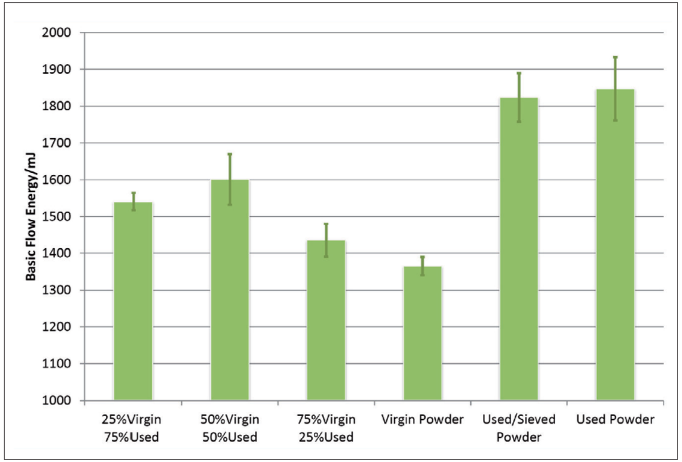


Figure 4: Flowability measurements show that used powders have poor flowability relative to the new material. Blending helps to produce a material that can be re-used with confidence.

Source: Metal-powder.net sept/oct 2014

Maintaining powder quality

It’s good practice to mix recycled powders

- L-PBF Process :
  - Increases the median of the powder size distribution (D50) → coarser particles in the hoppers
  - Decrease the asymmetry of the distribution → Skewness (tends to symetrical distribution)
  - Observations seem to indicate that the powder in the overload bottles is coarser (part of the finest particle population (10-15µm) has decreased)
    - → Risk of powder drift if multiple recycling steps during a single build process
    - → Need to Mix the powder after the process
    - → Need to apply a mixing step in order to blend the powder from the hoppers with the powder from the bed.
    - → Better to recycle the powder after a complete SLM process (not in a current process)
- When mixing various powder batches (virgin and recycled), it’s critical to maintain powder traceability. For each mixed powder batch, the history should be known (origin of the virgin powders and previous recycling and mixing steps). This information is crucial to determine potential origins of build failures, but also for part certification and qualification processes.

Storage and handling

Powder storage shall be in accordance with vendor’s instructions, and also include:

- Keep feedstock in separate, labelled, sealed containers in a designated dry storage area.
- Prevent contamination between different batches, especially when transferring powders.
- Prevent the inadvertent mixing of virgin and used feedstock.

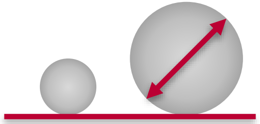
Quality control of powders

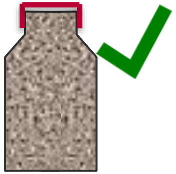
Quality control of powders

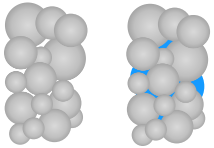
Powder testing is critical to track powder quality over time and guarantee part quality. The testing itself can be cumbersome and time consuming. In order to speed up production flows, a two-step process, based on fast response granulometric techniques was adopted in this project. It was found that compaction curves (automated tap density) give relevant information on oxidation, humidity, size distribution, spreadability and segregation and can be used as a fast method to detect anomalies (density vs. number of taps curve shifts up/down). In case an anomaly is detected, the powder batch can be temporarily taken out of rotation and further investigated to determine the cause of the anomaly and the possible impact on build part properties.
Powder should be extensively characterised when it arrives, and a reference compaction curve determined. The batch should be rejected if the properties (for example particle size distribution or flowability) are not within the specifications. Detection of drift over time can then be performed using the fast method of compaction curve determination. It should be remarked that the compaction curves are sensitive to the global effect of the process itself. I.e. samples taken from different locations in the process give different results (main tank - ref, recoater, build chamber, overflow). A good sampling procedure should therefore be put in place and respected. By building up a history for your printing equipment in your environment and threshold for powder acceptance based on compaction curves can be further fine-tuned.

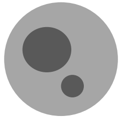
On the next page, an overview of a number of quality control methods are given.
After that, the two-step test procedure is discussed in more detail.

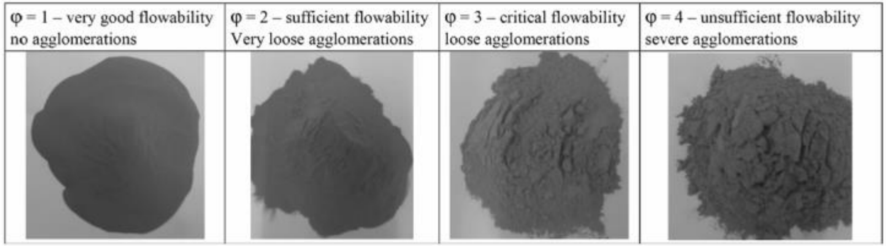
Powder characterization methods











Powder size range :

- Granulometer for size between 0.5 - 200 µm (number and volume)
- Nanophox (photon cross correlation spectroscopy) down 1 nm
- CPS (centrifugal sedimentation) down to 1nm

Powder handling :

- Development of powder handling/mixing solutions
- Huge glovebox for analysis in controlled atmosphere

Grains morphology :

- Optical microscope processed images
- MEB analysis

Spreadability :

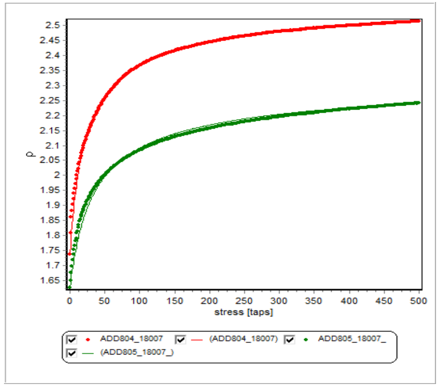
- Online image analysis
- Dedicated customizable test bench

