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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

ν
absolute value of the ratio of transverse strain to the corresponding axial strain, resulting from uniformly 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 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:

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

where

ν 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. <i>p</i> %	Radial crush- ing strength min. <i>K</i> MPa	Density (dry) <i>ρ</i> g/cm ³	Coefficient of linear expansion 10 ⁻⁶ K ⁻¹
	Graphite %	Sn %	Cu %	Total other elements max. %					
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.					
		%	%	%	%	%	%	%		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	
	F-00C2-K200	< 0,3	1 to 4	—	—	Balance	2	22	> 200	5,8	12	
Iron copper	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. This material has a higher strength than expected from the porosity listed, which can require different sintering parameters.

^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										Apparent hardness		
		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			
		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	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	6,7	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.																			
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 ^d 90 % survival	Apparent hardness		
	C combined	Cu	Fe	Total other elements max.													
	%	%	%	%	R _m MPa	ρ g/cm ³	R _m MPa	A ₂₅ %	GPa		J	(0,1 %) MPa	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.																	

Table 5 — Ferrous materials for structural parts: copper steel and copper-carbon steel — As-sintered

Grade		Normative values					Informative values														
		Chemical composition				Tensile yield strength min.	Density ρ g/cm ³	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	Bending fatigue limit 90 % survival ^b	Axial fatigue limit 90 % survival ^c	Apparent hardness	Rockwell
		C combined	Cu	Fe	Total other elements max.	$R_{p0,2}$ MPa		R_m MPa	$R_{p0,2}$ MPa	A_{25} %	GPa	J	(0,1 %) MPa	MPa	MPa	MPa	MPa	MPa	HV5		
Copper steel	F-00C2-110	< 0,3	1,3 to 3,0	Balance	2	110	6,2	180	150	1,5	110	0,25	6	130	340	70	—	—	—	60	16 HRB
	F-00C2-140	< 0,3	1,3 to 3,0	Balance	2	140	6,6	210	180	2	115	0,25	7	160	390	80	—	—	—	70	26 HRB
	F-00C2-175	< 0,3	1,3 to 3,0	Balance	2	175	7,0	235	205	3	140	0,27	8	185	445	89	—	—	—	90	39 HRB
	F-05C2-230	0,3 to 0,6	1,3 to 3,0	Balance	2	230	6,2	270	270	< 1	110	0,25	3	270	480	95	—	—	—	110	44 HRB
Copper-carbon steels	F-05C2-270	0,3 to 0,6	1,3 to 3,0	Balance	2	270	6,6	325	300	< 1	115	0,25	7	305	620	130	—	—	—	115	57 HRB
	F-05C2-300	0,3 to 0,6	1,3 to 3,0	Balance	2	300	7,0	390	330	< 1	140	0,27	10	330	760	190	—	150	150	150	68 HRB
	F-08C2-270	0,6 to 0,9	1,3 to 3,0	Balance	2	270	6,2	320	300	< 1	110	0,25	3	300	580	110	—	90	115	115	58 HRB
	F-08C2-350	0,6 to 0,9	1,3 to 3,0	Balance	2	350	6,6	390	360	< 1	115	0,25	7	330	800	150	—	120	140	140	70 HRB
	F-08C2-390	0,6 to 0,9	1,3 to 3,0	Balance	2	390	7,0	480	420	< 1	140	0,27	8	360	980	200	—	170	165	165	78 HRB
	F-08C2-410	0,6 to 0,9	1,3 to 3,0	Balance	2	410	7,2	520	450	< 1	155	0,28	9	380	1 070	230	—	190	185	185	84 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.																				
b	As-sintered test pieces (sintered surfaces) according to ISO 3928.																				
	Machined test pieces according to ISO 3928.																				

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.

^b As-sintered test pieces (sintered surfaces) according to ISO 3928.

^c Machined test pieces according to ISO 3928.

Table 6 — Ferrous materials for structural parts: copper-carbon steel — Heat-treated

Grade	Normative values					Informative values										
	Chemical composition				Ultimate tensile strength min. <i>R_m</i> MPa	Density g/cm ³	Tensile strength ^c <i>R_m</i> MPa	Elongation <i>A₂₅</i> %	Young's modulus GPa	Poisson's ratio	Unnotched Charpy impact J	Compressive yield strength (0,1 %) MPa	Transverse rupture strength MPa	Rotating fatigue limit ^d 90 % survival MPa	Apparent hardness	
	C combined %	Cu %	Fe %	Total other elements max. %											HV10	Rockwell
F-05C2-410H ^a	0,3 to 0,6	1,3 to 3,0	Balance	2	410	6,2	480	<1	110	0,25	3	390	660	190	270	19 HRC
F-05C2-500H ^a	0,3 to 0,6	1,3 to 3,0	Balance	2	500	6,6	580	<1	115	0,25	5	520	800	220	310	27 HRC
F-05C2-620H ^a	0,3 to 0,6	1,3 to 3,0	Balance	2	620	7,0	690	<1	140	0,27	7	660	930	260	390	36 HRC
F-08C2-360H ^b	0,6 to 0,9	1,3 to 3,0	Balance	2	360	6,2	470	<1	110	0,25	4	430	690	180	290	22 HRC
F-08C2-500H ^b	0,6 to 0,9	1,3 to 3,0	Balance	2	500	6,6	570	<1	115	0,25	6	560	830	230	360	33 HRC
F-08C2-620H ^b	0,6 to 0,9	1,3 to 3,0	Balance	2	620	7,0	690	<1	140	0,27	6	690	1 000	270	430	40 HRC
F-08C2-670H ^b	0,6 to 0,9	1,3 to 3,0	Balance	2	670	7,2	750	<1	155	0,28	7	750	1 070	290	470	44 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.

Table 7 — Ferrous materials for structural parts: phosphorus steels — 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	Transverse rupture strength	Bending fatigue limit 90 % survival ^b	Apparent hardness
		C combined	P	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	MPa	MPa	HV5 Rockwell
Phosphorus steel ^a	F-00P05-180	< 0,1	0,40 to 0,50	—	Balance	2	180	6,6	300	210	4	115	0,25	18	600	95	70
	F-00P05-210	< 0,1	0,40 to 0,50	—	Balance	2	210	7,0	400	240	9	140	0,27	30	900	125	120
Phosphorus-carbon steel	F-05P05-270	0,3 to 0,6	0,40 to 0,50	—	Balance	2	270	6,6	400	305	3	115	0,25	9	700	125	130
	F-05P05-320	0,3 to 0,6	0,40 to 0,50	—	Balance	2	320	7,0	480	365	5	140	0,27	15	1 000	160	150
Copper-phosphorus steel	F-00C2P-260	< 0,3	0,40 to 0,50	1,5 to 2,5	Balance	2	260	6,6	400	300	3	115	0,25	—	—	115	120
	F-00C2P-300	< 0,3	0,40 to 0,50	1,5 to 2,5	Balance	2	300	7,0	500	340	6	140	0,27	—	—	145	140
Copper-phosphorus-carbon steel	F-05C2P-320	0,3 to 0,6	0,40 to 0,50	1,5 to 2,5	Balance	2	320	6,6	450	360	2	115	0,25	—	820	135	140
	F-05C2P-380	0,3 to 0,6	0,40 to 0,50	1,5 to 2,5	Balance	2	380	7,0	550	400	3	140	0,27	—	1 120	165	160
Properties were derived from pressed and sintered test pieces (not machined) according to ISO 2740.																	
^a Consultation with the supplier is recommended before these materials are used in magnetic applications. Some soft magnetic PM materials are standardized in IEC 60404-8-9.																	
^b As-sintered test pieces (sintered surfaces) according to ISO 3928.																	

