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STANDARDS
Australia



Additive manufacturing — Feedstock materials — Methods to characterize metal powders



AS ISO/ASTM 52907:2021

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- Materials Australia
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Additive manufacturing — Feedstock materials — Methods to characterize metal powders

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Preface

This Standard was prepared by the Standards Australia Committee MB-028, Additive Manufacturing.

The objective of this document is to provide technical specifications for metallic powders intended to be used in additive manufacturing and covers the following aspects:

- (a) Documentation and traceability.
- (b) Sampling.
- (c) Particle size distribution.
- (d) Chemical composition.
- (e) Characteristic densities.
- (f) Morphology.
- (g) Flowability.
- (h) Contamination.
- (i) Packaging and storage.

This document does not deal with safety aspects.

In addition, this document gives specific requirements for used metallic powders in additive manufacturing.

This document is identical with, and has been reproduced from, ISO/ASTM 52907:2019, *Additive manufacturing — Feedstock materials — Methods to characterize metal powders*.

As this document has been reproduced from an International Standard, a full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM F 42, *Additive manufacturing technologies*, on the basis of a partnership agreement between ISO and ASTM International with the aim to create a common set of ISO/ASTM standards on additive manufacturing.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The document aims to simplify the relation between the supplier and the customer for the supply of metallic powder for additive manufacturing purpose whatever the process involved.

The document does not aim to develop new standards but provides a list of existing standards dedicated to metallic powder that are suitable for additive manufacturing.

NOTES

Australian Standard[®]

Additive manufacturing — Feedstock materials — Methods to characterize metal powders

1 Scope

This document provides technical specifications for metallic powders intended to be used in additive manufacturing and covers the following aspects:

- documentation and traceability;
- sampling;
- particle size distribution;
- chemical composition;
- characteristic densities;
- morphology;
- flowability;
- contamination;
- packaging and storage.

This document does not deal with safety aspects.

In addition, this document gives specific requirements for used metallic powders in additive manufacturing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2591-1, *Test sieving — Part 1: Methods using test sieves of woven wire cloth and perforated metal plate*

ISO 3252, *Powder metallurgy — Vocabulary*

ISO 3923-1, *Metallic powders — Determination of apparent density — Part 1: Funnel method*

ISO 3923-2, *Metallic powders — Determination of apparent density — Part 2: Scott volumeter method*

ISO 3953, *Metallic powders — Determination of tap density*

ISO 3954, *Powders for powder metallurgical purposes — Sampling*

ISO 4497, *Metallic powders — Determination of particle size by dry sieving*

ISO 13320, *Particle size analysis — Laser diffraction methods*

ISO 13322-1, *Particle size analysis — Image analysis methods — Part 1: Static image analysis methods*

ISO 13322-2, *Particle size analysis — Image analysis methods — Part 2: Dynamic image analysis methods*

ISO 22412, *Particle size analysis — Dynamic light scattering (DLS)*

ISO/ASTM 52900, *Additive manufacturing — General principles — Fundamentals and vocabulary*

ASTM B212, *Standard Test Method for Apparent Density of Free-Flowing Metal powders Using the Hall Flowmeter Funnel*

ASTM B214, *Standard Test Method for Sieve Analysis of Metal powders*

ASTM B215, *Standard Practices for Sampling Metal powders*

ASTM B243, *Standard Terminology of Powder Metallurgy*

ASTM B329, *Standard Test Method for Apparent Density of Metal powders and Compounds Using the Scott Volumeter*

ASTM B417, *Standard Test Method for Apparent Density of Non-Free-Flowing Metal powders Using the Carney Funnel*

ASTM B527, *Standard Test Method for Tap Density of Metal powders and Compounds*

ASTM B822, *Standard Test Method for Particle Size Distribution of Metal powders and Related Compounds by Light Scattering*

EN 10204:2005, *Metallic products — Types of inspection documents*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3252, ISO/ASTM 52900, ASTM B243 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

EDX

X-ray spectrometry in which the energy of individual photons is measured by a parallel detector and used to build up a histogram representing the distribution of X-rays with energy

[SOURCE: ISO/TS 80004-13:2017, 3.3.2.4, modified — "EDX" has been kept as the only term and "are" has been changed to "is"]

4 Technical specifications

4.1 General

The supplier and customer shall choose the test methods appropriate to the customer's requirements.

4.2 Documentation and traceability

To ensure traceability, statements of conformity and inspection documents shall specify the following:

- a unique document reference,
- the name and the address of the supplier,
- the reference of powder lot,
- the product description, including chemical composition, standard and/or trade/common name,
- the nature of powder production process (including e.g. type of gas used, environment conditions),

- the packaging description, including the packaging, the nature of the shielding gas and the desiccant bag, if relevant,
- the date of analysis,
- storage and preservation instructions,
- all of the information to ensure the traceability (e.g. order number, applicable specification).

