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Sintered metal materials — Specifications

Matériaux métalliques frittés — Spécifications

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 5755 was prepared by Technical Committee ISO/TC 119, *Powder metallurgy*, Subcommittee SC 5, *Specifications for powder metallurgical materials (excluding hardmetals)*.

This third edition cancels and replaces the second edition (ISO 5755:2001), which has been technically revised.

Sintered metal materials — Specifications

1 Scope

This International Standard specifies the requirements for the chemical composition and the mechanical and physical properties of sintered metal materials used for bearings and structural parts.

When selecting powder metallurgical (PM) materials, it should be taken into account that the properties depend not only on the chemical composition and density, but also on the production methods. The properties of sintered materials giving satisfactory service in particular applications may not necessarily be the same as those of wrought or cast materials that might otherwise be used. Therefore, liaison with prospective suppliers is recommended.

2 Normative references

The following referenced documents are indispensable for the application 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 437, *Steel and cast iron — Determination of total carbon content — Combustion gravimetric method*

ISO 1099, *Metallic materials — Fatigue testing — Axial force-controlled method*

ISO 1143, *Metallic materials — Rotating bar bending fatigue testing*

ISO 2738, *Sintered metal materials, excluding hardmetals — Permeable sintered metal materials — Determination of density, oil content and open porosity*

ISO 2739, *Sintered metal bushings — Determination of radial crushing strength*

ISO 2740, *Sintered metal materials, excluding hardmetals — Tensile test pieces*

ISO 2795, *Plain bearings — Sintered bushes — Dimensions and tolerances*

ISO 3325, *Sintered metal materials, excluding hardmetals — Determination of transverse rupture strength*

ISO 3928, *Sintered metal materials, excluding hardmetals — Fatigue test pieces*

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

ISO 4498, *Sintered metal materials, excluding hardmetals — Determination of apparent hardness and micro-hardness*

ISO 5754, *Sintered metal materials, excluding hardmetals — Unnotched impact test piece*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7625, *Sintered metal materials, excluding hardmetals — Preparation of samples for chemical analysis for determination of carbon content*

ISO 14317, *Sintered metal materials, excluding hardmetals — Determination of compressive yield strength*

ASTM E228, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

ASTM E1875, *Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Sonic Resonance*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
tensile strength
R_m
ability of a test specimen to resist fracture when a pulling force is applied in a direction parallel to its longitudinal axis – expressed in MPa

NOTE It is equal to the maximum load divided by the original cross-sectional area.

3.2
tensile yield strength
$R_{\mathrm{p}0,2}$
load at which the material exhibits a 0,2 % offset from proportionality on a stress-strain curve in tension, divided by the original cross-sectional area – expressed in MPa

3.3
Young's modulus
E
ratio of normal stress to corresponding strain for tensile or compressive stresses below the proportional limit of the material – expressed in GPa

3.4
Poisson's ratio
v
absolute value of the ratio of transverse strain to the corresponding axial strain, resulting from uniformally distributed axial stress below the proportional limit of the material

3.5
impact energy
measurement of the energy absorbed when fracturing a specimen with a single blow – measured in Joules (J)

3.6
compressive yield strength
stress at which a material exhibits a specified permanent set – expressed in MPa

3.7
transverse rupture strength
stress, calculated from the bending strength formula, required to break a specimen of a given dimension – expressed in MPa

3.8
fatigue strength
maximum alternating stress that can be sustained for a specific number of cycles without failure, the stress being reversed with each cycle unless otherwise stated – expressed in MPa

3.9

radial crushing strength

radial stress required to fracture a hollow cylindrical part of specified dimensions – expressed in MPa

3.10

density

mass per unit volume of the material – expressed in g/cm^3

3.11

apparent hardness

resistance of a powder metallurgical (PM) material to indentation, tested under specified conditions; for PM materials, it is a function of the density of the material

3.12

open porosity

oil content after full impregnation, divided by the volume of the test piece, and multiplied by 100 – expressed as a volume percentage

3.13

coefficient of linear expansion

change in length per unit length per degree change in temperature – expressed in 10^{-6} K^{-1}

4 Sampling

Sampling of powders to produce standard test pieces shall be carried out in accordance with ISO 3954.

5 Test methods for normative properties

5.1 General

The following test methods shall be used to determine the normative properties given in Tables 1 to 18.