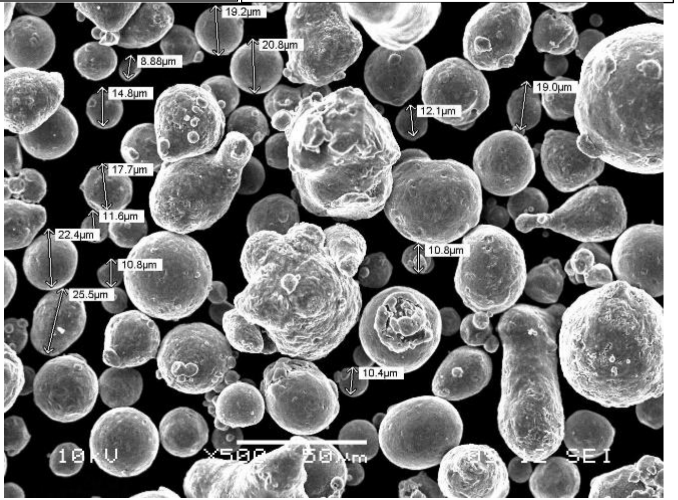
Humidity entrapment :

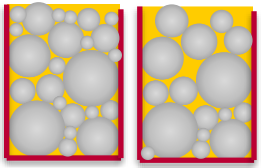
- Loss on drying method
- Karl Fischer method
- Combustion analysis C-HNO

Powder internal porosity :

- pycnometer







Physical analysis : Tap density

Material/Powder characterization methods

Property	Test equipment	Materials	Target value	Service Provider
Chemistry Composition, Chemistry Contamination	Wet chemical analysis, spectroscopy methods (ICP-AES/ICP-MS/AAS)			LPW Technology/Cepesi/KULeuven (MTM)/CRMG
	Globe Discharge Optical Emission Spectroscopy (GDOES)	Aluminium/Steels/Iron (not for powders)		Sirris
	Spark-OES	Aluminium/Steels/Iron (not for powders)		OCAS
	Combustion Analysis methods (carbon & sulfur)	Steel, Iron*, Nickel/Cobalt Alloys		LPW Technology/CRMG
	Combustion Analysis methods (hydrogen)	Aluminum and Aluminum Alloys		LPW Technology/CRMG
	Inert Gas Fusion methods (O, N and H in metallic materials)	Ferrous and non-ferrous alloys		CRMG
	X-ray Fluorescence (XRF)			KULeuven (MTM)
	SEM-EDX			Sirris/LPW Technology
	XRS spectroscopy			LPW Technology/CRMG
	Auger Microscopy			CRMG
	XPS spectroscopy			CRMG
Flow	Hall/Carney Flow funnel			Sirris/LPW Technology/ Engie
	shear cell rheometer	Powder/ liquid	cohesion strength	Engie/LPW Technology
	rotating drum principle	Powder/ liquid	cohesion index	Sirris/Engie
Powder shape (?)	Optical Microscopy			
	Static image analysis methods			Sirris/LPW Technology/CRMG
	Dynamic image analysis methods			CRIBC
Particle size distribution	Sieve Analysis (> 45µm), (volume based)			Sirris/LPW Technology/Engie
	Laser diffraction(< 45 µm) (volume based)			LPW Technology/Engie
	Static image analysis methods			LPW Technology/Sirris
	Dynamic image analysis methods			BCRC
Density	Tap density			
	Apparent density			Sirris
	Automated and improved tapped density measurement (granupack)		Hausner Ratio, n1/2, apparent density	Sirris
Particle porosity	Helium Pyncometry (entrapped porosity)			Sirris/LPW Technology
	powder cross section			LPW Technology/Sirris
Moisture content	Loss on drying			Sirris/LPW Technology/CRMG
	Karl-Fischer methode			Sirris
	Humidity- temperature probe			Sirris
	Microwave Technology			

Powder Quality Analysis

The main questions coming from the industry

Can I use my powder ?

Which parameters to control (is relevant) ?

How to reception the powder from supplier ?

How to manage the recycling ?

Which equipment to use (is relevant) ?

How to make the sampling ?

How to handle the material?

What are the acceptable range ?

What are the impacts on the final part quality?

How to follow the traceability during mixing ?

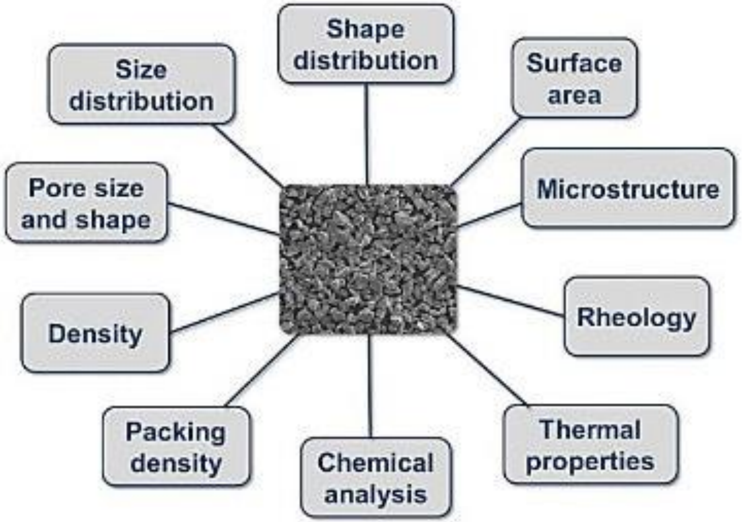
In situ monitoring

Powder methodologies

Standard – Final application

Powder Quality Analysis

Use the right equipment to characterize your powders



- Lot of equipment on the market in order to characterize the powder :
  - ✓ Each of them have pro and negative points
  - ✓ Depending on the nature of the material
  - ✓ Depending on the print technology

The main goal is to use the right characterization equipment to perform a relevant, quick and robust test.