NOTE 1 When a desiccant bag is in contact with the powder, it can be a source of contamination.

The inspection document shall comply with EN 10204:2005, 4.1.

The statement of conformity should follow ISO/IEC 17050-1.

The reported values shall be linked to the test method used and the corresponding standard. The relevant standards to characterize metallic powder or feedstock for additive manufacturing are detailed in this document. Powder characteristics shall be subjected to a prior customer/supplier agreement.

The product shall be supplied with its material safety data sheet (SDS).

NOTE 2 The inspection document and the statement of conformity can be on the same document.

EXAMPLES Product description: Ni alloy 718 powder 10 µm to 45 µm.

Nature of production process: Vacuum Induction Melting argon gas atomization.

Packaging description: 10 kg bottle under Argon protective atmosphere.

For an example of certificate, see [Annex B](#).

4.3 Sampling

Samples shall be representative of the powder lot, ensuring homogeneity when split. Methods and equipment shall follow the requirements in ISO 3954, ASTM B215 or another method subjected to a prior customer/supplier agreement with the method(s) reported.

Procedures should be included for equipment cleanliness prior to sampling to prevent cross contamination of powder.

4.4 Particle size distribution

Particle size and particle size distribution shall be determined in accordance with one or several of the methods and standards listed in [Table 1](#).

The standards according to the methods used shall be indicated in the report (see [Annex B](#)).

Table 1 — Methods used for particle size analysis

Method	Typical range (varies between instruments)	Expression of results	Advantages	Limitations
Laser diffraction (ISO 13320)	0,1 μm to 3 mm	Cumulative volume percentages on a plot, with calculated values D_X at which X % of the total volume is below this value	<ul style="list-style-type: none"> — Ease of use — Large sample sizes are not required — High accuracy and repeatability 	<ul style="list-style-type: none"> — Measurements shall be made on isolated particles (not touching) – liquid suspension can be necessary — Assumes spherical particles when calculating volumes
Light scattering (ISO 22412, ASTM B822)	1 nm to 0,1 mm			
Image analysis (static: ISO 13322-1)	$\geq 5 \mu\text{m}$	Either the number or volume of particles in each size interval	<ul style="list-style-type: none"> — Accounts for non-spherical particles — Capable of reporting shape factors 	<ul style="list-style-type: none"> — Measurements shall be made on isolated particles (not touching) – liquid suspension can be used — Result accuracy depends on number of pixels — Set up procedures to be determined by the operator to achieve optimum results for that specific powder
Image analysis (dynamic: ISO 13322-2)	$\geq 5 \mu\text{m}$	Either the number or volume of particles in each size interval and shape distribution	<ul style="list-style-type: none"> — Accounts for non-spherical particles — Capable of reporting shape factors — Large amount of particles can be measured in each sample, which provides a large dataset for statistical analysis 	<ul style="list-style-type: none"> — Measurements shall be made on isolated particles (not touching) – liquid suspension can be necessary — Result accuracy depends on number of pixels — Set up procedures to be determined by the operator to achieve optimum results for that specific powder

Table 1 (continued)

Method	Typical range (varies between instruments)	Expression of results	Advantages	Limitations
Sieving (ISO 2591-1, ISO 4497, ASTM B214)	≥45 μm	The amounts of particles present in specified particle size intervals, expressed as a percentage of the total particles	— Equipment required is cheaper overall than equipment required for other particle size distribution testing methods	<ul style="list-style-type: none"> — Appropriate sieve sizes required — Results obtained assume near spherical particles that pass through the sieve openings when the particle diameter is smaller than the size openings. This does not take into account long particles or particles with agglomerations. — Carefully controlled cleaning of sieves between tests required — Results obtained are discrete intervals — Not suitable for particles sized wholly or mostly under 45 μm

NOTE 1 The laser diffraction and dynamic image analysis method results in higher values than the sieving method. The sieving method gives a weight percent of powder impeded by or passing through a square net whereas the laser diffraction method gives an equivalent diameter calculated from laser interferences.

NOTE 2 The results can be obtained by different methods; for example, quantification of the largest particles by sieving and quantification of the thinnest particles by laser diffraction. The results obtained from different methods can produce different results.

NOTE 3 The results are often expressed in D10 (first decile, i.e. 1/10 of the statistical population is below this value), D50 (median value, i.e. half of the statistical population is below this value) and D90 (last decile, i.e. 9/10 of the statistical population is below this value).

NOTE 4 Generally, the particle size distribution of used powder shifts with use. The degree of shift is a function of multiple parameters including material and process.

