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Standard Terminology of Powder Metallurgy¹

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1. Scope

1.1 This terminology standard includes definitions that are helpful in the interpretation and application of powder metallurgy terms.

2. Referenced Documents

2.1 *ASTM Standards:*

B 331 Test Method for Compressibility of Metal Powders in Uniaxial Compaction²

3. Terminology

3.1 *Powder*—Terms associated with production, characterization, use, and testing of metal powders.

3.1.1 Table of Contents

1. Powders:

1.0 General, [3.1.2](#)

1.1 Processes to Produce Powder, [3.1.3](#)

1.2 Types of Powder, [3.1.4](#)

1.3 Shapes of Powder Particles, [3.1.5](#)

1.4 Additives to Powder, [3.1.6](#)

1.5 Treatment of Powder, [3.1.7](#)

1.6 Properties of Powder, [3.1.8](#)

1.7 Procedures to Evaluate Powder, [3.1.9](#)

1.8 Equipment to Evaluate Powder, [3.1.10](#)

2. Forming:

2.0 General, [3.2.1](#)

2.1 Processes for Compacting, [3.2.2](#)

2.2 Conditions of Compacting, [3.2.3](#)

2.3 Tools Used for Compacting, [3.2.4](#)

2.4 Phenomena Resulting from Compaction, [3.2.5](#)

2.5 Properties of Compacts, [3.2.6](#)

2.6 Forging, [3.2.7](#)

2.7 Metal Injection Molding, [3.2.8](#)

3. Sintering:

3.1 Process for Sintering, [3.3.1](#)

3.2 Conditions During Sintering, [3.3.2](#)

3.3 Phenomena Resulting from Sintering, [3.3.3](#)

3.4 Properties of Sintered Parts, [3.3.4](#)

3.5 Procedure to Evaluate Sintered Parts, [3.3.5](#)

3.6 Removal of Binders, [3.3.6](#)

4. Postsinter Treatments:

4.1 Processes, [3.4.1](#)

5. Miscellaneous:

5.1 Definitions, [3.5.1](#)

5.2 Processes, [3.5.2](#)

5.3 Materials, [3.5.3](#)

3.1.2 General:

1001 agglomerate, n—several particles adhering together.

1002 particulate matter, n—see **powder**.

1003 P/M, n—the acronym representing powder metallurgy. Used as **P/M Part**, **P/M Product**, **P/M Process**, and so forth.

1004 powder metallurgy, n—the production and utilization of metal powders.

1005 powder, n—particles that are usually less than 1000 μm (1 mm) in size.

1006 metal powder, n—particles of elemental metals or alloys, normally less than 1000 μm (1 mm) in size.

3.1.3 Processes to Produce Powder:

1101 atomization, n—the dispersion of a molten metal into particles by a rapidly moving gas or liquid stream or by mechanical means.

1102 granulation, n—the production of coarse metal particles by pouring the molten metal through a screen into water (shotting) or by violent agitation of the molten metal while solidifying.

1103 classification, n—separation of a powder into fractions according to particle size.

¹ This terminology is under the jurisdiction of ASTM Committee B09 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.01 on Nomenclature and Technical Data.

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² *Annual Book of ASTM Standards*, Vol 02.05.

1104 air classification, n—the separation of powder into particle size fractions by means of an air stream of controlled velocity.

1105 gas classification, n—the separation of powder into particle size fractions by means of a gas stream of controlled velocity.

1106 chemical deposition, n—the precipitation of one metal from a solution of its salts by the addition of another metal or reagent to the solution.

1107 chemically precipitated metal powder, n—powder produced by the reduction of a metal from a solution of its salts either by the addition of another metal higher in the electro-motive series or by other reducing agent.

1108 reduced metal powder, n—metal powder produced, without melting, by the chemical reduction of metal oxides or other compounds.

1109 disintegration, n—the reduction of massive material to powder.

1110 milling, n—the mechanical treatment of metal powder, or metal powder mixtures, as in a ball mill, to alter the size or shape of the individual particles or to coat one component of the mixture with another.

1111 pulverization, n—the reduction in particle size of metal powder by mechanical means, a specific type of disintegration.

3.1.4 Types of Powder:

1201 atomized metal powder, n—metal powder produced by the dispersion of a molten metal by a rapidly moving gas, or liquid stream, or by mechanical dispersion.