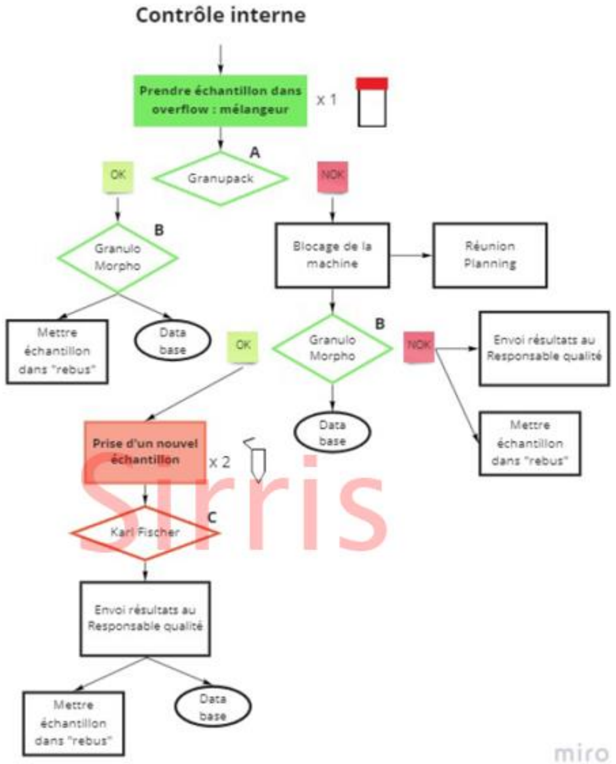
WP2 – Proposed workflow for powder characterization

sirris
driving industry by technology

- Powder transport, handling and recycling may cause drift in powder quality and properties (humidity, oxidation, particle size distribution, flowability, spreading)
- Powder testing can be cumbersome and time consuming
- To speed up production flows, a methodology based on fast response granulometric techniques is proposed as a two-step process
  - Fast methods to detect anomalies
  - In case of anomalies, more extensive testing to determine the origin and possible impact on final build properties

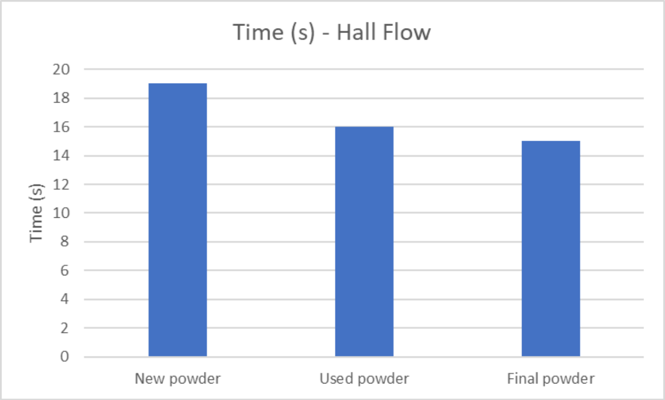
WP2 – Proposed workflow for powder characterization

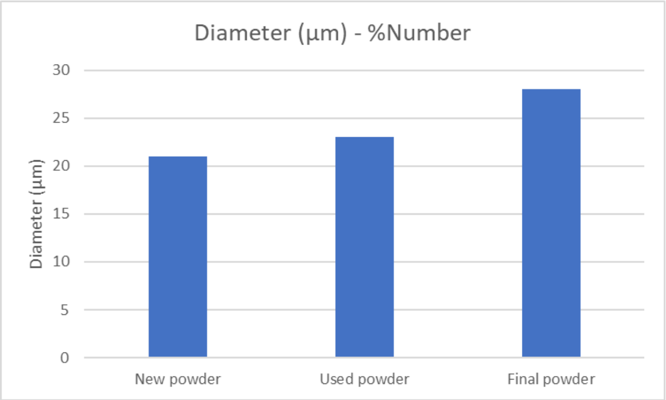
- Fast Physical behavior-based testing (drift detection on same powder)
  - Automated tapped density and packing dynamic measurements (Granupack)
- In case of anomalies, the powder batch can be temporarily taken out of rotation and further investigated to determine the cause of the anomaly and the possible impact on build part properties



Powder Quality Analysis

Process impacts the powder properties, which in turn impacts part properties.





- ✓ Printing
- ✓ Sieving
- ✓ Mixing
- ✓ Handling
- ✓ Storage

Mastery of the full chain of material handling is mandatory to reach good quality on final part and powder properties.

Powder Quality Analysis

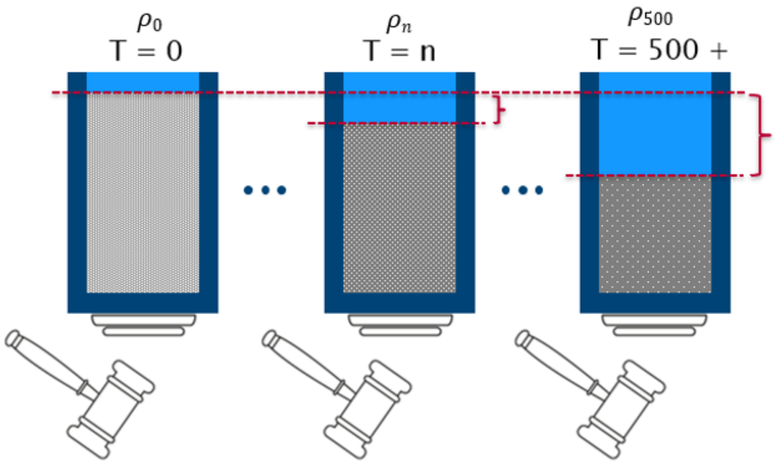
Packed density curves:

- Used to track powder drift based on evolution of physical behaviour
- It cannot only be used for evaluation of density of powder bed, but is a system sensitive enough to detect all types of drift (i.e. changes in powder properties)
- Sensitive enough to detect the influence of a single print and recycle step on the powder properties
- Packed density curves allow a process-oriented analysis of the powder. For a root cause analysis, further investigation is required.