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

^a Consultation with the supplier is recommended before these materials are used in magnetic applications. Some soft magnetic PM materials are standardized in IEC 60404-8-9.^b As-sintered test pieces (sintered surfaces) according to ISO 3928.

Table 8 — Ferrous materials for structural parts: nickel steels — As-sintered

Grade	Normative values					Informative values												
	Chemical composition					Tensile yield strength min. $R_{p0,2}$ MPa	Density ρ g/cm ³	Tensile strength R_m MPa	Tensile yield strength $R_{p0,2}$ MPa	Elongation A_{25} %	Young's modulus GPa	Poisson's ratio	Unnotched Charpy impact J	Compressive yield strength (0,1 %) MPa	Transverse rupture strength MPa	Rotating fatigue limit 90 % survival MPa	Apparent hardness HV5 Rockwell	
	C combined %	Ni %	Cu %	Fe %	Total other elements max. %													
F-05N2-140	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	140	6,6	280	170	1,5	115	0,25	8	170	450	100	80	44 HRB
F-05N2-180	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	180	7,0	360	220	2,5	140	0,27	20	210	740	130	130	62 HRB
F-05N2-210	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	210	7,2	440	240	4,0	155	0,28	28	240	860	150	145	69 HRB
F-05N2-240	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	240	7,4	480	280	5,5	170	0,28	46	280	1030	180	170	78 HRB
F-08N2-220	0,6 to 0,9	1,5 to 2,5	0,0 to 2,5	Balance	2	220	6,8	350	260	1,5	130	0,27	9	260	660	120	145	68 HRB
F-08N2-260	0,6 to 0,9	1,5 to 2,5	0,0 to 2,5	Balance	2	260	7,0	430	300	1,5	140	0,27	13	300	800	150	160	74 HRB
F-08N2-300	0,6 to 0,9	1,5 to 2,5	0,0 to 2,5	Balance	2	300	7,2	515	325	2,2	155	0,28	18	325	985	180	175	80 HRB
F-05N4-180	0,3 to 0,6	3,5 to 4,5	0,0 to 2,0	Balance	2	180	6,6	285	220	1,0	115	0,25	8	240	500	110	105	53 HRB
F-05N4-240	0,3 to 0,6	3,5 to 4,5	0,0 to 2,0	Balance	2	240	7,0	410	280	3,0	140	0,27	20	280	830	150	145	71 HRB
F-05N4-310	0,3 to 0,6	3,5 to 4,5	0,0 to 2,0	Balance	2	310	7,4	620	340	4,5	170	0,28	45	310	1 210	220	185	84 HRB
F-08N4-300	0,6 to 0,9	3,5 to 4,5	0,0 to 2,0	Balance	2	300	6,8	420	320	1,0	130	0,27	9	320	720	150	160	75 HRB
F-08N4-330	0,6 to 0,9	3,5 to 4,5	0,0 to 2,0	Balance	2	330	7,0	480	360	1,0	140	0,27	11	360	850	170	175	80 HRB
F-08N4-380	0,6 to 0,9	3,5 to 4,5	0,0 to 2,0	Balance	2	380	7,2	550	410	1,0	155	0,28	15	410	1 030	190	205	87 HRB
Properties were derived from pressed and sintered test pieces (not machined) according to ISO 2740.																		
Machined test pieces according to ISO 3928.																		

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

^a Machined test pieces according to ISO 3928.

Table 9 — Ferrous materials for structural parts: nickel steels — 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 ^d 90 % survival	Apparent hardness		
	C combined	NI	Cu	Fe	Total other elements max.													
	%	%	%	%	%	R _m MPa	ρ g/cm ³	R _m MPa	A ₂₅ %	GPa		J	(0,1 %) MPa	MPa	MPa	MPa	HV10	Rockwell
F-05N2-550H ^a	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	550	6,6	620	< 1	115	0,25	5	410	830	180	290	23 HRC	
F-05N2-800H ^a	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	800	7,0	900	< 1	140	0,27	7	600	1 200	260	350	31 HRC	
F-05N2-1070H ^a	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	1 070	7,2	1 100	< 1	155	0,28	9	830	1 480	320	390	36 HRC	
F-05N2-1240H ^a	0,3 to 0,6	1,5 to 2,5	0,0 to 2,5	Balance	2	1 240	7,4	1 280	< 1	170	0,28	13	970	1 720	370	430	40 HRC	
F-08N2-600H ^b	0,6 to 0,9	1,5 to 2,5	0,0 to 2,5	Balance	2	600	6,7	620	< 1	120	0,25	5	680	830	200	310	26 HRC	
F-08N2-900H ^b	0,6 to 0,9	1,5 to 2,5	0,0 to 2,5	Balance	2	900	7,0	1 000	< 1	140	0,27	7	940	1 280	320	380	35 HRC	
F-08N2-1070H ^b	0,6 to 0,9	1,5 to 2,5	0,0 to 2,5	Balance	2	1 070	7,2	1 170	< 1	155	0,28	9	1 120	1 520	370	420	39 HRC	
F-05N4-600H ^a	0,3 to 0,6	3,5 to 4,5	0,0 to 2,0	Balance	2	600	6,6	640	< 1	115	0,25	6	510	860	190	270	21 HRC	
F-05N4-900H ^a	0,3 to 0,6	3,5 to 4,5	0,0 to 2,0	Balance	2	900	7,0	930	≤ 1	140	0,27	9	710	1 380	290	350	31 HRC	
F-05N4-1240H ^a	0,3 to 0,6	3,5 to 4,5	0,0 to 2,0	Balance	2	1 240	7,4	1 280	≤ 1	170	0,28	18	910	1 930	390	430	40 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 260 °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 260 °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.