5.2 Chemical analysis

The chemical composition table for each material lists the principal elements by minimum and maximum mass percentage before any additional process, such as oil impregnation, resin impregnation or steam treatment, has taken place. “Other elements” may include minor amounts of elements added for specific purposes and is reported as a maximum percentage.

Whenever possible, and always in cases of dispute, the methods of chemical analysis shall be those specified in the relevant International Standards. If no International Standard is available, the method may be agreed upon and specified at the time of enquiry and order.

Samples for the determination of total carbon content shall be prepared in accordance with ISO 7625. Determination of the total carbon content shall be in accordance with ISO 437.

5.3 Open porosity

The open porosity shall be determined in accordance with ISO 2738.

5.4 Mechanical properties

5.4.1 General

The as-sintered mechanical properties given in Tables 1 to 18 were determined on pressed and sintered test pieces with a mean chemical composition. The heat-treated mechanical properties given in Tables 1 to 18 were determined on test bars which were either pressed and sintered or machined from pressed and sintered blanks. They are intended as a guide to the initial selection of materials (see also Clause 1). They may also be used as a basis for specifying any special tests that may be indicated on the drawing.

The mechanical properties shall neither be calculated from hardness values nor be determined on tensile test pieces taken from a component and used for verifying the values given in Tables 1 to 18. If the customer requires that a specified level of mechanical properties be obtained by tests on the component, these shall be agreed with the supplier and shall be stated on the drawing and/or any technical documentation of the customer referred to on the drawing.

5.4.2 Tensile properties

The ultimate tensile strength and the yield strength shall be determined in accordance with ISO 2740 and, ISO 6892-1. For heat-treated materials, tensile strength and yield strength are approximately equal and in this case, tensile strength is specified.

The normative yield strengths (as-sintered condition) and ultimate tensile strengths (heat-treated condition) are shown as minimum values. These strengths may be used in designing PM part applications. To select a material which is optimum in both properties and cost-effectiveness, it is essential that the part application be discussed with the PM parts manufacturer.

The minimum values were developed from tensile specimens prepared specifically for evaluating PM materials.

Tensile specimens machined from commercial parts may differ from those obtained from prepared tensile specimens. To evaluate the part strength, it is recommended that static or dynamic proof-testing be agreed between the purchaser and the manufacturer and carried out on the first production lot of parts. The results of testing to failure can be used statistically to determine a minimum breaking force for future production lots.

Acceptable strength can also be demonstrated by processing tensile specimens prepared specifically for evaluating PM materials manufactured from the same batch of powder as the production parts and processed with them.

As indicated above, the testing of test bars machined from the PM component is the least desirable method for demonstrating minimum properties.

For heat-treated properties, the test bars were quench-hardened and tempered to increase the strength, hardness and wear resistance. Tempering is essential to develop the properties given in this International Standard. Heat-treat equipment that utilizes a gas atmosphere or vacuum is recommended. The use of liquid salts is not recommended due to entrapment of the salts in the porosity causing “salt bleed-out” and “internal corrosion”. Some materials may be heat-treated directly after the sintering process by controlling the cooling rate within the sintering furnace. This process is usually known as “sinter hardening”. Materials processed by this route also require tempering to develop their optimum strengths.

5.4.3 Radial crushing strength

The radial crushing strength shall be determined in accordance with ISO 2739. The wall thicknesses of test pieces to be used shall be in the range covered by ISO 2795. For test pieces outside this range, the specified radial crushing strength values are different and shall be agreed between the customer and the supplier.

6 Test methods for informative properties

6.1 General

Typical values are given for each material; these include tensile and yield strengths. These typical values are given for general guidance only. They should not be used as minimum values.

These typical properties should be achievable through normal manufacturing processing. Again, any specific tests on components should be discussed and agreed between the purchaser and the manufacturer.

6.2 Density

Density is expressed in grams per cubic centimetre (g/cm^3). The density shall be determined in accordance with ISO 2738. Density is normally determined after the removal of any oils or non-metallic materials from the porosity and is known as the "dry density". The "wet density" is sometimes reported on production bearings or parts, this is the mass per unit volume, including any oil or non-metallic material that has impregnated the component.

6.3 Tensile strength

The tensile strength shall be determined in accordance with ISO 2740 and ISO 6892-1.

6.4 Tensile yield strength

The tensile yield strength shall be determined in accordance with ISO 2740 and ISO 6892-1.