This procedure can be used for both smaller size particles, as typically used for L-PBF processes (15-45µm) and for larger particle sizes as used for EBM processes or LMD processes (45-156µm)

Powder Quality Analysis

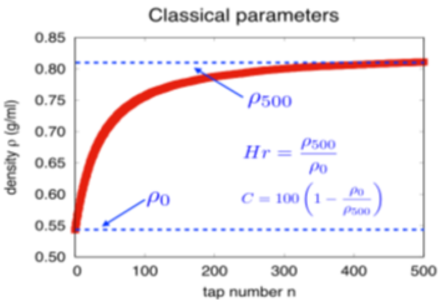
Compaction curves give relevant information on



$$\rho_0 = intial\ density$$

$$\rho_n = density\ after\ "n"\ taps$$

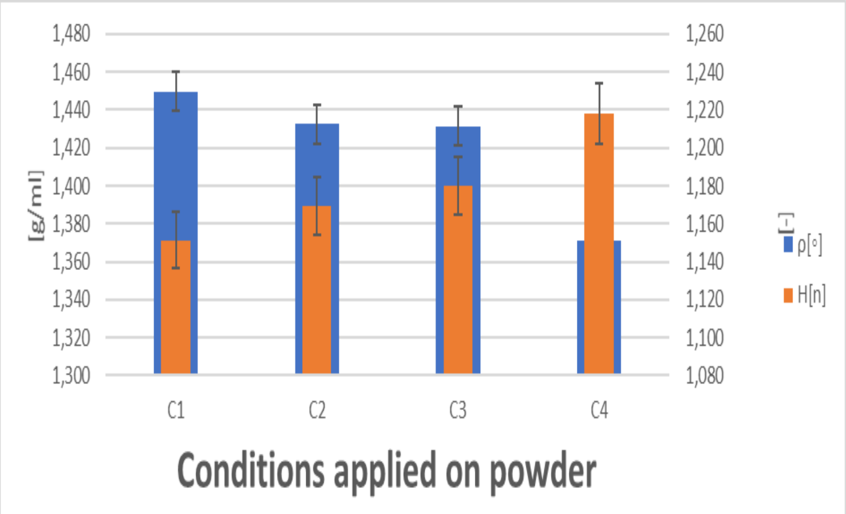
$$H[n] = \frac{\rho_n}{\rho_0} = Hausner\ ratio$$



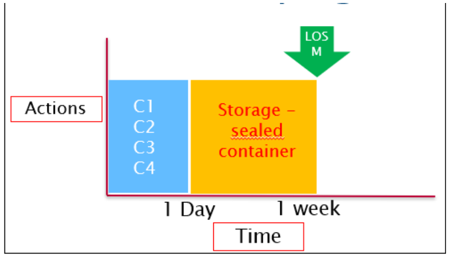
- ✓ Oxidation
- ✓ Humidity
- ✓ Size distribution
- ✓ Spreadability
- ✓ Segregation

Powder Quality Analysis

Compaction curves give relevant information



conditions	Fresh powder	AR/22°C/24h	44%/22°C/24h	95%/22°C/24h	stabilisation (168h)	rH% after stabilisation
C1	x				x	0,038
C2	x	x			x	0,039
C3	x		x		x	0,037
C4	x			x	x	0,043

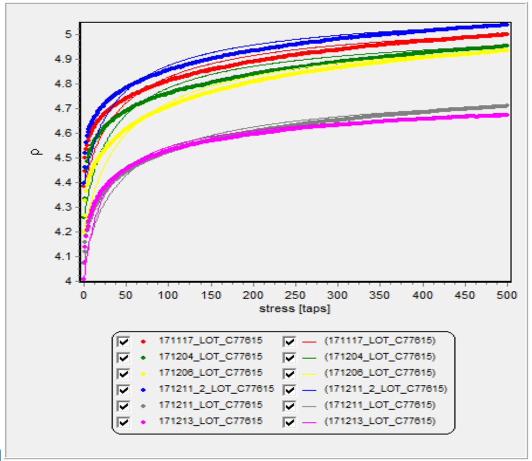


Compaction curves are sensitive to the level of humidity of the powder

Powder Quality Analysis

Compaction curves give relevant information

Sensitivity of the densification curve to moisture

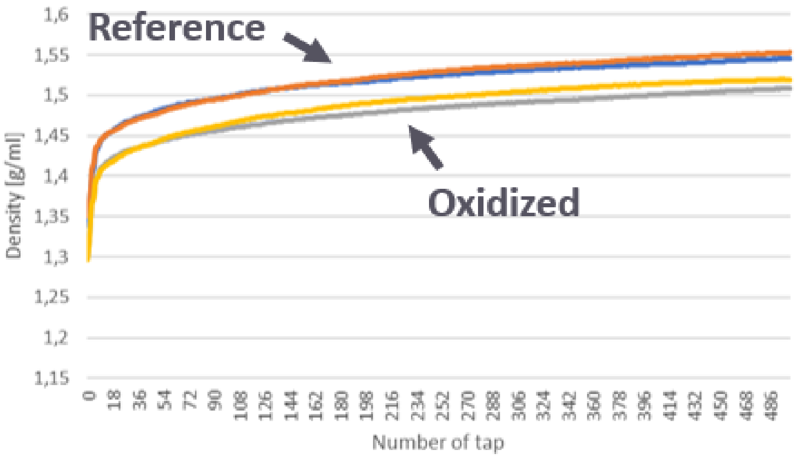


<u>316L Powder</u>

- Red: no treatment
- Green: 4 days exposure to humidity
- Yellow: 1 day exposure to humidity
- Blue: Dried
- Grey: 7 days exposure to humidity
- Pink: 9 days exposure to humidity