1202 electrolytic powder, n—powder produced by electrolytic deposition or by the pulverization of an electrodeposit.

1203 dendritic powder, n—particles, usually of electrolytic origin, having the typical pine tree structure.

1204 carbonyl powder, n—a metal powder prepared by the thermal decomposition of a metal carbonyl.

1205 master-alloy powder, n—a powder with high alloy concentration, designed to be diluted when mixed with a base powder to produce the desired composition.

1206 pre-alloyed powder, n—powder composed of two or more elements that are alloyed in the powder manufacturing process in which the particles are of the same nominal composition throughout. Synonymous with **completely alloyed powder**.

1207 completely alloyed powder, n—see **pre-alloyed powder**.

1208 partially alloyed powder, n—a powder in which the alloy addition or additions are metallurgically bonded to an elemental or pre-alloyed powder.

1209 diffusion-alloyed powder, n—a partially alloyed powder produced by means of a diffusion anneal.

1210 mechanically alloyed powder, n—a composite powder produced by mechanically incorporating other constituents which are generally insoluble within the deformable particles of the matrix metal.

1211 matrix metal, n—the continuous phase of a polyphase alloy or mechanical mixture; the physically continuous metallic constituent in which separate particles of another constituent are embedded.

1212 composite powder, n—a powder in which each particle consists of two or more distinct constituents.

1213 spongy, n—a porous condition in metal powder particles usually observed in reduced oxides.

1214 sponge iron, n—a coherent, porous mass of substantially pure iron produced by solid-state reduction of iron oxide (for example, iron ore or mill scale).

1215 sponge iron powder, n—ground and sized sponge iron, which may have been purified or annealed or both.

1216 mixed powder, n—a powder made by mixing two or more powders as uniformly as possible. The constituent powders will differ in chemical composition or in particle size or shape, or a combination thereof.

1217 premix, n—a uniform mixture of ingredients to a prescribed analysis, prepared by the powder producer, for direct use in compacting powder metallurgy products.

3.1.5 Shapes of Powder Particles:

1301 acicular powder, n—needle-shaped particles.

1302 needles, n—elongated rod-like particles.

1303 granular powder, n—particles having approximately equidimensional nonspherical shapes.

1304 nodular powder, n—irregular particles having knotted, rounded, or similar shapes.

1305 irregular powder, n—particles lacking symmetry.

1306 spherical powder, n—globular-shaped particles.

1307 flake powder, n—flat or scale-like particles whose thickness is small compared with the other dimensions.

1308 plates, n—flat particles of metal powder having considerable thickness.

3.1.6 Additives to Powder:

1401 binder, n—a cementing medium; either a material added to the powder to increase the green strength of the compact, and which is expelled during sintering; or a material (usually of relatively lower melting point) added to a powder mixture for the specific purpose of cementing together powder particles which alone would not sinter into a strong body.

1402 feedstock, n—in metal injection molding (MIM), a moldable mixture of metal powder and binder.

1403 powder lubricant, n—an agent mixed with or incorporated in a powder to facilitate the pressing and ejecting of the compact.

1404 dispersion-strengthened material, n—a material consisting of a metal and finely dispersed, substantially insoluble, metallic or nonmetallic phase.

1405 pore-forming material, n—a substance included in a powder mixture that volatilizes during sintering and thereby produces a desired kind and degree of porosity in the finished compact.

3.1.7 Treatment of Powder:

1501 *blending, n*—the thorough intermingling of powders of the same nominal composition (not to be confused with mixing).

1502 *equalizing, n*—see **blending**.

1503 *mixing, n*—the thorough intermingling of powders of two or more materials.

1504 *cross-product contamination, n*—the unintentional mixing of powders with distinct differences in either physical characteristics or chemical composition or both.

1505 *lubricating, n*—mixing with, or incorporating in, a powder, some agent to facilitate pressing and ejecting the compact from the die body; applying a lubricant to the die walls and punch surfaces.

3.1.8 *Properties of Powder:*

1601 *apparent density, n*—the mass of a unit volume of powder, usually expressed as grams per cubic centimetre, determined by a specified method.

1602 *bulk density, n*—the mass per unit volume of a powder under nonstandard conditions, for example, in a shipping container (not to be confused with apparent density).

1603 *tap density, n*—the apparent density of the powder in a container that has been tapped under specified conditions.