6.5 Elongation

Elongation (plastic) shall be determined in accordance with ISO 6892-1. It is expressed as a percentage of the original gauge length (usually 25 mm), and is determined by on measuring the increase in gauge length after the fracture, providing the fracture takes place within the gauge length. Elongation can also be measured with a break-away extensometer on a tensile specimen. The recorded stress/strain curve displays total elongation (elastic and plastic). The elastic strain must be subtracted from the total elongation to give the plastic elongation (this can sometimes be provided with the test machine's software).

6.6 Young's modulus

Young's modulus shall be determined in accordance with ASTM E1875. Data for the elastic constants in this International Standard were generated from resonant frequency testing. An equation relating the three elastic constants is:

$$v = \left(E/2G\right) - 1$$

where

v is Poisson's ratio;

E is Young's modulus;

G is the shear modulus.

6.7 Poisson's ratio

Poisson's ratio shall be determined in accordance with ASTM E1875.

6.8 Impact energy

The impact energy shall be determined in accordance with ISO 5754. The data in this International Standard were obtained using an unnotched Charpy specimen.

6.9 Compressive yield strength

The compressive yield strength shall be determined in accordance with ISO 14317. For certain heat-treated materials listed in the tables, the hardenability is not sufficient to completely through-harden the 9,00 mm diameter test specimen. Due to variation in hardenability among the heat-treated steels listed in the tables, the compressive yield strength data are appropriate only for 9,00 mm sections. Typically, smaller cross-sections have higher compressive yield strengths and larger sections have somewhat lower strengths due to the hardenability response. Since the cross-section of the tensile yield test specimen is smaller than the compressive yield specimen, a direct correspondence between tensile and compressive yield strength data is not possible.

6.10 Transverse rupture strength

The transverse rupture strength shall be determined in accordance with ISO 3325.

The strength formula in ISO 3325 is strictly valid only for non-ductile materials; nevertheless, it is widely used for materials that bend at fracture, and is useful for establishing comparative strengths. Data for such materials are included as typical properties in ISO 3325.

6.11 Fatigue strength

6.11.1 General

The number of cycles survived should be stated with each strength listed.

For PM ferrous materials, like wrought ferrous materials, fatigue strengths of 10^7 cycles in duration using unnotched specimens are considered to be sustainable indefinitely and are therefore considered to be fatigue limits (also termed endurance limits). By contrast, non-ferrous PM materials do not have 10^7 cycle maximum fatigue strengths sustainable for indefinite times and these stress limits therefore simply remain as the fatigue strength at 10^7 cycles.

The fatigue limits in this International Standard were generated through statistical analysis of the test data. Due to the limited number of data points available for the analysis, these fatigue strengths were determined as the 90 % survival stress, i.e. the fatigue stress at which 90 % of the test specimens survived 10^7 cycles.

There are three methods of stressing the test specimens and each gives different fatigue strengths. These are described in 6.11.2 to 6.11.4.

6.11.2 Rotating bending fatigue strength

This test method uses a machined, round, smooth test specimen (in accordance with ISO 3928), with an R. R. Moore testing machine. Testing is conducted in accordance with ISO 1143. The specimen is held at one end and rotated while it is stressed at the other end. The surface of the test bar is the most highly stressed area and the centre line has a neutral stress. This test method gives the highest fatigue strength.

6.11.3 Plane-bending fatigue strength

This method used for plane-bending fatigue uses a standard sintered fatigue test bar (in accordance with ISO 3928) that is subjected to an alternating stress. This test method gives a slightly lower fatigue strength than the rotating bending fatigue test, as more of the cross-sectional area is subjected to the stress. Evaluation of fatigue strength is done according to the staircase method described in MPIF Standard 56.

6.11.4 Axial fatigue strength

This method uses either a machined, round or standard sintered fatigue test bar (in accordance with ISO 3928) that is tested in a test machine by clamping both ends and subjecting the test bar to alternating stresses where $R = -1$. Testing is conducted in accordance with ISO 1099. As the whole of the cross-section is stressed, this test method gives the lowest fatigue strength.

6.12 Apparent hardness

The apparent hardness shall be determined in accordance with ISO 4498. The hardness value of a PM part when using a conventional indentation hardness tester is referred to as “apparent hardness” because it represents a combination of matrix hardness plus the effect of porosity. Apparent hardness measures the resistance to indentation.

Because of possible density variations in a finished PM part, the location of critical apparent hardness measurements should be specified on the engineering drawing of the part. As surface pore closure can affect the apparent hardness, the surface condition should also be specified.