Table 10 — Ferrous materials for structural parts: diffusion-alloyed nickel-copper-molybdenum steels — As-sintered

Grade ^a	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 ^b	Bending fatigue limit 90 % survival ^b	Apparent hardness
	C.combined	Ni	Cu	Mo	Fe	Total other elements max.			R _{p0.2} MPa	R _m MPa										
FD-05N2C-360	% 0,3 to 0,6	% 1,5 to 2,0	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 360	ρ g/cm ³ 6,9	R _m MPa 540	R _{p0.2} MPa 390	A ₂₅ % 2	GPa 135	0,27	J 14	(0,1 %) MPa 350	MPa 1 040	MPa 190	MPa 170	HV5 155	Rockwell 74 HRB
FD-05N2C-400	% 0,3 to 0,6	% 1,5 to 2,0	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 400	ρ g/cm ³ 7,1	R _m MPa 590	R _{p0.2} MPa 420	A ₂₅ % 3	GPa 150	0,27	J 22	(0,1 %) MPa 380	MPa 1 200	MPa 220	MPa 195	HV5 180	Rockwell 81 HRB
F D - 05N2C-440	% 0,3 to 0,6	% 1,5 to 2,0	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 440	ρ g/cm ³ 7,4	R _m MPa 680	R _{p0.2} MPa 460	A ₂₅ % 4	GPa 170	0,28	J 38	(0,1 %) MPa 430	MPa 1 450	MPa 260	MPa 220	HV5 210	Rockwell 86 HRB
FD-08N2C-350	% 0,6 to 0,9	% 1,5 to 2,0	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 350	ρ g/cm ³ 6,8	R _m MPa 500	R _{p0.2} MPa 440	A ₂₅ % < 1	GPa 130	0,27	J 10	(0,1 %) MPa 410	MPa 980	MPa 195	MPa 190	HV5 175	Rockwell 80 HRB
FD-08N2C-390	% 0,6 to 0,9	% 1,5 to 2,0	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 390	ρ g/cm ³ 7,0	R _m MPa 580	R _{p0.2} MPa 450	A ₂₅ % 1	GPa 140	0,27	J 14	(0,1 %) MPa 450	MPa 1 160	MPa 240	MPa 210	HV5 190	Rockwell 84 HRB
FD-08N2C-430	% 0,6 to 0,9	% 1,5 to 2,0	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 430	ρ g/cm ³ 7,2	R _m MPa 680	R _{p0.2} MPa 490	A ₂₅ % 1	GPa 155	0,28	J 20	(0,1 %) MPa 490	MPa 1 300	MPa 300	MPa 230	HV5 215	Rockwell 87 HRB
F D - 05N4C-400	% 0,3 to 0,6	% 3,6 to 4,4	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 400	ρ g/cm ³ 6,9	R _m MPa 650	R _{p0.2} MPa 445	A ₂₅ % 1	GPa 135	0,27	J 21	(0,1 %) MPa 410	MPa 1 220	MPa —	MPa 205	HV5 170	Rockwell 79 HRB
FD-05N4C-420	% 0,3 to 0,6	% 3,6 to 4,4	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 420	ρ g/cm ³ 7,1	R _m MPa 750	R _{p0.2} MPa 465	A ₂₅ % 2	GPa 150	0,27	J 28	(0,1 %) MPa 440	MPa 1 380	MPa —	MPa 215	HV5 200	Rockwell 85 HRB
FD-05N4C-450	% 0,3 to 0,6	% 3,6 to 4,4	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 450	ρ g/cm ³ 7,4	R _m MPa 875	R _{p0.2} MPa 485	A ₂₅ % 3	GPa 170	0,28	J 39	(0,1 %) MPa 510	MPa 1 630	MPa 290	MPa 235	HV5 230	Rockwell 89 HRB
FD-08N4C-360	% 0,6 to 0,9	% 3,6 to 4,4	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 360	ρ g/cm ³ 6,8	R _m MPa 540	R _{p0.2} MPa 410	A ₂₅ % 1	GPa 130	0,27	J 14	(0,1 %) MPa 450	MPa 1 000	MPa —	MPa 240	HV5 205	Rockwell 86 HRB
FD-08N4C-390	% 0,6 to 0,9	% 3,6 to 4,4	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 390	ρ g/cm ³ 7,0	R _m MPa 650	R _{p0.2} MPa 440	A ₂₅ % 1	GPa 140	0,27	J 19	(0,1 %) MPa 480	MPa 1 190	MPa —	MPa 255	HV5 220	Rockwell 88 HRB
FD-08N4C-410	% 0,6 to 0,9	% 3,6 to 4,4	% 1,3 to 1,7	% 0,4 to 0,6	% Balance	% 2	R _{p0.2} MPa 410	ρ g/cm ³ 7,2	R _m MPa 760	R _{p0.2} MPa 460	A ₂₅ % 1,5	GPa 155	0,28	J 24	(0,1 %) MPa 500	MPa 1 380	MPa —	MPa 270	HV5 235	Rockwell 90 HRB
^a These materials are produced from diffusion-alloyed powders with the addition of elemental graphite.																				
^b Machined test pieces according to ISO 3928.																				
As-sintered test pieces (sintered surfaces) according to ISO 3928.																				

^a These materials are produced from diffusion-alloyed powders with the addition of elemental graphite.^b Machined test pieces according to ISO 3928.^c As-sintered test pieces (sintered surfaces) according to ISO 3928.

Table 11 — Ferrous materials for structural parts: diffusion-alloyed nickel-copper-molybdenum steels — Heat-treated

Grade ^a	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 (0,1 %) MPa	Transverse rupture strength	Rotating fatigue limit ^d 90 % survival ^d	Apparent hardness	
	C combined	Ni	Cu	Mo	Fe	Total other elements max.												
	%	%	%	%	%	%	R_m MPa	ρ g/cm ³	R_m MPa	A ₂₅ %	GPa		J		MPa	MPa	HV10	Rockwell
FD-05N2C-700H ^b	0,3 to 0,6	1,5 to 2,0	1,3 to 1,7	0,4 to 0,6	Balance	2	700	6,8	770	<1	130	0,27	8	950	1 150	310	340	30 HRC
FD-05N2C-950H ^b	0,3 to 0,6	1,5 to 2,0	1,3 to 1,7	0,4 to 0,6	Balance	2	950	7,1	1 020	<1	150	0,27	11	1 170	1 420	430	400	37 HRC
FD-05N2C-1100H ^b	0,3 to 0,6	1,5 to 2,0	1,3 to 1,7	0,4 to 0,6	Balance	2	1 100	7,4	1 170	<1	170	0,28	15	1 380	1 650	520	480	45 HRC
FD-05N4C-725H ^b	0,3 to 0,6	3,6 to 4,4	1,3 to 1,7	0,4 to 0,6	Balance	2	725	6,8	780	<1	130	0,27	8	890	1 130	—	320	31 HRC
FD-05N4C-930H ^b	0,3 to 0,6	3,6 to 4,4	1,3 to 1,7	0,4 to 0,6	Balance	2	930	7,1	1 000	<1	150	0,27	10	1 060	1 420	—	390	36 HRC
FD-05N4C-1100H ^b	0,3 to 0,6	3,6 to 4,4	1,3 to 1,7	0,4 to 0,6	Balance	2	1 100	7,4	1 170	<1	170	0,28	15	1 240	1 650	—	460	43 HRC

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

^a These materials are produced from diffusion-alloyed powders with the addition of elemental graphite.