1604 *flow rate, n*—the time required for a powder sample of standard weight to flow through an orifice in a standard instrument according to a specified procedure.

1605 *specific surface, n*—the surface area of one gram of powder, usually expressed in square centimetres.

1606 *compactibility, n*—a conceptual term, encompassing the *powder* characteristics of compressibility, green strength, edge retention, and lamination tendency, that relates to the ability of a powder to be consolidated into a usable green compact.

1607 *compressibility, n*—the capacity of a metal powder to be densified under a uniaxially applied pressure in a closed die.

DISCUSSION—Compressibility is measured in accordance with Test Method B 331 and may be expressed numerically as the pressure to reach a specified density, or alternatively the density at a given pressure.³

1608 *compression ratio, n*—the ratio of the volume of the loose powder to the volume of the compact made from it. Synonymous with **fill ratio**.

1609 *fill ratio, n*—see **compression ratio**.

1610 *oversize powder, n*—particles coarser than the maximum permitted by a given particle size specification.

1611 *plus sieve, n*—the portion of a powder sample retained on a standard sieve of specified number. (See **minus sieve**.)

1612 *minus sieve, n*—the portion of a powder sample which passes through a standard sieve of specified number. (See **plus sieve**.)

1613 *finer, n*—the portion of a powder composed of particles which are smaller than a specified size, currently less than 44 μm . See also **superfines**.

1614 *superfines, n*—the portion of a powder composed of particles that are smaller than a specified size, currently less than 10 μm .

1615 *fraction, n*—that portion of a powder sample that lies between two stated particle sizes. Synonymous with **cut**.

1616 *cut, n*—see **fraction**.

1617 *subsieve fraction, n*—particles all of which will pass through a 44- μm (No. 325) standard sieve.

1618 *sieve fraction, n*—that portion of a powder sample that passes through a standard sieve of specified number and is retained by some finer sieve of specified number.

1619 *particle size, n*—the controlling lineal dimension of an individual particle as determined by analysis with sieves or other suitable means.

1620 *particle size distribution, n*—the percentage by weight, or by number, of each fraction into which a powder sample has been classified with respect to sieve number or microns. (Preferred usage: “particle size distribution by frequency.”)

1621 *hydrogen loss, n*—the loss in weight of metal powder or of a compact caused by heating a representative sample for a specified time and temperature in a purified hydrogen atmosphere—broadly, a measure of the oxygen content of the sample when applied to materials containing only such oxides as are reducible with hydrogen and no hydride-forming element.

3.1.9 *Procedures to Evaluate Powder:*

1701 *sieve analysis, n*—particle size distribution; usually expressed as the weight percentage retained upon each of a series of standard sieves of decreasing size and the percentage passed by the sieve of finest size. Synonymous with **screen analysis**.

1702 *screen analysis, n*—see **sieve analysis**.

1703 *sieve classification, n*—the separation of powder into particle size ranges by the use of a series of graded sieves.

3.1.10 *Equipment to Evaluate Powder:*

1801 *powder flow meter, n*—an instrument for measuring the rate of flow of a powder according to a specified procedure.

3.2 *Forming*—Terms associated with consolidation of metal powders and mixes, including tooling, equipment, and characterization of sintered compacts.

3.2.1 *General:*

2001 *green*—unsintered (not sintered); for example, green compact, green density, green strength.

2002 *preforming*—the initial pressing of a metal powder to form a compact that is subjected to a subsequent pressing operation other than coining or sizing. Also, the preliminary shaping of a refractory metal compact after presintering and before the final sintering.

2003 *blank, n*—a pressed, presintered, or fully sintered compact, usually in the unfinished condition, requiring cutting, machining, or some other operation to give it its final shape.

2004 *briquet, n*—see **compact**.

2005 *compact, n*—an object produced by the compression of metal powder, generally while confined in a die, with or without the inclusion of nonmetallic constituents. Synonymous with **briquet**.

³ See Test Method B 331.



2006 *pressed bar*, *n*—a compact in the form of a bar; a green compact.

2007 *rolled compact*, *n*—a compact made by passing metal powder continuously through a rolling mill so as to form relatively long sheets of pressed material.

2008 *composite compact*, *n*—a metal powder compact consisting of two or more adhering layers, rings, or other shapes of different metals or alloys with each material retaining its original identity.

2009 *compound compact*, *n*—a metal powder compact consisting of mixed metals, the particles of which are joined by pressing or sintering or both, with each metal particle retaining substantially its original composition.

