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Sintered metal material — 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.

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 Technical Committee ISO/TC 119, *Powder metallurgy,* Subcommittee SC 5, *Specifications for powder metallurgical materials (excluding hardmetals)*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/SS M11, *Powder metallurgy,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 5755:2012), which has been technically revised.

The main changes are as follows:

— Annex B has been updated to include information on metallography of sintered materials;

— a new Annex C has been added to include tables of equivalences of the materials of the standard with the materials of other international standards of habitual use.

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.

Sintered metal material — Specifications

1 Scope

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

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

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 3954, *Powders for powder metallurgical purposes — Sampling*

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

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.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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

Note 1 to entry: It is equal to the maximum load divided by the original cross-sectional area.

Note 2 to entry: It is expressed in MPa.

3.2
tensile yield strength
$R_{p0,2}$
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

Note 1 to entry: It is 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

Note 1 to entry: It is 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

Note 1 to entry: It is expressed in Joules (J).

3.6
compressive yield strength
stress at which a material exhibits a specified permanent set

Note 1 to entry: It is expressed in MPa.

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

Note 1 to entry: It is 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

Note 1 to entry: It is expressed in MPa.

3.9
radial crushing strength
radial stress required to fracture a hollow cylindrical part of specified dimensions

Note 1 to entry: It is expressed in MPa.

3.10
density
mass per unit volume of the material

Note 1 to entry: It is expressed in g/cm^3.

3.11
apparent hardness
resistance of a powder metallurgical (PM) material to indentation, tested under specified conditions

Note 1 to entry: 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

Note 1 to entry: It is expressed as a volume percentage.

3.13
coefficient of linear expansion
change in length per unit length per degree change in temperature

Note 1 to entry: It is 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 can 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 . 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 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 document. 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

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 shall 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 document were generated from resonant frequency testing. Formula (1) relates the three elastic constants:

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

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 document 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 are 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 document 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 shall be 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 shall be 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/cm³	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 is expected from the porosity listed, which can 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/cm³	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 expected from the porosity listed, which can require different sintering parameters.

Table 3 — Ferrous materials for structural parts: iron and carbon steel — As-sintered

	Grade	Normative values					Informative values											
		Chemical composition				Tensile yield strength min.	Density	Tensile strength	Tensile yield strength	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % survival[a]	Apparent hardness	
		C combined	Cu	Fe	Total other elements max.													
		%	%	%	%	$R_{p0,2}$ MPa	ρ g/cm^3	R_m MPa	$R_{p0,2}$ MPa	A_{25} %	GPa		J	(0,1 %) MPa	MPa	MPa	HV5	Rockwell
Iron	F-00–100	< 0,3	—	Balance	2	100	6,7	170	120	3	120	0,25	8	120	340	65	60	60 HRF
	F-00–120	< 0,3	—	Balance	2	120	7,0	210	150	4	140	0,27	24	125	500	80	75	70 HRF
	F-00–140	< 0,3	—	Balance	2	140	7,3	260	170	7	160	0,28	47	130	660	100	85	80 HRF
Carbon steel	F-05–100	0,3 to 0,6	—	Balance	2	100	6,1	170	120	< 1	105	0,25	4	125	330	60	70	25 HRB
	F-05–140	0,3 to 0,6	—	Balance	2	140	6,6	220	160	1	115	0,25	5	160	440	80	90	40 HRB
	F-05–170	0,3 to 0,6	—	Balance	2	170	7,0	275	200	2	140	0,27	8	200	550	105	120	60 HRB
Carbon steel	F-08–170	0,6 to 0,9	—	Balance	2	170	6,2	240	210	< 1	110	0,25	4	210	420	100	110	50 HRB
	F-08–210	0,6 to 0,9	—	Balance	2	210	6,6	290	240	1	115	0,25	5	210	510	120	120	60 HRB
	F-08–240	0,6 to 0,9	—	Balance	2	240	7,0	390	260	1	140	0,27	7	250	690	170	140	70 HRB

These materials may be supplied with additives to improve machinability.

Properties were derived from pressed and sintered test pieces (not machined) according to ISO 2740.

a Machined test pieces according to ISO 3928.

Table 4 — Ferrous materials for structural parts: carbon steel — Heat-treated

Grade	Normative values					Informative values										
	Chemical composition				Ultimate tensile strength min.	Density	Tensile strength[c]	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % survival[d]	Apparent hardness	
	C combined	Cu	Fe	Total other elements max.												
	%	%	%	%	R_m MPa	ρ g/cm³	R_m MPa	A_{25} %	GPa		J	(0,1 %) MPa	MPa	MPa	HV10	Rockwell
F-05-340H[a]	0,3 to 0,6	—	Balance	2	340	6,6	410	< 1	115	0,25	4	300	720	160	280	20 HRC
F-05-410H[a]	0,3 to 0,6	—	Balance	2	410	6,8	480	< 1	130	0,27	5	360	830	190	290	22 HRC
F-05-480H[a]	0,3 to 0,6	—	Balance	2	480	7,0	550	< 1	140	0,27	5	420	970	220	300	25 HRC
F-08-450H[b]	0,6 to 0,9	—	Balance	2	450	6,6	520	< 1	115	0,25	5	550	790	210	320	28 HRC
F-08-500H[b]	0,6 to 0,9	—	Balance	2	500	6,8	570	< 1	130	0,27	6	600	860	230	345	31 HRC
F-08-550H[b]	0,6 to 0,9	—	Balance	2	550	7,0	620	< 1	140	0,27	7	655	950	260	360	33 HRC

Heat-treated tensile properties were derived from machined test bars according to ISO 2740.

[a] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,5 % carbon potential, oil-quenched and tempered at 180 °C for 1 h.

[b] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,8 % carbon potential, oil-quenched and tempered at 180 °C for 1 h.

[c] Tensile yield and ultimate tensile strength are approximately the same for heat-treated materials.

[d] Machined test pieces according to ISO 3928.