NOTE 5 Particle size is considered to be a useful property for comparing and controlling different lots of powder over time as this characteristic will change with powder use.

4.5 Chemical composition

The chemical composition of the metallic powder shall be determined by any suitable testing procedure, e.g. wet chemical processes, atomic absorption spectrometry, flame emission spectroscopy, or X-ray fluorescence analysis.

For powder mixtures, preparation of the sample for chemical analysis shall be performed in accordance with recognised methods.

NOTE 1 Example of recognised methods are available in MPIF STM 67.

[Table 2](#) identifies examples of standards for determination of carbon, sulphur, oxygen, nitrogen and hydrogen elements by various combustion and fusion techniques. The chemical composition shall be determined on a sample that is representative of the lot used (or reused) for additive manufacturing.

Table 2 — Examples of testing standards for chemical composition of metals

Alloys\Elements	Carbon	Sulphur	Oxygen	Nitrogen	Hydrogen
Steel and iron	ISO 9556, or ISO 15349-2 or ISO 15350 or ASTM E1019	ISO 13902 or ISO 15350 or ASTM E1019	ISO 17053 or ASTM E1019	ISO 10720 and ISO 15351 or ASTM E1019	
Titanium and titanium alloys	ASTM E1941		ISO 22963 or ASTM E1409	ASTM E1409	ASTM E1447
Nickel and nickel alloys	ISO 7524 or ASTM E1019	ISO 7526 or ASTM E1019	ASTM E1019	ASTM E1019	
Aluminum and aluminum alloys					ASTM E2792
Cobalt alloys	ISO 11873 or ASTM E1019	ISO 11873 or ASTM E1019	ASTM E1019	ASTM E1019	
Copper and copper alloys		ISO 7266	ASTM E2575		

NOTE 2 Chemical composition can shift with powder recycling, e.g. oxygen level can increase with each reuse.

The applicability of standards listed in [Table 2](#) needs to be checked for powders, and material grade selected.

It can be necessary to use multiple testing procedures in combination.

The values shall be expressed in weight percentage.

Analysis method(s) should be reported with results.

4.6 Characteristic densities

Apparent and tap densities are useful powder characteristics, enabling the control of different powder lots, or different powder mixtures from virgin and used powders over time, respectively.

Apparent density shall be determined by Hall funnel method according to ISO 3923-1 or ASTM B212 for free flowing powder. For non-free flowing powder, the Carney funnel method according to ISO 3923-1 or ASTM B417 shall be used; for powders that do not flow freely through a Carney funnel, a Scott apparatus according to ISO 3923-2 or ASTM B329 shall be used.

To determine the appropriate size of graduated cylinder used in tap density measurement, apparent density should be measured first. Tap density shall be measured according to ISO 3953 or ASTM B527.

NOTE 1 In practice, the minimum number of taps, N , is determined such that no further change in volume takes place. For all further tests on the same type of powder, the cylinder is subjected to $2N$ taps, except where general experience and acceptance has established a specific number of taps (no less than N taps) as being satisfactory. For fine refractory metallic powders, 3 000 taps has been found to be satisfactory for all sizes.

Skeletal density by gas pycnometry can be determined according to ISO 12154 or ASTM B923. The skeletal density gives the true density of the material and can therefore be used to evaluate porosity level.

NOTE 2 SEM images of the powder after a sample preparation can give qualitative information only about internal porosity. For example, see EN 1274.

4.7 Morphology

Powder morphology is strongly linked to the process used to produce the powder; as stated and illustrated in EN 1274. Particle morphology shall be described using the vocabulary defined in ISO 3252 or ASTM B243 (see [Annex A](#) for examples).

NOTE 1 Powder morphology is considered to be a useful property for comparing and controlling different lots of powders over time.

In addition, qualitative image comparison and/or quantitative criteria can be subjected to a prior customer/supplier agreement e.g. a quantitative shape factor defined as the maximum Feret's diameter divided by minimum Feret's diameter, etc.

NOTE 2 The preferred method using SEM is secondary electron imaging.

Quantitative values shall be determined by automatic or semi-automatic methods with the number of analysed particles being included in the report.

NOTE 3 A standard method for spreadability is under development within ISO/TC 261 and ASTM F 42. Information on spreadability can be found in ASTM D7891.

4.8 Flowability

Powder flowability is a function of multiple factors, particularly the following:

- powder size distribution,
- cohesive strength by adsorbed water on the particles' surfaces from condensed, i.e. presence of agglomerating forces such as capillary bridges formed by adsorbed water on particles' surfaces from condensed atmospheric vapour, electromagnetic forces in ferromagnetic materials, or Van der Waals bonds,
- inter-particles friction, affected mostly by particles "surface roughness" and morphology of the particle surfaces.