Powder Quality Analysis

Compaction curves give relevant information

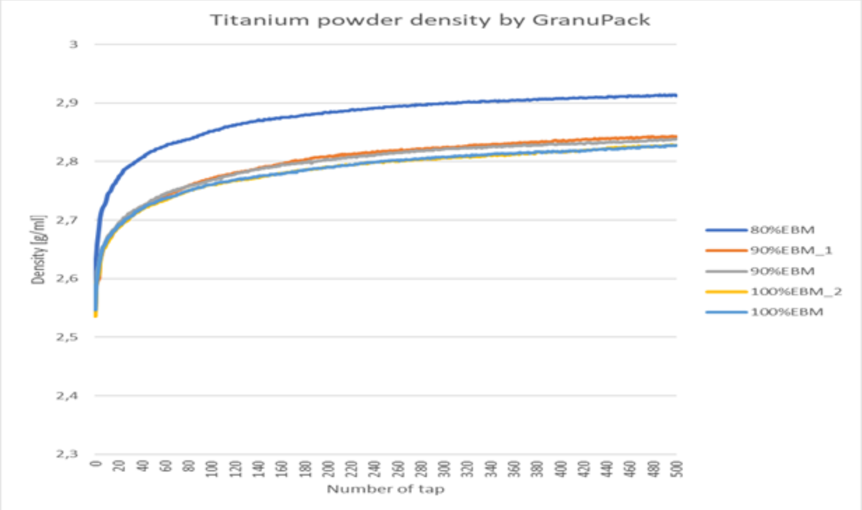


- Issue during sieving of powder : batch of oxidized powder injected

Compaction curves are sensitive to the level of oxidation of the powder

Powder Quality Analysis

Compaction curves give relevant information

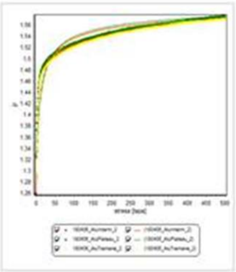


- Mix of two same material with 2 PSD range :
  - EBM : 45-100µm
  - SLM : 20-63µm

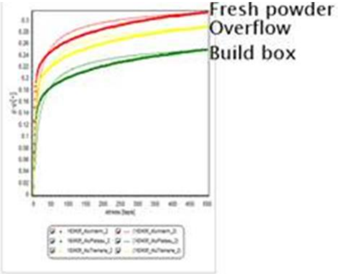
Compaction curves are sensitive to the particle size distribution of the powder

Powder Quality Analysis

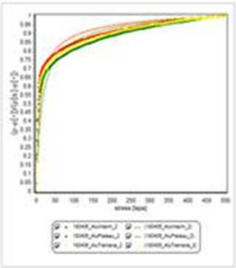
Compaction curves give relevant information



Initial density



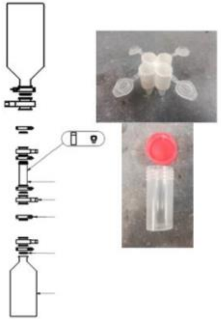
Hausner ratio

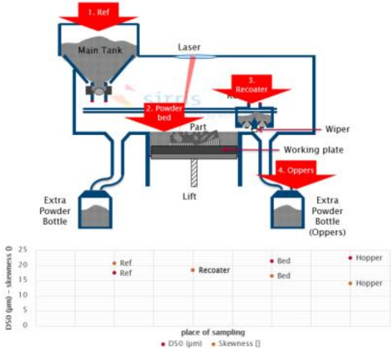


Compaction speed

	ρ[•]		ρ[n]		n½		H[n]	
	average		average		average		average	
new	1,258333	0,28%	1,567333	0,27%	3,666667	4,64%	1,245	0,30%
Over Flow	1,278667	0,33%	1,570333	0,26%	4,433333	1,06%	1,228667	0,21%
Build box	1,323	0,43%	1,580333	0,27%	5,6	11,57%	1,194667	0,67%