3.2.2 Processes for Compacting:

2101 *molding*, *v*—the pressing of powder to form a compact.

2102 *press*, *v*—to apply force to a mass of powder, generally while confined in a die or container, to form a compact.

2103 *double press-double sinter*, *n*—to repress and sinter a previously presintered or sintered compact.

DISCUSSION—Used to describe a four-step manufacturing process.

2104 *single-action pressing*, *n*—a method by which a powder is pressed in a stationary die between one moving and one fixed punch.

DISCUSSION—Only during ejection does either the stationary die or punch move.

2105 *double-action pressing*, *n*—a method by which a powder is pressed in a die between opposing moving punches.

2106 *withdrawal pressing*, *n*—a powder consolidation method in which the die moves downward in relation to the lower punch(es) during compaction. It further descends over the fixed lower punch(es) for ejection, so that the compact may then be pushed off the tooling at this point.

2107 *multiple pressing*, *n*—a method of pressing whereby two or more compacts are produced simultaneously in separate die cavities.

2108 *roll compacting*, *n*—the progressive compacting of metal powders by the use of a rolling mill. Synonymous with **powder rolling**.

2109 *powder rolling*, *n*—see **roll compacting**.

2110 *cold pressing*, *n*—the forming of a compact at room temperature.

3.2.3 Conditions for Compacting:

2201 *die lubricant*, *n*—a lubricant applied to the walls of the die and to the punches to facilitate the pressing and ejection of the compact.

DISCUSSION—Contrast with **powder lubricant**. Synonymous with **die-wall lubricant**.

2202 *die-wall lubricant*, *n*—synonymous with **die lubricant**.

3.2.4 Tools Used for Compacting:

2301 *mold*, *n*—in metal or powder injection molding, the member of the tooling into which the powder and binder mixture is forced, and the configuration of which forms the

surfaces of the green part. In isostatic compacting, a mold is also the confining form in which powder is isostatically compacted.

2302 *compacting tool set*, *n*—an assembly of tooling items in which powder is pressed.

DISCUSSION—May include a die, punches, and core rods.

2303 *die*, *n*—a member of the compacting tool set forming the cavity in which the powder is compacted or a P/M compact is repressed.

2304 *die body*, *n*—the stationary or fixed part of a die.

2305 *die set*, *n*—the parts of a press that hold and locate the die in proper relation to the punches.

2306 *core rod*, *n*—a member of the compacting tool set that forms internal features such as splines, diameters, keyways, or other profiles in a P/M compact.

2307 *punch*, *n*—a member of a compacting tool set used to close the die cavity and transmit the applied pressure to the powder or P/M compact.

DISCUSSION—Multiple upper or lower punches may be needed to compact multilevel parts.

2308 *stripper punch*, *n*—a punch that, in addition to forming the top or bottom of the die cavity, later moves further into the die to eject the compact.

2309 *split die*, *n*—a die made of parts that can be separated for ready removal of the compact.

2310 *die insert*, *n*—a removable liner or part of a die body.

2311 *segment die*, *n*—a die fabricated by the assembly of several die sections within a retaining bolster or shrinkage ring.

2312 *rotary press*, *n*—a machine fitted with a rotating table carrying multiple dies in which a material is pressed.

3.2.5 Phenomena Resulting from Compaction:

2401 *bridging*, *v*—the formation of arched cavities in a powder mass.

2402 *green*, *adj*—unsintered (not sintered); for example, green compact, green density, green strength.

2403 *springback*, *n*—see **green expansion**.

2404 *cold welding*, *n*—cohesion between two surfaces of metal, generally under the influence of externally applied pressure, at room temperature.

DISCUSSION—Often used to describe the mechanism by which powder particles develop initial bonds and a pressed compact develops green strength.

3.2.6 Properties of Compacts:

2501 *green density*, *n*—the mass per unit volume of an unsintered compact.

2502 *pressed density*, *n*—synonymous with **green density**.

2503 *green expansion*, *n*—the increase in dimensions of an ejected compact relative to the die dimensions, measured at right angles to the direction of pressing. Synonymous with **springback**.

3.2.7 Forging:

2601 *powder forging (P/F)*, *v*—hot densification by forging of an unsintered, presintered, or sintered preform made from powder. Also referred to by the acronyms **P/F**, **P/M forging**, or