As moisture content is a key factor in determining flowability, where drying is required or prohibited by the customer/supplier agreement or the selected flowability standard method (see list below), this shall be performed in accordance with the conditions specified in a standard operating procedure.

Flowability should be determined using one of the methods specified below:

- ISO 4490 or ASTM B213 (results reported in s/50 g),
- ASTM B964 using a Carney funnel (results reported in s/150 g or s/200 g),
- ISO 13517 using a Gustavsson funnel (results reported in s/50 g),
- ISO 4324.

The flowability test report shall include the initial powder condition, i.e. stationary or moving powder.

NOTE 1 Flowability measured by the aforementioned standards is not necessarily correlated to spreadability.

NOTE 2 The requirement of a powder for additive manufacturing to be able to flow is relevant with regard to AM-systems that use piping and/or nozzle to deliver powder, and to mechanical devices to create thin layers necessary to control the manufacturing process. Other techniques, for example rotating cylinder, can be used to fulfil both requirements, whereas the funnel techniques are primarily able to assess powder flowability with regard to piping and/or nozzle requirements.

NOTE 3 Various indices (e.g. index describing cohesive forces between powder particles, for instance avalanche angles) and ratios (e.g. Hausner ratio) can be calculated to evaluate the flowability of the non-freely flowing powder. Those indices and ratios cannot replace the flowability measurement.

4.9 Contamination

Contamination of the powder lot shall be determined by examining a representative sample of the powder. Powder sampling shall be performed according to 4.3. Powder testing shall be performed by examining at least 625 mm² (25 mm × 25 mm) of a closely packed layer of powder at 20×, or by an alternative testing practice, subjected to a prior customer/supplier agreement. As agreed by customer/supplier, no foreign material containing morphology or chemistry outside of specification shall be visible under these test conditions.

NOTE In addition, EDX mapping can be used to detect cross contamination with another metallic powder.

4.10 Packaging, handling and storage

4.10.1 General

Powder contamination from any form of foreign material (e.g. desiccant bag) shall be avoided during handling, packaging and storage.

4.10.2 Packaging and handling

The powder should be climatized (temperature) before introduced to the machine.

If required by the customer, powder containers can be filled by inert gas (argon or nitrogen) to provide protective atmosphere. Powder traceability shall be secured. The label shall include the following:

- the name and the address of the supplier,
- the reference of powder lot,
- quantity of the packaging unit,
- the packaging description, including the packaging, the nature of the shielding gas and the desiccant bag if relevant,
- the product description, including standard and/or trade/common name,
- the safety notice according to local regulation, which can include pictogram(s).

The following information can be included in the certificate if not included in the label:

- if applicable, the order number of the customer,
- the nature of powder production process (including e.g. type of gas used, environment conditions),
- the packing date.

NOTE If desiccant bag is used, guidance can be found in DIN 55474 and BS 1133-19.

EXAMPLES Product description: Alloy of nickel 718 powder 10 µm to 45 µm.

Packaging description: 10 kg bottle under Ar protective atmosphere with desiccant bag.

Nature of powder production process: Vacuum induction melting (VIM), argon gas atomization or argon electrode induction-melting, Nitrogen gas atomization or Air induction melting, water atomization.

4.10.3 Storage

The required storage conditions for products are given in regulations which apply to the local facility housing powder which are also in agreement with the powder supplier product.

NOTE If the container is opened in a humid environment, it can have a detrimental effect on the powder properties due to moisture contamination.

The required storage conditions for any powder remaining in the container or left over after manufacturing, judged to be reusable by the user, are given in regulations which apply to the local facility housing powder which are also in agreement with the powder supplier.

After use, the container shall be closed securely and, if possible, filled with inert gas (argon or nitrogen). The container should also be impervious to moisture ingress.

Annex A (informative)