^b 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.

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

^d Machined test pieces according to ISO 3928.

Table 12 — Ferrous materials for structural parts: pre-alloyed steels — As-sintered

Grade ^a	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 ^b	Bending fatigue limit 90 % survival ^b	Apparent hardness	
	C combined	Ni	Mo	Cr	Mn	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	MPa	HV5	Rockwell
FFL-05M1N-240 ^b	0,4 to 0,7	0,35 to 0,55	0,50 to 0,85	—	0,20 to 0,40	Balance	2	240	6,8	360	290	1	130	0,27	8	290	690	140	—	120	60 HRB
FFL-05M1N-290 ^b	0,4 to 0,7	0,35 to 0,55	0,50 to 0,85	—	0,20 to 0,40	Balance	2	290	7,0	420	330	1	140	0,27	13	330	810	200	—	140	67 HRB
FFL-05M1N-325 ^b	0,4 to 0,7	0,35 to 0,55	0,50 to 0,85	—	0,20 to 0,40	Balance	2	325	7,2	480	380	1,5	155	0,28	19	375	940	250	—	155	72 HRB
FFL-05M1-260 ^c	0,4 to 0,7	—	0,75 to 0,95	—	0,05 to 0,30	Balance	2	260	6,8	380	305	1	130	0,27	11	290	770	165	175	130	63 HRB
FFL-05M1-295 ^c	0,4 to 0,7	—	0,75 to 0,95	—	0,05 to 0,30	Balance	2	295	7,0	430	340	1	140	0,27	18	335	910	205	205	150	70 HRB
FFL-05M1-325 ^c	0,4 to 0,7	—	0,75 to 0,95	—	0,05 to 0,30	Balance	2	325	7,2	480	380	1,5	155	0,28	26	375	1 050	250	235	160	76 HRB
FFL-05N2M-250 ^d	0,4 to 0,7	1,75 to 2,00	0,45 to 0,60	—	0,05 to 0,30	Balance	2	250	6,8	370	295	1	130	0,27	10	295	720	150	150	125	61 HRB
FFL-05N2M-285 ^d	0,4 to 0,7	1,75 to 2,00	0,45 to 0,60	—	0,05 to 0,30	Balance	2	285	7,0	410	330	1	140	0,27	17	330	865	200	185	140	66 HRB
FFL-05N2M-320 ^d	0,4 to 0,7	1,75 to 2,00	0,45 to 0,60	—	0,05 to 0,30	Balance	2	320	7,2	470	370	1,5	155	0,28	24	370	1 010	235	215	155	72 HRB

Table 12 (continued)

Grade ^a	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 ^b	Bending fatigue limit 90 % survival ^b	Apparent hardness	
	C combined	Ni	Mo	Cr	Mn	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	MPa	HV5	Rockwell
FL-07Cr2M-485 ^e	0,6 to 0,8	—	0,15 to 0,30	1,3 to 1,7	0,05 to 0,30	Balance	2	485	6,8	690	515	1	130	0,27	14	465	1 205	200	200	195	84 HRB
FL-07Cr2M-535 ^e	0,6 to 0,8	—	0,15 to 0,30	1,3 to 1,7	0,05 to 0,30	Balance	2	535	7,0	795	575	1,5	140	0,27	18	555	1 415	230	230	220	88 HRB
FL-07Cr2M-570 ^e	0,6 to 0,8	—	0,15 to 0,30	1,3 to 1,7	0,05 to 0,30	Balance	2	570	7,2	880	630	2,5	155	0,28	22	625	1 640	260	250	240	90 HRB
FL-05Cr3M-570 ^f	0,4 to 0,6	—	0,40 to 0,60	2,7 to 3,3	0,05 to 0,30	Balance	2	570	6,8	810	640	< 1	130	0,27	12	560	1 365	205	—	235	90 HRB
FL-05Cr3M-670 ^f	0,4 to 0,6	—	0,40 to 0,60	2,7 to 3,3	0,05 to 0,30	Balance	2	670	7,0	915	740	< 1	140	0,27	14	645	1 520	240	—	260	92 HRB
FL-05Cr3M-775 ^f	0,4 to 0,6	—	0,40 to 0,60	2,7 to 3,3	0,05 to 0,30	Balance	2	775	7,2	1 040	845	< 1	155	0,28	16	740	1 655	275	—	320	28 HRC

Table 12 (continued)

Grade ^a	Normative values							Informative values													
	Chemical composition							Tensile yield strength min.	Density	Tensile strength R_m MPa	Tensile yield strength $R_{p0.2}$ MPa	Elongation A_{25} %	Young's modulus GPa	Poisson's ratio	Unnotched Charpy impact J	Compressive yield strength (0,1 %) MPa	Transverse rupture strength MPa	Rotating fatigue limit 90 % survival ^h MPa	Bending fatigue limit 90 % survival ^h MPa	Apparent hardness	
	C combined	Ni	Mo	Cr	Mn	Fe	Total other elements max.													ρ g/cm ³	HV5
	%	%	%	%	%	%	%	$R_{p0.2}$ MPa													
Properties were derived from pressed and sintered test pieces (not machined) according to ISO 2740.																					
^a These materials are produced from pre-alloyed powders with the addition of elemental graphite.																					
^b Pre-alloy base powder with a nominal composition 0,45 % Ni, 0,7 % Mo, 0,35 % Mn, balance Fe.																					
^c Pre-alloy base powder with a nominal composition 0,85 % Mo, 0,2 % Mn, balance Fe.																					
^d Pre-alloy base powder with a nominal composition 1,8 % Ni, 0,5 % Mo, 0,2 % Mn, balance Fe.																					
^e Pre-alloy base powder with a nominal composition 1,5 % Cr, 0,2 % Mo, 0,2 % Mn, balance Fe.																					
^f Pre-alloy base powder with a nominal composition 3,0 % Cr, 0,5 % Mo, 0,2 % Mn, balance Fe.																					
^g Machined test pieces according to ISO 3928.																					
^h As-sintered test pieces (sintered surfaces) according to ISO 3928.																					