Lower Flowability
Better Flowability

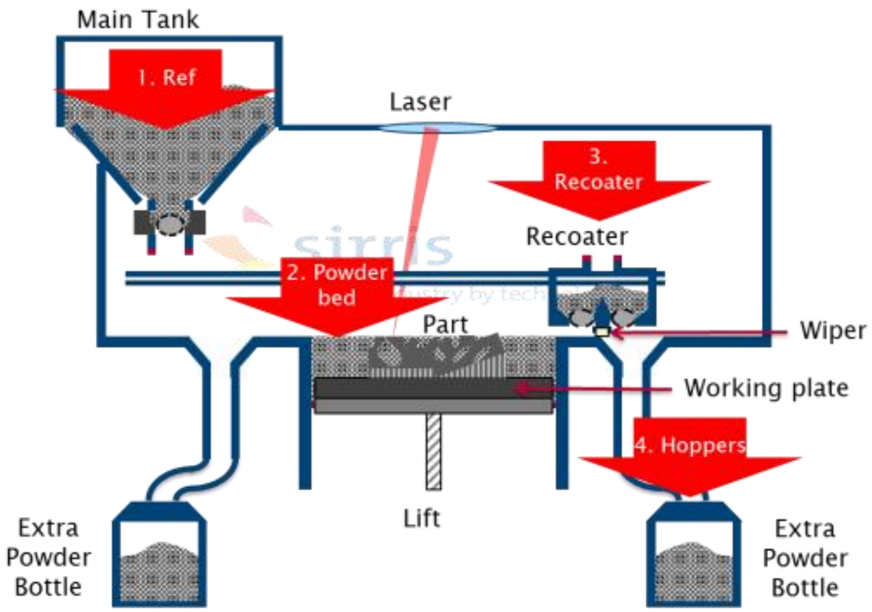


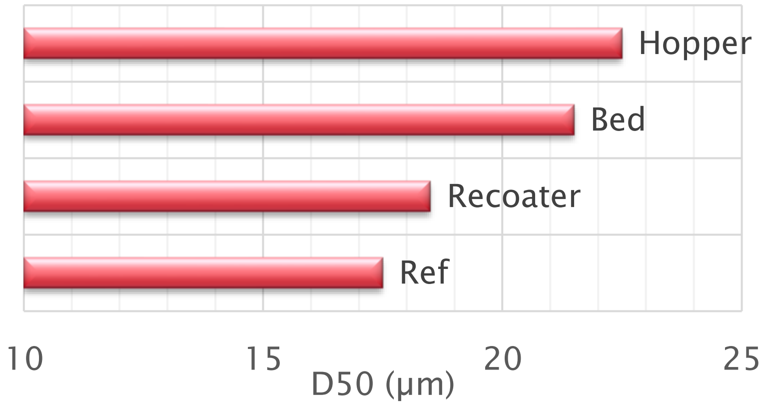


Compaction curves are sensitive to the global effect of the process itself

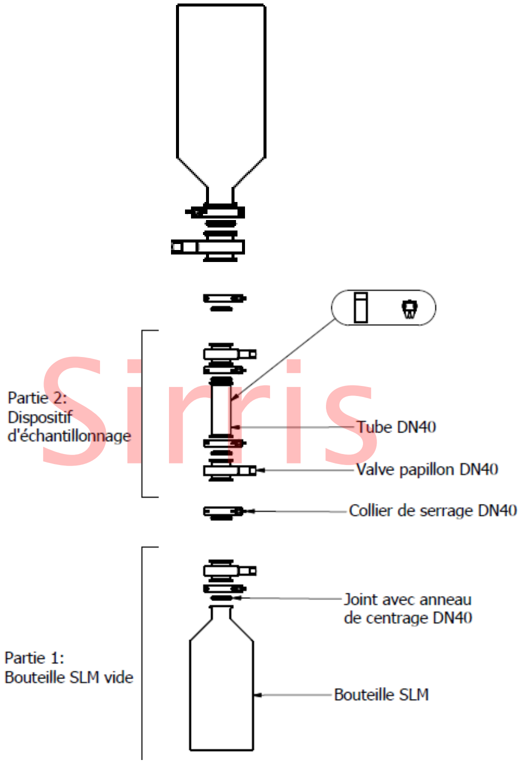
Powder Quality Analysis

- Different distributions were found at different locations in the process





How to take the sample

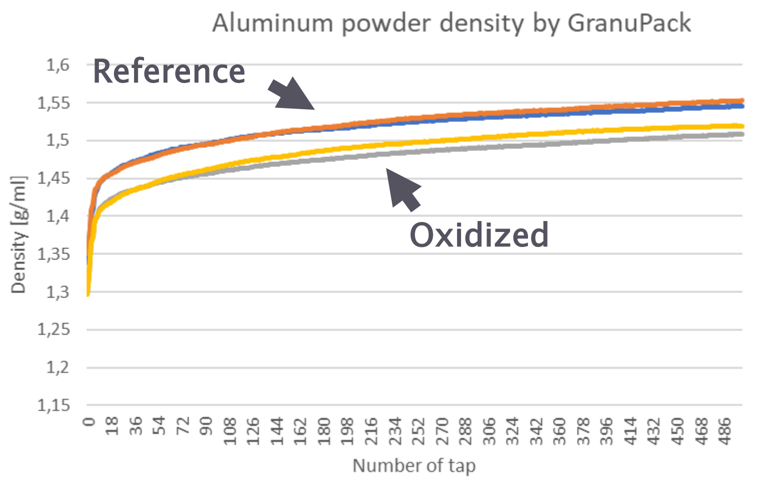


Always in the same place→ over flow

FIG.3: PROTOTYPE IMPRIMÉ EN PA

Powder Quality Analysis

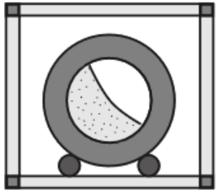
Process oriented powder analysis



- ✓ Oxidation
- ✓ Humidity
- ✓ Size distribution
- ✓ Spreadability
- ✓ Segregation

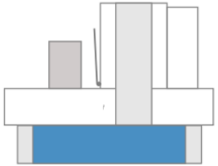
Build up a history for your printing equipment in your environment and define a threshold for powder acceptance.

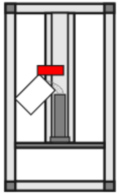
Key take-aways on powders



Use the right equipment to characterize

Process impacts the powder properties





Compaction curves give relevant information

Build up a history for your printing equipment in your environment and define a threshold for powder acceptance

Qualification and certification

Qualification and certification

Qualification and certification of AM parts is required, especially for critical applications. Although AM can no longer be called a new technology, many standards and guidelines on quality control and certification are still under development. This is also true for certification and quality control of the feedstock material, which is an important link in the entire qualification and certification chain.

As this is a fast-evolving landscape, the goal of the current document is not to give a comprehensive overview of the guidelines and standards available for feedstock material. It rather provides a short introduction to the state of affairs at the time of writing of this document and to raise awareness on the importance of certification for critical applications such as for example in automotive and aerospace.
At Sirris, there is a norm Antenna for Additive Manufacturing, meaning that we keep track of the latest developments and provide information to the industry. For more in-depth, and depending on the time of reading, updated information, the reader is therefore invited to contact us directly.