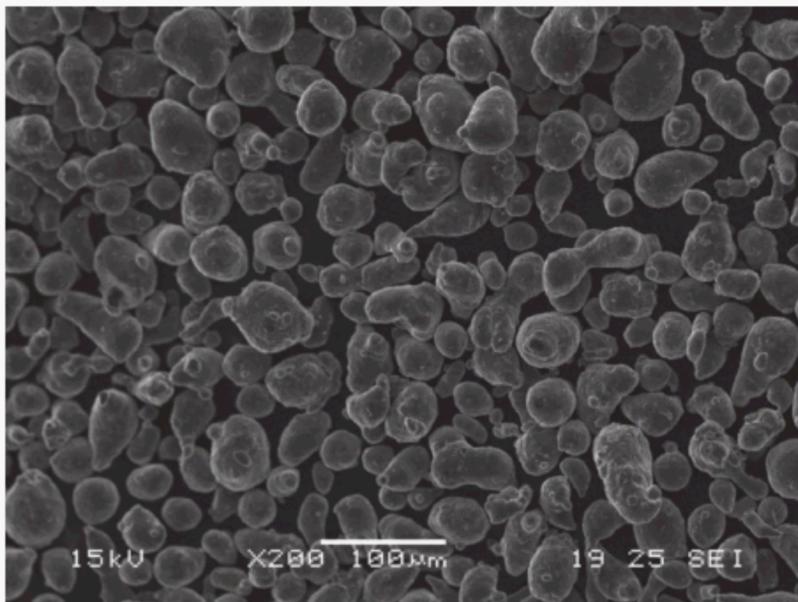
Examples of morphology

Figures A.1 and A.2 give examples of different particle shapes for different alloy-based powders used for additive manufacturing processes.

The alloy-base and production powder process description are provided for information only. The intent is not to show the optimal morphology for any particular process or alloy.

Powders were characterized by Scanning Electron Microscopy (SEM) using secondary electron imaging. The powders are comprised in two lots: A1 – virgin powder (see Figure A.1) and A2 – used powders (see Figure A.2)

Pictures



Description

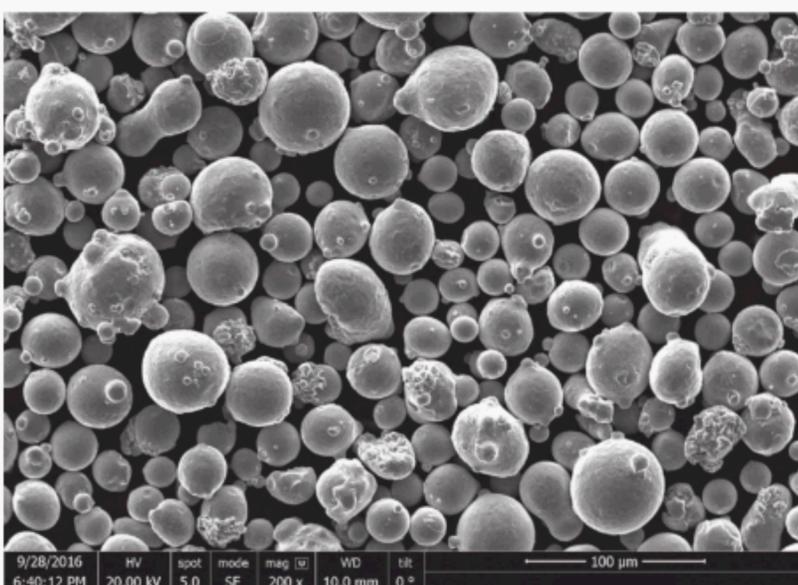
Alloy base: Aluminium

Powder production process and product description:

Gas atomization AlSi10Mg 10 μm to 45 μm.

Particle shape:

The virgin batch appears to consist of a mix of elongated and spherical particles. The surface of the particles is smooth. The phenomenon of “Satellite” particles is barely noticeable in this batch.



Alloy base: Nickel

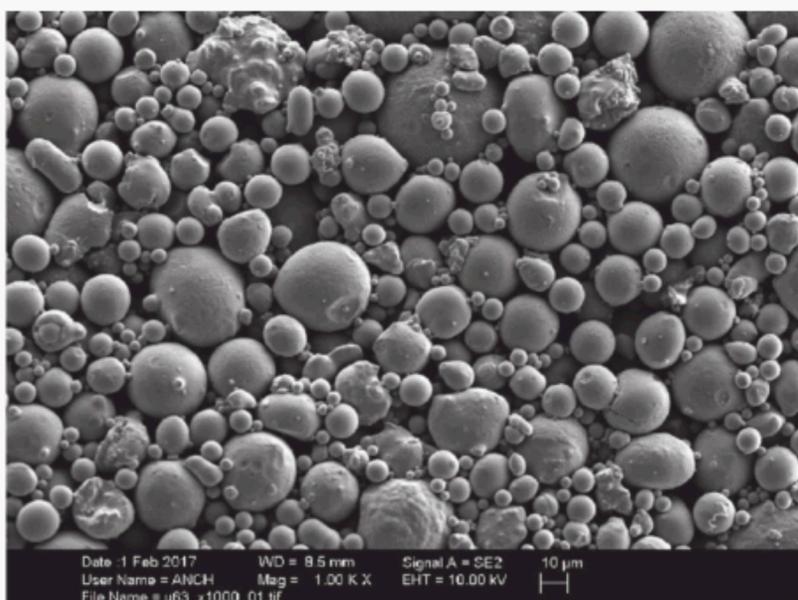
Powder production process and product description:

Vacuum Induction Melting argon gas atomization Alloy of nickel 718 10 μm to 53 μm.