Table 13 — Ferrous materials for structural parts: pre-alloyed steels — Heat-treated

Grade ^a	Normative values							Informative values												
	Chemical composition							Ultimate tensile strength min.	Density	Tensile strength ^f	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % survival	Bending fatigue limit 90 % survival	Apparent hardness	
	C combined	Ni	Mo	Cr	Mn	Fe	Total other elements max.												R _m MPa	ρ g/cm ³
FL-05MIN-690H ^{b,g}	0,4 to 0,7	0,35 to 0,55	0,50 to 0,85	—	0,20 to 0,40	Bal- ance	2	690	6,8	760	< 1	130	0,27	9	760	1 100	260	—	340	32 HRC
FL-05MIN-830H ^{b,g}	0,4 to 0,7	0,35 to 0,55	0,50 to 0,85	—	0,20 to 0,40	Bal- ance	2	830	7,0	900	< 1	140	0,27	11	970	1 280	300	—	380	36 HRC
FL-05MIN-970H ^{b,g}	0,4 to 0,7	0,35 to 0,55	0,50 to 0,85	—	0,20 to 0,40	Bal- ance	2	970	7,2	1 030	< 1	155	0,28	16	1 170	1 480	340	—	420	39 HRC
FL-05M1-770H ^{c,g}	0,4 to 0,7	—	0,75 to 0,95	—	0,05 to 0,30	Bal- ance	2	770	6,8	840	< 1	130	0,27	8	1 000	1 240	260	—	305	26 HRC
FL-05M1-940H ^{c,g}	0,4 to 0,7	—	0,75 to 0,95	—	0,05 to 0,30	Bal- ance	2	940	7,0	1 020	< 1	140	0,27	10	1 140	1 480	310	—	350	32 HRC
FL-05M1-1120H ^{c,g}	0,4 to 0,7	—	0,75 to 0,95	—	0,05 to 0,30	Bal- ance	2	1 120	7,2	1 190	< 1	155	0,28	15	1 270	1 750	360	—	380	36 HRC
FL-05N2M-720H ^{d,g}	0,4 to 0,7	1,75 to 2,00	0,45 to 0,60	—	0,05 to 0,30	Bal- ance	2	720	6,8	800	< 1	130	0,27	9	830	1 190	275	—	340	30 HRC
FL-05N2M-860H ^{d,g}	0,4 to 0,7	1,75 to 2,00	0,45 to 0,60	—	0,05 to 0,30	Bal- ance	2	860	7,0	930	< 1	140	0,27	12	1 000	1 390	330	—	380	35 HRC
FL-05N2M-970H ^{d,g}	0,4 to 0,7	1,75 to 2,00	0,45 to 0,60	—	0,05 to 0,30	Bal- ance	2	970	7,2	1 070	< 1	155	0,28	16	1 170	1 590	370	—	420	39 HRC
FL-05Cr3M-830SH ^{e,h}	0,4 to 0,6	—	0,40 to 0,60	2,7 to 3,3	0,05 to 0,30	Bal- ance	2	830	6,8	900	< 1	130	0,27	12	930	1 520	230	—	340	30 HRC
FL-05Cr3M-930SH ^{e,h}	0,4 to 0,6	—	0,40 to 0,60	2,7 to 3,3	0,05 to 0,30	Bal- ance	2	930	7,0	1 000	< 1	140	0,27	14	1 030	1 830	280	—	380	35 HRC
FL-05Cr3M-1030SH ^{e,h}	0,4 to 0,6	—	0,40 to 0,60	2,7 to 3,3	0,05 to 0,30	Bal- ance	2	1 030	7,2	1 100	< 1	155	0,28	16	1 170	2 140	340	—	430	40 HRC

Table 13 (continued)

Grade ^a	Normative values							Informative values											
	Chemical composition						Ultimate tensile strength min.	Density	Tensile strength ^f	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % survival	Bending fatigue limit 90 % survival	Apparent hardness	
	C combined	Ni	Mo	Cr	Mn	Fe												Total other elements max.	R _m MPa
%	%	%	%	%	%	%	%	R _m MPa	g/cm ³	MPa	%	GPa	J	(0,1 %) MPa	MPa	MPa	MPa	HV10	Rockwell
As-heat-treated tensile properties were derived from machined test bars according to ISO 2740.																			
^a These materials are produced from pre-alloyed powders with the addition of elemental graphite.																			
^b Pre-alloy base powder with a nominal composition 0,45 % Ni, 0,7 % Mo, 0,35 % Mn, balance Fe.																			
^c Pre-alloy base powder with a nominal composition 0,85 % Mo, 0,2 % Mn, balance Fe.																			
^d Pre-alloy base powder with a nominal composition 1,8 % Ni, 0,5 % Mo, 0,2 % Mn, balance Fe.																			
^e Pre-alloy base powder with a nominal composition 3,0 % Cr, 0,5 % Mo, 0,2 % Mn, balance Fe.																			
^f Tensile yield strength and ultimate tensile strength are approximately the same for heat-treated materials.																			
^g Austenitized for 30 min at 850 °C in a protective atmosphere with a 0,5 % carbon potential, oil-quenched and tempered for 1 h at 180 °C.																			
^h SH are materials produced by the Sinter Hardening Process; -FL-05Cr3M- is tempered at 180 °C.																			
ⁱ Machined test pieces according to ISO 3928.																			
^j As-sintered test pieces (sintered surfaces) according to ISO 3928.																			

Table 14 — Ferrous materials for structural parts: hybrid-alloy steels — As-sintered

Grade ^a	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 (0,1 %) MPa	Transverse rupture strength	Rotating fatigue limit 90 % survival MPa	Bending fatigue limit 90 % survival MPa	Axial fatigue limit 90 % survival MPa	Apparent hardness	
	C combined	Ni	Mo	Mn	Cu	Fe	Total other elements max.														R _{p0.2} MPa	R _m MPa
	%	%	%	%	%	%	%	R _{p0.2} MPa	g/cm ³	MPa	MPa	%	GPa				MPa	MPa	MPa			
FLA-05M1-N2C-430 ^b	0,4 to 0,7	1,55 to 1,95	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	Balance	2	430	6,8	550	465	1	130	0,27	12	395	1 100	—	—	160	185	82 HRB
FLA-05M1-N2C-465 ^b	0,4 to 0,7	1,55 to 1,95	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	Balance	2	465	7,0	670	500	2	140	0,27	18	430	1 290	—	—	190	200	86 HRB
FLA-05M1-N2C-495 ^b	0,4 to 0,7	1,55 to 1,95	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	Balance	2	495	7,2	780	535	3	155	0,28	28	470	1 470	—	—	230	220	90 HRB
FLA-05M1-N4C-500 ^b	0,4 to 0,7	3,6 to 4,4	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	Balance	2	500	6,8	640	555	<1	130	0,27	17	450	1 270	—	—	170	200	86 HRB
FLA-05M1-N4C-535 ^b	0,4 to 0,7	3,6 to 4,4	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	Balance	2	535	7,0	740	580	<1	140	0,27	26	485	1 500	—	—	220	225	91 HRB
FLA-05M1-N4C-570 ^b	0,4 to 0,7	3,6 to 4,4	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	Balance	2	570	7,2	840	600	1	155	0,28	43	520	1 720	—	—	265	250	96 HRB
FLA-05M1N-N1-310 ^c	0,4 to 0,7	1,35 to 2,50	0,50 to 0,85	0,20 to 0,40	—	Balance	2	310	6,8	460	360	1	130	0,27	11	340	860	190	—	—	150	83 HRB
FLA-05M1N-N1-335 ^c	0,4 to 0,7	1,35 to 2,50	0,50 to 0,85	0,20 to 0,40	—	Balance	2	335	7,0	490	390	1,5	140	0,27	17	380	1 000	215	—	—	160	88 HRB
FLA-05M1N-N1-360 ^c	0,4 to 0,7	1,35 to 2,50	0,50 to 0,85	0,20 to 0,40	—	Balance	2	360	7,2	560	420	2	155	0,28	25	400	1 140	250	—	—	175	95 HRB
FLA-05M1-N ₂ -340 ^d	0,4 to 0,7	1,0 to 3,0	0,65 to 0,95	0,05 to 0,30	—	Balance	2	340	6,8	450	400	1	130	0,27	9	380	1 070	170	—	—	175	80 HRB
FLA-05M1-N ₂ -370 ^d	0,4 to 0,7	1,0 to 3,0	0,65 to 0,95	0,05 to 0,30	—	Balance	2	370	7,0	530	430	1,5	140	0,27	15	420	1 260	210	—	—	190	84 HRB

