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Standard Terminology of Powder Metallurgy[1]

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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.

1.2 *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]

B331 Test Method for Compressibility of Metal Powders in Uniaxial Compaction

3. Terminology

3.1 *Definitions:*

acicular powder, *n*—needle-shaped particles.

activated sintering, *n*—a sintering process during which the rate of sintering is increased, for example, by addition of a substance to the powder or by changing sintering conditions.

additive manufacturing (AM), *n*—the process of joining materials to make parts from three-dimensional (3-D) model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies.

DISCUSSION—

Examples include **binder jetting (BJT)**,**directed energy deposition (DED)**, and **powder-bed fusion (PBF)**.

agglomerate, *n*—several particles adhering together.

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

angle of repose, *n*—the basal angle of a pile formed by powder when freely poured under specified conditions onto a horizontal surface.

[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] 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.

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

apparent hardness, *n*—the hardness of a PM material (including the effects of porosity), measured using macroindentation hardness equipment.

DISCUSSION—
See general description of production, properties, and uses of sintered metal powder bearings and structural parts, paragraph on density and mechanical properties, information on hardness measurement, Volume 02.05.[3]

apparent porosity, *n*—specific to cemented carbides, microstructural features that appear to be pores in a properly prepared, unetched surface; these features may result from uncombined carbon or nonmetallic inclusions as well as actual porosity.

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

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.

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.

binder (MIM), *n*—a mixture of polymers or other materials, or both, that when combined with metal powders enables the mixture to flow during the injection molding process. The binder imparts green strength to the MIM part and allows it to retain its molded shape.

binder jetting (BJT), *n*—additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials.

binder removal, *n*—the chemical or thermal extraction of binder from a compact. Synonymous with **debinding**.

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.

blending, *n*—the thorough intermingling of powders of the same nominal composition and made by the same production method.

DISCUSSION—
Not to be confused with mixing.

blister crack, *n*—typically small defects (star burst) over or around a bump or blister.

DISCUSSION—
These may occur during sintering as a result of rapid outgassing of the lubricant. The rapid outgassing may be caused by the specified amount of lubricant being subjected to an excessive heating rate. The defects may also be caused by "concentrated balls" of lubricant, or moisture. During the sintering of the copper base PM parts, hydrogen gas from the furnace atmosphere can diffuse into the compact and react with residual oxygen, producing steam that can form blisters and cracks. In that industry, this is also called embrittlement, and is not to be confused with the hydrogen embrittlement of high strength steel.

blistered compact, *n*—a sintered object characterized by having blisters or eruptions on the surface.

[3] For a discussion of apparent hardness, see the section on Density in General Description of Production, Properties, and Uses of Sintered Metal Powder Bearings and Structural Parts, which appears in the *Annual Book of ASTM Standards*, Vol 02.05.

DISCUSSION—
In ferrous materials, this effect is often caused by *in situ* gas decomposition and soot formation that forces particles apart and causes the compact to blister.

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

briquet, *n*—see **compact**.

brown part, *n*—an MIM part that has had a majority of the binder (first stage) removed. Synonymous with **debound part**.

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**).

burn-off, *n*—removal of organic additives (binder or lubricant) from a compact by heating.

cake, *n*—a bonded mass of unpressed metal powder.

DISCUSSION—
Often refers to the form of powder as it exits a furnace.

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

cavity (MIM), *n*—the hollow space of a mold that forms one part.

cemented carbide, *n*—sintered material characterized by high strength and wear resistance and comprising one or more carbides of refractory metals as the main component bonded by metallic binder phase.

cermet, *n*—sintered material containing at least one metallic phase and at least one nonmetallic phase that is generally of a ceramic nature.

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.

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 electromotive series or by other reducing agent.

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

closed pore, *n*—a pore not communicating or connected with an exterior surface.

coin, *v*—to repress a sintered compact to obtain a definite surface configuration. Synonymous with emboss (not to be confused with **restrike** or **size**).

cold isostatic pressing (CIP), *n*—isostatic pressing at ambient temperature.

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

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.

comminuted powder, *n*—a powder produced by mechanical attrition of solid metal or powder

communicating pores, *n*—see **interconnected porosity**.

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.**

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.

compacting, *n*—a process in which a powder held in a die or other container is subjected to an external force in order to densify the powder and produce a compact of prescribed shape and dimensions.

compacting pressure (uniaxial), *n*—applied force divided by the projected area of contact with the punch(es).