Particle shape:

Powder particles are mainly spheroidal with some nodular particles.

The surface of the particles is smooth with some satellite particles.



Alloy base: Iron

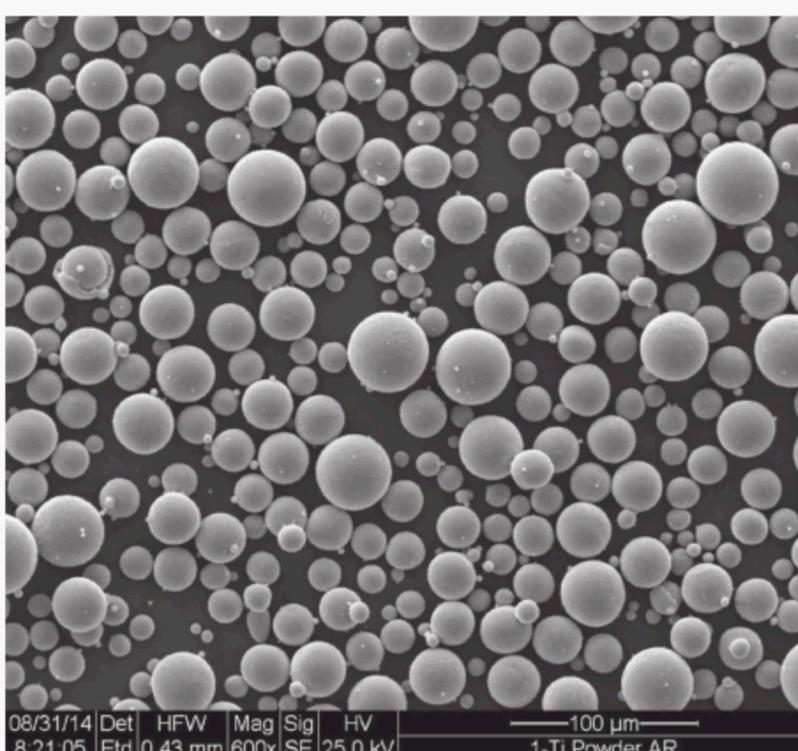
Powder production process and product description:

Induction Melting, Nitrogen gas atomization, 17-4PH 10 µm to 53 µm.

Particle shape:

Powder particles are mainly spheroidal with some nodular particles.

The surface of the particles is smooth with some satellite particles.



Alloy base: Ti6Al4V

Powder production process and product description:

Plasma gas atomization, Alloy of Titanium 70 µm to 130 µm.

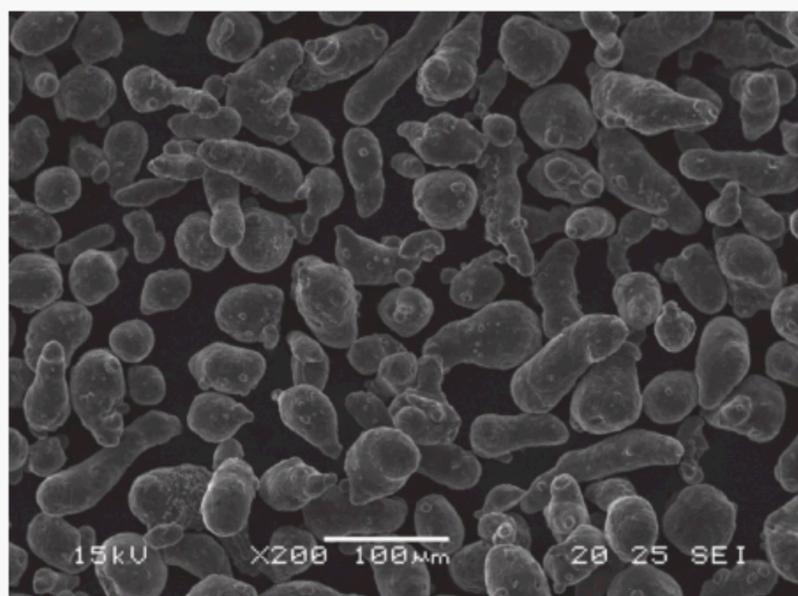
Particle shape:

Powder particles are mainly spheroidal.

The surface of the particles is smooth with some sub micron satellite particles.