Table 14 (continued)

Grade ^a	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 (0,1 %) MPa	Transverse rupture strength	Rotating fatigue limit 90 % survival ^b MPa	Bending fatigue limit 90 % survival ^b MPa	Axial fatigue limit 90 % survival ^b MPa	Apparent hardness		
	C combined	Ni	Mo	Mn	Cu	Fe														Total other elements max.	R _{p0.2} MPa	ρ g/cm ³
	%	%	%	%	%	%																
FLA-05M1-N ₂ -400 ^d	0,4 to 0,7	1,0 to 3,0	0,65 to 0,95	0,05 to 0,30	—	Bal-ance	2	400	7,2	620	460	2	155	0,28	24	460	1 435	255	—	—	210	87 HRB
FLA-05M1-N4-480 ^d	0,4 to 0,7	3,0 to 5,0	0,65 to 0,95	0,05 to 0,30	—	Bal-ance	2	480	6,8	570	530	< 1	130	0,27	11	380	970	190	—	—	185	83 HRB
FLA-05M1-N4-570 ^d	0,4 to 0,7	3,0 to 5,0	0,65 to 0,95	0,05 to 0,30	—	Bal-ance	2	570	7,0	680	630	< 1	140	0,27	15	410	1 240	215	—	—	210	86 HRB
FLA-05M1-N4-660 ^d	0,4 to 0,7	3,0 to 5,0	0,65 to 0,95	0,05 to 0,30	—	Bal-ance	2	660	7,2	790	780	< 1	155	0,28	27	440	1 510	245	—	—	245	90 HRB
FLD-08M2-N ₂ -500 ^e	0,6 to 0,9	1,8 to 2,2	1,30 to 1,70	0,05 to 0,30	—	Bal-ance	2	500	6,8	590	560	< 1	130	0,27	10	420	1 150	200	200	—	260	92 HRB
FLD-08M2-N ₂ -570 ^e	0,6 to 0,9	1,8 to 2,2	1,30 to 1,70	0,05 to 0,30	—	Bal-ance	2	570	7,0	700	630	< 1	140	0,27	14	480	1 380	230	220	—	280	95 HRB
FLD-08M2-N ₂ -640 ^e	0,6 tp 0,9	1,8 to 2,2	1,30 to 1,70	0,05 to 0,30	—	Bal-ance	2	640	7,2	830	710	1	155	0,28	21	540	1 650	260	240	—	340	99 HRB
FLD-05M2-N4C-360 ^e	0,3 to 0,6	3,6 to 4,4	1,30 to 1,70	0,05 to 0,30	1,6 to 2,4	Bal-ance	2	360	6,8	620	415	1	130	0,27	14	360	1 160	—	—	—	210	86 HRB
FLD-05M2-N4C-430 ^e	0,3 to 0,6	3,6 to 4,4	1,30 to 1,70	0,05 to 0,30	1,6 to 2,4	Bal-ance	2	430	7,0	755	480	1	140	0,27	17	420	1 420	—	—	—	250	91 HRB
FLD-05M2-N4C-500 ^e	0,3 to 0,6	3,6 to 4,4	1,30 to 1,70	0,05 to 0,30	1,6 to 2,4	Bal-ance	2	500	7,2	890	545	1,5	155	0,28	30	470	1 680	—	—	—	320	97 HRB

Table 14 (continued)

Grade ^a	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 ^b	Bending fatigue limit 90 % survival ^c	Axial fatigue limit 90 % survival ^d	Apparent hardness	
	C combined	Ni	Mo	Mn	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	MPa		
	%	%	%	%	%	%	%	$R_{p0,2}$ MPa												HV5	Rockwell

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

^a These materials are produced from pre-alloyed powders plus addition of diffusion-alloyed elemental metal powders and graphite.

^b Pre-alloy base powder with a nominal composition 0,5 % Mo, 0,2 % Mn, balance Fe.

^c Pre-alloy base powder with a nominal composition 0,7 % Mo, 0,45 % Ni, 0,35 % Mn, balance Fe.

^d Pre-alloy base powder with a nominal composition 0,85 % Mo, 0,2 % Mn, balance Fe.

^e Pre-alloy base powder with a composition 1,5 % Mo, 0,2 % Mn, balance Fe.

^f Machined test pieces according to ISO 3928.

^g As-sintered test pieces (sintered surfaces) according to ISO 3928.

^h Machined test pieces according to ISO 3928.