General guidelines for powder feedstock

- The importance of traceability has already been indicated above. It is important to know the exact origin of mixed powder batches to determine potential origins of build and part failures, but also for part certification and qualification processes.
- Following information shall be provided to demonstrate control and traceability:
    - Powder supplier contact information.
    - Packing date.
    - Unique identification of the powder (batch number).
    - Product description (material name and grade and/or trade name).
    - Process used for melting/producing the powder (e.g. argon gas atomisation).
    - Packaging and storage instructions (specifying maximum oxygen content).
    - Material Safety Data Sheet (MSDS).
    - History of recycling and mixing of powder batches.

Source: https://www.qualitymag.com/gdpr-policy?url=https%3A%2F%2Fwww.qualitymag.com%2Farticles%2F94637-achieving-consistency-and-reliability-in-additive-manufacturing

General guidelines for powder feedstock

- Samples of (new) powder batches (e.g. sampling procedure ISO 3954) should be tested following available standard and includes:
  - Chemical composition (including crystalline phases and test methods).
  - Thermal characteristics (melting temperature).
  - Particle size and distribution (e.g. by sieving or laser diffraction). Content outside the specified range shall be reported.
  - Characteristic density (i.e. apparent density, tap density or skeletal density).
  - Powder flow properties (e.g. using a Hall Flowmeter).
  - Description of morphology.
  - Oxygen content.
- If required information not available on material certificates → testing shall be conducted by manufacturer (see ISO/ASTM 52907 - Methods to characterize metal powders).
- With some AM process, powder may be sieved and reused.
  - Tracking number of times powder is reused
  - Testing of recycled powder and validation against original incoming powder specification before reuse.
  - Adequate checking frequency to eliminate risk of unsuitable feedstock being used during manufacturing.

Ongoing work

Joint Group for Technical Specification on Metal Powders

- ISO/TC261/JG66
- Developing standards for documentation and traceability, sampling, particle size distribution, chemical composition, characteristic densities, morphology, flowability, thermal characteristics, cleanliness, packaging and storage.
- Does not cover safety aspects.
- ISO/ASTM 52907 – Additive manufacturing – Feedstock materials – Methods to characterize metal powders

Joint Group for Test Methods for the Characterization of Powder Flow Properties for Additive Manufacturing Applications

- ISO/TC261/JG63
- Developing standards for evaluation of the flow properties of powders intended for AM, considering factors that influence powder behaviour and introducing test methodologies and protocols for characterizing the flow properties of powders to created consistency across all applications and sectors.
- ISO/ASTM 52913 – Additive Manufacturing – Process characteristics and performance – Standard test methods for characterization of powder flow properties
- Agreement between groups (JG63, JG66, JG71) that current measurement methods are not sufficient to describe well metallic powder behaviour inside a printer (for example: Hall flowmeter doesn't correlate well with powder behaviour), motivating further work.

Ongoing work

- Spreadability measurements as a standard for AM powder characterization
  - A good standard should be relevant. This means it should provide a useful information about what it is supposed to be measuring
  - Agreement between groups (JG63, JG66, JG71) that current measurement methods are not sufficient to describe well metallic powder behaviour inside a printer.
  - The Hall flowmeter cannot characterise the spreadability. Therefore it is not relevant for the application in AM
  - This is the motivation for a new test method which is investigated within JG63
- ASTM group WK66030 – New guide for quality assessment of metal powder feedstock characterization data for additive manufacturing (https://www.astm.org/DATABASE.CART/WORKITEMS/WK66030.htm)

Existing ISO AM standards

- In the following slides, an overview is given of standards for Additive Manufacturing.
- Standards with the strongest link to powder quality are indicated in ‘bolt’
- Colour indications:

Data Processing

Test Methods

Methods-Processes-Materials

Terminology

Existing ISO AM standards

Terminology | Methods-Processes-Materials | Test Methods | Data Processing

- ISO 17296-2:2015 : Additive manufacturing - General principles - Part 2: Overview of process categories and feedstock.
- ISO 17296-3:2014 : Additive manufacturing - General principles - Part 3: Main characteristics and corresponding test methods.
- ISO 17296-4:2014 : Additive manufacturing - General principles - Part 4: Overview of data processing.
- ISO 27547-1:2010: Plastics - Preparation of test specimens of thermoplastic materials using mouldless technologies - Part 1: General principles, laser sintering of test specimens
- ISO/ASTM 52900:2015 : Additive manufacturing - General principles - Terminology.
- ISO/ASTM 52901:2017: Additive manufacturing - General principles - Requirements for purchased AM parts
- **ISO/ASTM 52902:2019: Additive manufacturing - Test artifacts - Geometric capability assessment of additive manufacturing systems**
- **ISO/ASTM FDIS 52903-1:2020: Additive manufacturing — Material extrusion-based additive manufacturing of plastic materials — Part 1: Feedstock materials**
- **ISO/ASTM 52904:2019: Additive manufacturing - Process characteristics and performance - Practice for metal powder bed fusion process to meet critical applications**
- **ISO/ASTM 52907:2019: Additive manufacturing - Feedstock materials - Methods to characterize metal powders**
- ISO/ASTM 52910:2018: Standard Practice - Guidelines for Additive Manufacturing Design.
- ISO/ASTM 52911-1:2019: Additive manufacturing - Design - Part 1: Laser-based powder bed fusion of metals
- ISO/ASTM 52911-2:2019: Additive manufacturing - Design - Part 2: Laser-based powder bed fusion of polymers
- ISO/ASTM 52915:2016 : Specification for additive manufacturing file format (AMF) Version 1.2.
- ISO/ASTM 52921:2013 : Standard terminology for additive manufacturing - Coordinate systems and test methodologies.