6.13 Coefficient of linear expansion

The coefficient of linear expansion shall be determined in accordance with ASTM E228.

7 Specifications

The chemical composition and mechanical properties are given in Tables 1 to 18.

The liquid lubricant content of materials for bearings, impregnated with liquid lubricant, shall be not less than 90 % of the measured open porosity.

8 Designations

Designations shall be in accordance with Annex A.

Table 1 — Non-ferrous materials for bearings: bronze and bronze with graphite

	Grade[a]	Normative values						Informative values	
		Chemical composition				Open porosity min.	Radial crushing strength min.	Density (dry)	Coefficient of linear expansion
		Graphite	Sn	Cu	Total other elements max.				
		%	%	%	%	p %	K MPa	ρ g/cm^3	10^{-6} K^{-1}
Bronze	-C-T10-K110		8,5 to 11,0	Balance	2	27	110	6,1	18
	-C-T10-K140		8,5 to 11,0	Balance	2	22	140	6,6	18
	-C-T10-K180		8,5 to 11,0	Balance	2	15	180	7,0	18
Bronze with graphite	-C-T10G-K90	0,5 to 2,0	8,5 to 11,0	Balance	2	27	90	5,9	18
	-C-T10G-K110[b]	0,5 to 2,0	8,5 to 11,0	Balance	2	25	110	6,0	18
	-C-T10G-K120	0,5 to 2,0	8,5 to 11,0	Balance	2	22	120	6,4	18
	-C-T10G-K170[b]	0,5 to 2,0	8,5 to 11,0	Balance	2	19	170	6,5	18
	-C-T10G-K160	0,5 to 2,0	8,5 to 11,0	Balance	2	17	160	6,8	18
	-C-T10G-K115	3 to 5	8,5 to 11,0	Balance	2	11	115	6,8	19

[a] All materials can be oil-impregnated.

[b] These materials have a higher strength than would be expected from the porosity listed, which may require different sintering parameters.

Table 2 — Ferrous materials for bearings: iron, iron-copper, iron-bronze and iron-carbon graphite

	Grade[a]	Normative values								Informative values	
		Chemical composition						Open porosity min.	Radial crushing strength	Density (dry)	Coefficient of linear expansion
		C combined[b]	Cu	Sn	Graphite	Fe	Total other elements max.				
		%	%	%	%	%	%	p %	K MPa	ρ g/cm^3	10^{-6} K^{-1}
Iron	-F-00-K170	<0,3				Balance	2	22	>170	5,8	12
	-F-00-K220	<0,3				Balance	2	17	>220	6,2	12
Iron copper	-F-00C2-K200	<0,3	1 to 4			Balance	2	22	>200	5,8	12
	-F-00C2-K250	<0,3	1 to 4			Balance	2	17	>250	6,2	12
	-F-03C22-K150	<0,5	18 to 25			Balance	2	18	>150	6,4	13
	-F-03C22G-K150	<0,5	18 to 25		0,3 to 1,0	Balance	2	18	>150	6,4	13
	-F-03C22G-K200[d]	<0,5	18 to 25		1,0 to 3,0	Balance	2	18	>200	6,4	13
	-F-03C25T-K120	<0,5	20 to 30	1,0 to 3,0		Balance	2	17	120 to 250	6,4	13
Iron bronze[c]	-F-03C36T-K90	<0,5	34 to 38	3,5 to 4,5	0,3 to 1,0	Balance	2	24	90 to 265	5,8	14
	-F-03C36T-K120	<0,5	34 to 38	3,5 to 4,5	0,3 to 1,0	Balance	2	19	120 to 345	6,2	14
	-F-03C45T-K70	<0,5	43 to 47	4,5 to 5,5	<1,0	Balance	2	24	70 to 245	5,6	14
	-F-03C45T-K100	<0,5	43 to 47	4,5 to 5,5	<1,0	Balance	2	19	100 to 310	6,0	14
Iron-carbon graphite[c]	-F-03G3-K70	<0,5			2,0 to 3,5	Balance	2	20	70 to 175	5,6	12
	-F-03G3-K80	<0,5			2,0 to 3,5	Balance	2	13	80 to 210	6,0	12

[a] All materials can be oil-impregnated.

[b] On the basis of iron phase only.

[c] The range of values given for radial crushing strength (K) indicates the necessity to maintain a balance between combined carbon and free graphite.

[d] This material has a higher strength than would be expected from the porosity listed, which may require different sintering parameters.