Table 15 — Ferrous materials for structural parts: hybrid-alloy steels — Heat-treated

Grade ^a	Normative values							Informative values															
	Chemical composition							Ultimate tensile strength min.	Density	Tensile strength ^b	R _m MPa	Tensile yield strength	R _{p0.2} MPa	A ₂₅ %	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % sur-vival ^k	Bending fatigue limit 90 % sur-vival ^k	Axial fatigue limit 90 % sur-vival ^m	Apparent hardness
	C combined	Ni	Mo	Mn	Cu	Cr	Fe																
	%	%	%	%	%	%	%	%	g/cm ³	MPa	MPa	MPa	%	GPa		J	(0,1 %) MPa	MPa	MPa	MPa	MPa	Rockwell HV10	
FLA-05M1-N2C-830H ^{bi}	0,4 to 0,7	1,55 to 1,95	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	—	Bal- ance	2	830	900	—	<1	130	0,27	9	800	1 430	—	—	220	315	27 HRC	
FLA-05M1-N2C-1060H ^{bi}	0,4 to 0,7	1,55 to 1,95	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	—	Bal- ance	2	1 060	1 140	—	<1	140	0,27	15	980	1 800	—	—	300	350	32 HRC	
FLA-05M1-N2C-1280H ^{bi}	0,4 to 0,7	1,55 to 1,95	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	—	Bal- ance	2	1 280	1 410	—	<1	155	0,28	21	1 170	2 200	—	—	380	390	36 HRC	
FLA-05M1-N4C-860H ^{bi}	0,4 to 0,7	3,6 to 4,4	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	—	Bal- ance	2	860	930	800	<1	130	0,27	13	740	1 400	—	—	245	290	23 HRC	
FLA-05M1-N4C-1050H ^{bi}	0,4 to 0,7	3,6 to 4,4	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	—	Bal- ance	2	1 050	1 130	950	<1	140	0,27	18	880	1 735	—	—	310	315	27 HRC	
FLA-05M1-N4C-1260H ^{bi}	0,4 to 0,7	3,6 to 4,4	0,4 to 0,6	0,05 to 0,30	1,3 to 1,7	—	Bal- ance	2	1 260	1 360	1 080	<1	155	0,28	28	1 010	2 060	—	—	380	350	32 HRC	
FLA-05M1-N1-720H ^{ch}	0,4 to 0,7	1,35 to 2,50	0,50 to 0,85	0,20 to 0,40	—	—	Bal- ance	2	720	790	—	<1	130	0,27	9	1 000	1 170	260	—	—	340	30 HRC	
FLA-05M1-N1-920H ^{ch}	0,4 to 0,7	1,35 to 2,50	0,50 to 0,85	0,20 to 0,40	—	—	Bal- ance	2	920	980	—	<1	140	0,27	11	1 140	1 500	310	—	—	380	35 HRC	
FLA-05M1-N1-1110H ^{ch}	0,4 to 0,7	1,35 to 2,50	0,50 to 0,85	0,20 to 0,40	—	—	Bal- ance	2	1 110	1 180	—	1	155	0,28	16	1 280	1 830	360	—	—	430	40 HRC	
FLA-05M1-N ₂ -830H ^{dh}	0,4 to 0,7	1,0 to 3,0	0,65 to 0,95	0,05 to 0,30	—	—	Bal- ance	2	830	900	—	<1	130	0,27	8	860	1 450	280	—	—	350	32 HRC	
FLA-05M1-N ₂ -1040H ^{dh}	0,4 to 0,7	1,0 to 3,0	0,65 to 0,95	0,05 to 0,30	—	—	Bal- ance	2	1 040	1 120	—	<1	140	0,27	13	1 050	1 740	330	—	—	400	37 HRC	
FLA-05M1-N ₂ -1230H ^{dh}	0,4 to 0,7	1,0 to 3,0	0,65 to 0,95	0,05 to 0,30	—	—	Bal- ance	2	1 230	1 340	—	<1	155	0,28	16	1 240	2 040	380	—	—	450	42 HRC	

Table 15 (continued)

Grade ^a	Normative values							Informative values														
	Chemical composition							Density	Tensile strength ^b	Tensile yield strength ^c	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % sur-vial ^k	Bending fatigue limit 90 % sur-vial ^l	Axial fatigue limit 90 % sur-vial ^m	Apparent hardness		
C com-bined	Ni	Mo	Mn	Cu	Cr	Fe	Total other elements max.													R _m MPa	ρ g/cm ³	R _m MPa
FLA-05M1-N4-830H ^{dh}	%	%	0,05 to 0,30	%	%	%	%	830	6,8	900	—	<1	130	0,27	11	720	1 260	260	—	—	300	25 HRC
FLA-05M1-N4-1070H ^{dh}	%	%	0,05 to 0,30	%	%	%	%	1 070	7,0	1 140	—	<1	140	0,27	15	890	1 620	320	—	—	340	30 HRC
FLA-05M1-N4-1260H ^{dh}	%	%	0,05 to 0,30	%	%	%	%	1 260	7,2	1 370	—	<1	155	0,28	21	1 060	1 980	390	—	—	390	36 HRC
FLA-08M1-N2C-590SH ^{dj}	%	%	0,05 to 0,30	1,0 to 3,0	—	—	2	590	6,8	660	—	<1	130	0,27	9	590	1 310	180	—	—	280	21 HRC
FLA-08M1-N2C-720SH ^{dj}	%	%	0,05 to 0,30	1,0 to 3,0	—	—	2	720	7,0	790	—	<1	140	0,27	16	660	1 520	230	—	—	300	25 HRC
FLA-08M1-N2C-900SH ^{dj}	%	%	0,05 to 0,30	1,0 to 3,0	—	—	2	900	7,2	970	—	1	155	0,28	22	720	1 720	290	—	—	340	30 HRC
FLA-08N2M-C2-480SH ^{ej}	%	%	0,05 to 0,30	1,0 to 3,0	—	—	2	480	6,8	550	—	<1	130	0,27	9	—	1 030	160	—	—	305	26 HRC
FLA-08N2M-C2-620SH ^{ej}	%	%	0,05 to 0,30	1,0 to 3,0	—	—	2	620	7,0	690	—	<1	140	0,27	12	—	1 310	230	—	—	345	31 HRC
FLA-08N2M-C2-760SH ^{ej}	%	%	0,05 to 0,30	1,0 to 3,0	—	—	2	760	7,2	830	—	<1	155	0,28	19	—	1 590	290	—	—	400	37 HRC
FLA-06N1M-C1-690SH ^{fi}	%	%	0,3 to 0,5	0,75 to 1,35	—	—	2	690	6,8	760	—	<1	130	0,27	9	900	1 380	—	190	—	330	29 HRC
FLA-06N1M-C1-970SH ^{fi}	%	%	0,3 to 0,5	0,75 to 1,35	—	—	2	970	7,0	1 030	—	<1	140	0,27	14	1 100	1 650	—	245	—	370	34 HRC
FLA-06N1M-C1-1210SH ^{fi}	%	%	0,3 to 0,5	0,75 to 1,35	—	—	2	1 210	7,2	1 280	—	<1	155	0,28	20	1 280	1 970	—	320	—	410	39 HRC

Table 15 (continued)