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

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

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

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.

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

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.

compounding (MIM), *n*—process whereby the metal powders and molten binder constituents are combined to produce a feedstock.

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 B331 and may be expressed numerically as the pressure to reach a specified density, or alternatively the density at a given pressure.[4]

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**.

continuous sintering, *n*—presintering, or sintering, in such manner that the objects are advanced through the furnace at a fixed rate by manual or mechanical means. Synonymous with **stoking**.

cooling rate, *n*—the average temperature change per second between prescribed temperatures during the cooling phase of a thermal process.

[4] See Test Method B331.

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

cored bar, *n*—a compact of bar shape heated by its own electrical resistance to a temperature high enough to melt its interior.

crack (RD), *n*—generally a planar defect.

cracked ammonia, *n*—see **dissociated ammonia**.

cracks (rigid die system (RD)), *n*—the following names and definitions apply only to items produced in a rigid die system (RD) as opposed to those cracks produced by other systems, that is, metal injection molding, vacuum hot pressing, and so forth.[5]

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

cut, *n*—see **fraction**.

debinding, *n*—see **binder removal**.

debound part, *n*—see **brown part**.

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

densification crack, *n*—a defect caused by differential stresses in a region of a part that has experienced large differences in shrinkage during sintering.

density (dry), *n*—see **sintered density**.

density (wet), *n*—see **impregnated density**.

density ratio, *n*—the ratio, often expressed as a percentage, of the density of a porous material to the density of the same material completely free of porosity. Synonymous with **relative density**.

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

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

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

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

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

[5] There is detailed information on numerous cracks, their location, cause, and prevention in a handbook published by Metal Powder Industries Federation, Princeton, New Jersey, "The Common Cracks in PM Compacts" by D. Zenger and H. Cai.

dimensional change of a compact, *n*—the difference, at room temperature, between the size of the sintered specimen and the die size.

DISCUSSION—
The difference in dimensions is usually reported as a percentage of the die size. It should include a (+) when the sintered part is larger than the die size and a (−) when the sintered part is smaller than the die size.

directed energy deposition (DED), *n*—additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited.

DISCUSSION—
"Focused thermal energy" means that an energy source (for example, laser, electron beam, or plasma arc) is focused to melt the materials being deposited.

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

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

dissociated ammonia, *n*—a reducing gas produced by the thermal decomposition of anhydrous ammonia over a catalyst, resulting in a gas of 75 % hydrogen and 25 % nitrogen. Synonymous with **cracked ammonia**.

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

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

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

ejection crack, *n*—a defect that occurs during the removal of the compact from the tooling (usually occurs in multilevel parts that are not supported uniformly on all lower surfaces).

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

endothermic gas, *n*—a reducing gas atmosphere used in sintering, produced by the reaction of a hydrocarbon vapor and air over a catalyst with the use of an external heat source. It is low in carbon dioxide and water vapor while containing combustibles of about 60 atomic percent hydrogen and carbon monoxide combined.

equalizing, *n*—see **blending**.

exothermic atmosphere (gas), *n*—a reducing gas atmosphere used in sintering, produced by partial or complete combustion of hydrocarbon fuel gas and air with the associated generation of heat. The maximum combustible content is approximately 25 atomic percent.

explosive compaction, *n*—high-energy consolidation of powders by means of a detonation shock wave.

exudation, *n*—the action by which all or a portion of the low melting constituent of a compact is forced to the surface during sintering. Sometimes referred to as "bleed out." Synonymous with **sweating**.

feedshoe, *n*—a part of the compacting press that delivers powder to the die cavity, usually by sliding an open-bottomed powder container over the open top of the die.

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

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

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

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

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.

fluid permeability, *n*—see **permeability**.

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

fully dense material, *n*—a material completely free of porosity and voids.

Discussion—
This is a conceptual term. In practice, complete densification is difficult to achieve and some microporosity will generally be present. The measured density of a material depends on its specific chemistry, thermomechanical condition, and microstructure.

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

gate, *n*—the interface in the flow channel between the runner and the mold cavity.

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

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.

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

green crack, *n*—a defect that occurs prior to sintering.

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

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**.

green strength, *n*—stress required to break an unsintered compact.

growth, *n*—an increase in dimensions of a compact which may occur during sintering. (Converse of **shrinkage**.)

hardmetal, *n*—see **cemented carbide**.

heating rate, *n*—the average temperature change per unit time between prescribed temperatures during the heating phase of a thermal process.