Figure A.1 — Particle shape of virgin powder

Pictures



Description

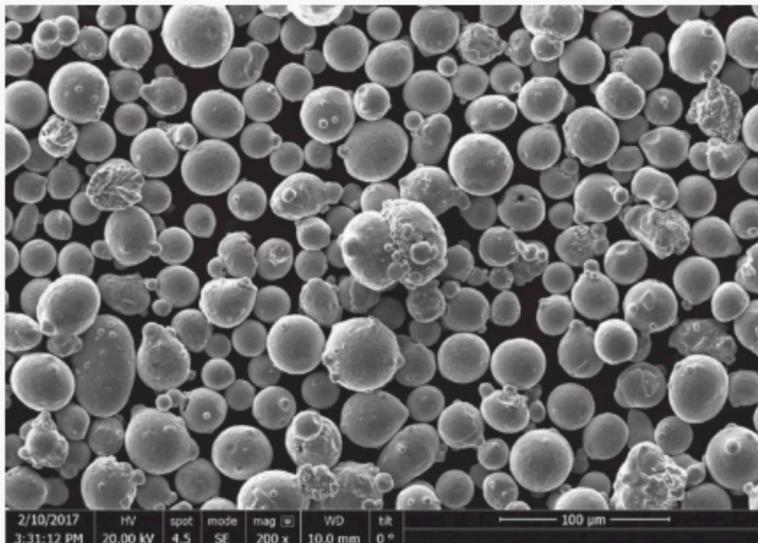
Alloy base: Aluminium

Powder production process and product description:

Gas atomization AlSi10Mg 10 µm to 45 µm.

Particle shape:

The virgin batch appears to consist of relatively small and a mix of elongated and spherical particles. The surface of the particles is smooth. The phenomenon of "Satellite" particles is barely noticeable in this batch. Defects are evident within some particles.



Alloy base: Nickel

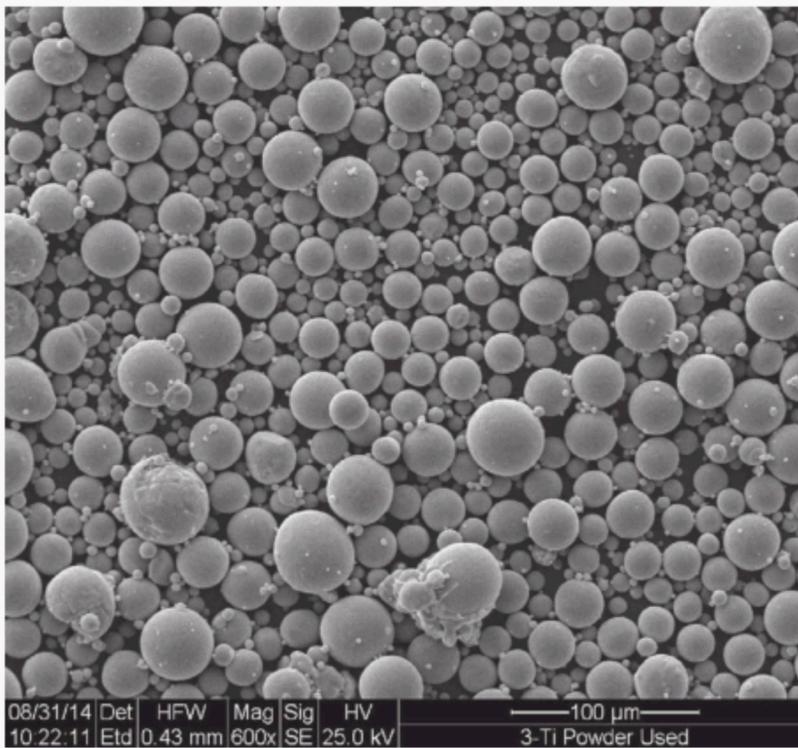
Powder production process and product description:

Vacuum Induction Melting argon gas atomization, Alloy of nickel 718 10 μm to 53 μm.

Particle shape:

Powder particles are mainly spheroidal with some nodular particles.

The surface of the particles is smooth with some satellite particles.



Alloy base: Ti6Al4V

Powder production process and product description:

