Designation: F3522 – 22

# Standard Guide for
# Additive Manufacturing of Metals — Feedstock Materials — Assessment of Powder Spreadability[1]

This standard is issued under the fixed designation F3522; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide provides definitions of the spreading behavior or spreadability of metal powder feedstock used in powder bed additive manufacturing (AM) – Powder Bed Fusion and Metal Binder Jetting. Definitions are made in terms of powder bed characteristic parameters, and suggests measurement methods that could be used to measure these parameters.

1.2 This standard is intended for the producers and users of powder feedstock used in powder bed AM to provide a common understanding of spreadability parameters. These parameters can be used as the basis for developing powder specifications that ensure proper powder spreadability.

1.3 This guide provides guidance to manufacturers and users of AM machines by providing possible techniques to quantify powder bed spreadability, and highlighting possible process parameters that may affect this spreadability. These parameters can be used as the basis for developing process specifications and for developing measures to improve the quality of spreadability in AM processes.

1.4 The values stated in SI units are to be regarded as the standard units. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

B243 Terminology of Powder Metallurgy

2.2 *ISO/ASTM Standard:*[2]

52900 Additive manufacturing – General principles – Fundamentals and vocabulary

2.3 *ISO Standard:*[3]

ISO 25178-2 Geometrical product specifications (GPS) – Surface texture: Areal – Part 2: Terms, definitions and surface texture parameters

## 3. Terminology

3.1 *Definitions*—Powder metallurgy terms can be found in Terminology B243 and AM processes and terms can be found in Terminology ISO/ASTM 52900.

## 4. Significance and Use

4.1 The overall aim of this guide is to provide a common understanding of spreadability in relation to powder bed AM. This guide provides an overview of spreadability parameters and measurement methods that could be used to measure these parameters. These parameters could be used as the basis to develop process specifications for the powder bed.

## 5. Introduction/Background

5.1 Understanding of powder spreading behavior or spreadability is essential for ensuring that powder feedstock material can be processed in powder bed AM machines. Desirable spreadability is the one that results in a powder bed with a uniform layer thickness and powder bed density, a smooth even surface, an equal particle size distribution across the bed, and with an absence of defects.

5.2 There are a range of test methods that can measure powder flow properties; however, it is not clear if these tests adequately address the requirement for spreadability in the

[1] This guide is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.01 on Test Methods.

Current edition approved Nov. 15, 2022. Published January 2023. DOI: 10.1520/F3522-22.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

powder bed AM process. This challenge is exacerbated by the wide range of powder bed AM machine designs available.

5.3 There is a need to define standardized spreadability parameters, which are physical characteristics of the powder bed. This is essential to help end users understand what good spreading powder means in terms of part quality, so that appropriate limits on spreadability parameters can be defined. These limits would be specific to the design of the powder bed AM machine.

5.4 Guidelines will help powder feedstock manufacturers to develop appropriate powder specifications that guarantee their powders will be processable to an acceptable level in powder bed AM machines. These specifications will ultimately enable AM users to optimize the powder-process property relationship for powder bed AM, and enable end users to understand when to accept powder batches from suppliers, when to refresh powders for re-use, and when to quarantine powder batches.

## 6. Powder Processing with Powder Bed AM Machines

6.1 There are many powder bed AM machines available commercially, which have slightly different architecture set-ups and parameters. However, many features of these powder bed AM machines are similar, allowing a generalized powder bed AM machine design to be described for *(1)* piston-fed (Fig. 1) and *(2)* gravity-fed machine designs (Fig. 2). There are other emerging systems too, for example, utilizing a non-contact recoater, or a cartridge system for material deposition.

6.2 Many powder bed AM machines operate with heated build platforms and are typically back-filled with inert gas or evacuated, which might be essential for keeping powder oxidation levels low during the build. A generalized powder bed AM machine consists of the following elements:

1. *Feed region*—Please refer to ISO/ASTM 52900.
2. *Powder delivery system*—A batch powder feeding system. The powder can either be delivered and metered by a hopper, or supplied by a dosing platform working in the opposite direction to the build platform.
3. *Powder spreading device*—A device which moves powder uniaxially across the build chamber to spread powder in a thin and even layer.
4. *Build platform*—Refer to ISO/ASTM 52900.

6.3 The scope of spreadability relates to the process of transferring powder (see Fig. 1 and Fig. 2) from the 1. Feed region to the 4. Build platform, and includes the powder processing stages of dosing and spreading, performed by the 2. Powder delivery system and the 3. Powder spreading device.

## 7. Powder Bed Spreadability Characteristic Parameters

7.1 The terminology definition of spreadability is given in ISO/ASTM 52900. Consequently, spreadability depends on evaluation of properties of the spread layer. The layer thickness in question is approximately 20 µm to 300 µm, and the resultant powder bed should have a uniform surface texture, uniform layer density, an absence of segregation and an absence of defects. A two dimensional schematic diagram of the cross-section through a powder layer is given in Fig. 3. The powder layer quality could be defined in terms of the following six powder bed characteristic parameters, described in Table 1 alongside potential methods of their determination. It is recommended that users characterize powder feedstock in terms of the defined powder bed characteristic parameters and assess whether powder is spreading properly in the process, in order to understand when a powder should not be used in the process.

7.2 *Measurement Methods of Powder Layer Characteristic Parameters*—This section outlines potential assessment methods of powder bed characteristic parameters. The techniques described currently are ex-situ unless manufacturers of AM systems integrate those system into AM machines. Most of the described techniques can include both in-situ and ex-situ measurements. A summary of the measurement methods are given in Table 2. For each assessment method, a basic rating system (low to high) was used to score five key areas; namely Resolution, Cost, Data Complexity and Analysis Time, Data Variability, and Suitability. A 'high' rating denotes a higher value of the factor, while footnote$^{B}$ in Table 2 denotes how favorable the factor is.

7.2.1 *Laser Line Scanning*—Laser line scanning is a non-contact method used for capturing the shape of a three-dimensional (3D) object. The operating principle of a laser line scanner is based on the laser triangulation technique for two-dimensional detection. A laser line scanner projects a laser line onto the surface of an object, and the reflection of that line on the object's surface is captured by a camera. A type of

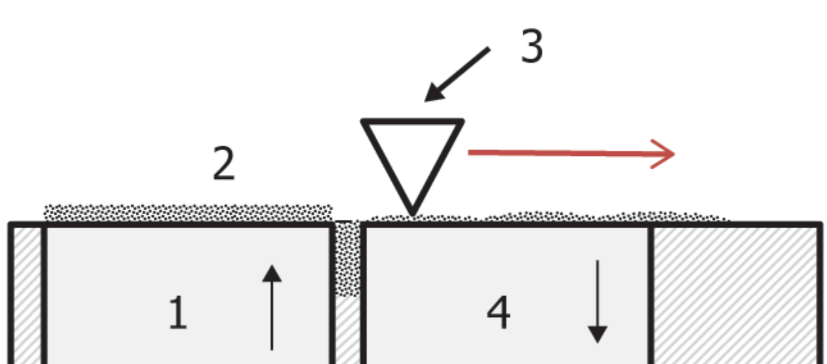


**FIG. 1 Schematic of a Generalized Piston-fed Powder Bed Additive Manufacturing (AM) Machine – 1. Feed Region, 2. Powder Delivery System, 3. Powder Spreading Device, 4. Build Platform**