Existing ASTM AM standards

Terminology | Methods-Processes-Materials | Test Methods | Data Processing

- ASTM F2924-14: Specification for Ti6Al4V with Powder Bed Fusion.
- ASTM F2971-13: Reporting Data for Test Specimens.
- ASTM F3001-14: Standard Specification for Additive Manufacturing Ti6Al4V ELI (Extra Low Interstitial) with Powder Bed Fusion.
- ASTM F3049-14: **Standard guide for characterizing properties of metal powders used for additive manufacturing processes.**
- ASTM F3055-14A: Specification for Ni Alloy (UNS N07718) with Powder Bed Fusion.
- ASTM F3056-14E1: Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion.
- ASTM F3091-14 - F3091M-14: Standard Specification for Powder Bed Fusion of Plastic Materials.
- ASTM F3122-14: Evaluating Mechanical Properties of Metal Materials.
- ASTM F3184-16: Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion.
- ASTM F3187-16: Standard Guide for Directed Energy Deposition of Metals.
- ASTM F3213-17: Standard for AM – Finished Part Properties – Standard Specification for Co28-Cr6-Mo via Powder Bed Fusion
- ASTM F3301-18: Standard for AM – Post Processing Methods – Standard Specification for Thermal Post-Processing Metal Parts Made Via Powder Bed Fusion
- ASTM F3302-18: Standard for AM – Finished Part Properties – Standard Specification for Titanium Alloys via Powder Bed Fusion
- ASTM F3303-18: Standard for AM – Process Characteristics and Performance: Practice for Metal Powder Bed Fusion Process to Meet Critical Applications
- ASTM F3318-18: Standard for Additive Manufacturing – Finished Part Properties – Specification for AlSi10Mg with Powder Bed Fusion – Laser Beam

Draft ISO AM standards

NWI = New Work Item
DIS = Draft International Standard
FDIS = Final draft Int. Standard
TR = Technical Report

- ISO/ASTM DIS 52900: Additive manufacturing - General principles - Fundamentals and vocabulary
- ISO/ASTM NWI 52902: Additive manufacturing - Test artifacts - Geometric capability assessment of additive manufacturing systems
- **ISO/ASTM FDIS 52903-1: Additive manufacturing - Standard specification for material extrusion based additive manufacturing of plastic materials - Part 1: Feedstock materials.**
- ISO/ASTM DIS 52903-2: Additive manufacturing - Standard specification for material extrusion based additive manufacturing of plastic materials - Part 2: Process - Equipment.
- ISO/ASTM TR 52905: Additive manufacturing - General principles - Non-destructive testing of additive manufactured products.
- ISO/ASTM TR 52906: Additive manufacturing - Non-destructive testing and evaluation - Standard guideline for intentionally seeding flaws in parts
- ISO/ASTM NWI 52908: Additive manufacturing - Post-processing methods - Standard specification for quality assurance and post processing of powder bed fusion metallic
- ISO/ASTM NWI 52909: Additive manufacturing - Finished part properties - Orientation and location dependence of mechanical properties for metal powder bed fusion
- ISO/ASTM TR 52912: Design of functionally graded additive manufactured parts.
- **ISO/ASTM PWI 52913: Additive manufacturing — Process characteristics and performance — Standard test methods for characterization of powder flow properties**
- ISO/ASTM FDIS 52915: Specification for AM file format (AMF) Version 1.2
- ISO/ASTM NWI 52916: Additive manufacturing - Data formats - Standard specification for optimized medical image data
- ISO/ASTM NWI 52917: Additive manufacturing - Round Robin Testing - Guidance for conducting Round Robin studies
- ISO/ASTM TR 52918: Additive manufacturing - Data formats - File format support, ecosystem and evolutions
- ISO/ASTM NWI 52919-1: Additive manufacturing - Test method of sand mold for metalcasting - Part 1: Mechanical properties
- ISO/ASTM NWI 52919-2: Additive manufacturing - Test method of sand mold for metalcasting - Part 2: Physical properties
- **ISO/ASTM NWI 52920: Additive manufacturing — Qualification principles — Quality requirements for industrial additive manufacturing sites**
- ISO/ASTM DIS 52921: Additive manufacturing - General principles - Standard practice for part positioning, coordinates and orientation
- ISO/ASTM NWI 52924: Additive manufacturing - Qualification principles - Classification of part properties for additive manufacturing of polymer parts
- ISO/ASTM NWI 52925: Additive manufacturing - Qualification principles - Qualification of polymer materials for powder bed fusion using a laser
- ISO/ASTM NWI 52931: Additive manufacturing - Environmental, health and safety - Standard guideline for use of metallic materials
- ISO/ASTM NWI 52932: Additive manufacturing - Environmental health and safety - Standard test method for determination of particle emission rates from desktop 3D printers using material extrusion
- ISO/ASTM DIS 52941: Additive manufacturing - System performance and reliability - Standard test method for acceptance of powder-bed fusion machines for metallic materials for aerospace application.
- ISO/ASTM DIS 52942: Additive manufacturing - Qualification principles – Standard guideline for qualifying operators of equipment used in aerospace applications
- ISO/ASTM DIS 52950: Additive manufacturing - General principles - Overview of data processing

Data Processing

Test Methods

Methods-Processes-Materials

Terminology

Activities @ Sirris

- Sirris is participating to the ASTM Centre of Excellence project about the good methodology for measuring moisture on AM powder.
- Sirris is active in ISO/TC 261 JG 63 concerning the writing of a technical note linked to Additive Manufacturing — Metallic powder spreadability using a rotating drum.
- Sirris is active on several prenormative project on powder characterization linked to AM.
- Sirris has a Norm Antenna on AM.

CENTER of EXCELLENCE

Research to Standards

https://amcoe.org/standards-activities

Jeroen Tacq

jeroen.tacq@sirris.be

+32 493 31 06 44

sirris

driving industry by technology

http://www.sirris.be

http://techniline.sirris.be

#sirris

http://www.linkedin.com/company/sirris