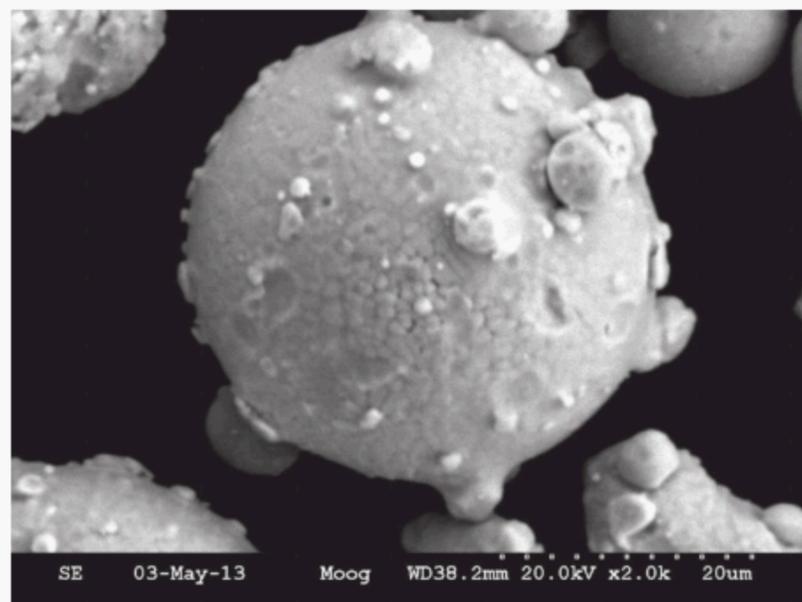
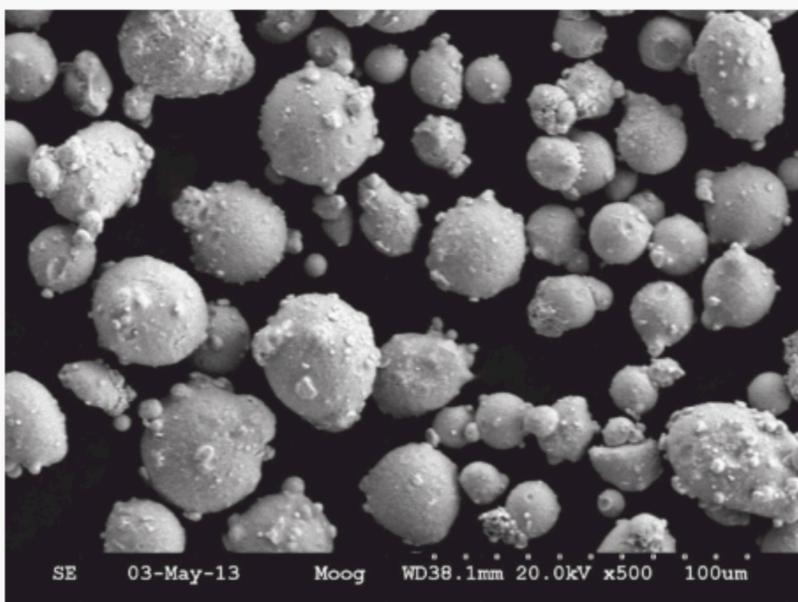
Plasma gas atomization, Alloy of Titanium 70 μm to 130 μm.

Particle shape:

Powder particles are mainly spheroidal. The surface of the particles is smooth with some satellite particles and agglomeration.

Figure A.2 — Particle shape of used powder

The used powder of batch A2 has larger particles compared to batch A1. These particles are even less spherical in nature.



Alloy base: Stainless steel 440C (X105CrMo10 or 1.4125)

Figure A.3 — Example of satellite for stainless steel 440C

Annex B (informative)

Example of certificate

Supplier information

Name: _____
 Address: _____
 Telephone: _____
 Fax: _____
 E-mail: _____

Customer information

Name: _____
 Order reference: _____
 Customer article reference: _____
 Customer specification reference: _____

Product information

Grade: _____
 Powder lot reference: _____
 Nature of melting process to produce the powder: _____
 Nature of production process: _____
 Packaging: _____
 Weight: _____

Particle size distribution:

Sieving

	>X μm	X μm – Y μm	<Y
Customer requirement			
Results (%)			

According to ASTM B214 or ISO 2591-1.

Laser diffraction

	D10	D50	D90
Customer requirement			
Results (μm)			

According to ASTM B822 or ISO 13320.

Chemical composition (weight %):

elements	A ^a	B ^b	C ^c		
Minimum					
Maximum					
Result					
a Technique. b Technique. c Technique.					

Characteristic densities:

	Apparent density^a	Tap density^b	True density^c
Imposed (g/cm ³)			
Results (g/cm³)			
a According ASTM B212 or ASTM B417 or ASTM B329 and ISO 3923-1 or 3923-2. b According ASTM B527 or ISO 3953. c According ASTM B923 or ISO 12154.			

Flowability^a

	Hall flowmeter^b	Carney flowmeter^c	Gustavsson flowmeter^d
Imposed			
Results (s/50 g)			
a Pretest state of the powder e.g. drying condition, when applicable or requested by the customer b According ASTM B213 and ISO 4490. c According ASTM B964. d According ISO 13517.			

Contamination

Morphology

SEM PICTURES

SEM PICTURES

SEM PICTURES

SEM PICTURES

Bibliography

- [1] ISO 4324, *Surface active agents — Powders and granules — Measurement of the angle of repose*
- [2] ISO 4490, *Metallic powders — Determination of flow rate by means of a calibrated funnel (Hall flowmeter)*
- [3] ISO 7266, *Copper and copper alloys — Determination of sulfur content — Combustion titrimetric method*
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