Grade ^a	Normative values							Informative values														
	Chemical composition							Ultimate tensile strength min.	Density	Tensile strength ^b	Tensile yield strength	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % sur-vial ^k	Bending fatigue limit 90 % sur-vial ^k	Axial fatigue limit 90 % sur-vial ^m	Apparent hardness	
C.combined	Ni	Mo	Mn	Cu	Cr	Fe	Total other elements max.														R _m MPa	ρ g/cm ³
FLA-08N1M-C2-590SH ^{fi}	1,2 to 1,6	1,1 to 1,4	0,3 to 0,5	1,0 to 3,0	—	Balance	2	590	6,8	620	—	<1	130	0,27	15	790	1 240	—	—	200	340	30 HRC
FLA-08N1M-C2-760SH ^{fi}	1,2 to 1,6	1,1 to 1,4	0,3 to 0,5	1,0 to 3,0	—	Balance	2	760	7,0	830	—	<1	140	0,27	19	930	1 590	—	—	250	380	35 HRC
FLA-08N1M-C2-1000SH ^{fi}	1,2 to 1,6	1,1 to 1,4	0,3 to 0,5	1,0 to 3,0	—	Balance	2	1 000	7,2	1 070	—	<1	155	0,28	23	1 100	1 860	—	—	295	430	40 HRC
FLA-07Cr2M-C2-660SH ^g	—	0,15 to 0,30	0,05 to 0,30	1,6 to 2,4	1,3 to 1,7	Balance	2	660	6,8	720	620	<1	130	0,27	12	760	1 590	260	—	—	310	27 HRC
FLA-07Cr2M-C2-760SH ^g	—	0,15 to 0,30	0,05 to 0,30	1,6 to 2,4	1,3 to 1,7	Balance	2	760	7,0	830	690	<1	140	0,27	15	830	1 760	320	—	—	340	30 HRC
FLA-07Cr2M-C2-830SH ^g	—	0,15 to 0,30	0,05 to 0,30	1,6 to 2,4	1,3 to 1,7	Balance	2	830	7,2	900	760	<1	155	0,28	18	900	1 930	380	—	—	360	33 HRC

Table 15 (continued)

Grade ^a	Normative values							Informative values													
	Chemical composition							Ultimate tensile strength min.	Density	Tensile strength ⁿ	Tensile yield strength	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength	Transverse rupture strength	Rotating fatigue limit 90 % sur-vial ^k	Bending fatigue limit 90 % sur-vial ^l	Axial fatigue limit 90 % sur-vial ^m	Apparent hardness
C com-bined	Ni	Mo	Mn	Cu	Cr	Fe	Total other elements max.														R _m MPa
%	%	%	%	%	%	%	%														
As-heat-treated tensile properties were derived from machined test bars according to ISO 2740.																					
^a These materials are produced from pre-alloyed powders with the addition of elemental metal powders and graphite.																					
^b Pre-alloy base powder with a nominal composition 0,5 % Mo, 0,2 % Mn, balance Fe.																					
^c Pre-alloy base powder with a nominal composition 0,45 % Ni, 0,7 % Mo, 0,35 % Mn, balance Fe.																					
^d Pre-alloy base powder with a nominal composition 0,85 % Mo, 0,2 % Mn, balance Fe.																					
^e Pre-alloy base powder with a nominal composition 1,8 % Ni, 0,5 % Mo, 0,2 % Mn, balance Fe.																					
^f Pre-alloy base powder with a nominal composition 1,4 % Ni, 1,25 % Mo, 0,4 % Mn, balance Fe.																					
^g Pre-alloy base powder with a nominal composition 1,5 % Cr, 0,25 % Mo, 0,2 % Mn, balance Fe.																					
^h Austenitized for 30 min at 850 °C in a protective atmosphere with a 0,5 % carbon potential, oil-quenched and tempered for 1 h at 180 °C.																					
ⁱ Austenitized for 30 min at 850 °C in a protective atmosphere with a 0,5 % carbon potential, oil-quenched and tempered for 1 h at 205 °C.																					
^j SH are materials produced by the Sinter Hardening Process; material name -FLA-08M1-N2C2 and -FLA-08N2M-C2 are tempered at 180 °C. -FLA-06N1M-C and -FLA-08N1M-C2 are tempered at 205 °C.																					
^k Machined test pieces according to ISO 3928.																					
^l As-sintered test pieces (sintered surfaces) according to ISO 3928.																					
^m Machined test pieces according to ISO 3928. Tempered for 1 h at 205 °C.																					
Tensile yield strength and ultimate tensile strength are approximately the same for heat-treated materials.																					

Table 16 — Ferrous materials for structural parts: copper-infiltrated steels

Grade	Normative values					Informative values													
	Chemical composition			Total other elements max.	Tensile yield strength min.	Ultimate tensile strength min.	Density	Tensile strength		Tensile yield strength	Elongation	Young's modulus	Poisson's ratio	Unnotched Charpy impact	Compressive yield strength (0,1 %) MPa	Transverse rupture strength	Rotating fatigue limit 90 % sur- vival ^d	HV	Rockwell
	C combine- d ^a	Cu	Fe																
	%	%	%	%	R _{p0.2} MPa	R _m MPa	ρ g/ cm ³	R _m MPa	R _{p0.2} MPa	A ₂₅ %	GPa	J	(0,1 %) MPa	MPa	MPa	MPa			
FX-08C10-340	0,6 to 0,9	8 to 15	Balance	2	340	—	7,3	600	410	3	160	0,28	14	490	1 140	230	210/5	89 HRB	
FX-08C20-410	0,6 to 0,9	15 to 25	Balance	2	410	—	7,3	550	480	1	145	0,24	9	480	1 080	160	210/5	90 HRB	
FX-08C10-760H ^c	0,6 to 0,9	8 to 15	Balance	2	—	760	7,3	830	b	< 1	160	0,28	9	790	1 300	280	460/10	43 HRC	
FX-08C20-620H ^c	0,6 to 0,9	15 to 25	Balance	2	—	620	7,3	690	b	< 1	145	0,24	7	510	1 100	190	390/10	36 HRC	

^a Properties were derived from machined test bars according to ISO 2740.

^b All data are based on single-pass infiltration.

^c On the basis of iron phase only.

^d Tensile yield strength and ultimate tensile strength are approximately equal for heat-treated materials.

^e 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.

^f Machined test pieces according to ISO 3928.

Table 17 — Ferrous materials for structural parts: austenitic, ferritic and martensitic steels

Type	Grade	Normative values										Informative values													
		Chemical composition										Tensile yield strength min	Ultimate tensile 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	Apparent hardness	
		C combined	Cr	Ni	Mo	S	N	Fe	Total other elements max.	R _{p0.2} MPa	R _m MPa													ρ g/cm ³	R _m MPa
Austenitic	303	FL-303–170N ^a	< 0,15	17 to 19	8 to 13	—	0,15 to 0,30	0,2 to 0,6	Bal-ance	2	170	—	6,4	270	220	< 1	105	0,25	5	260	590	90	120/5	62 HRB	
	303	FL-303–260N ^b	< 0,15	17 to 19	8 to 13	—	0,15 to 0,30	0,2 to 0,6	Bal-ance	2	260	—	6,9	470	310	10	140	0,27	47	320	n.m	145	180/5	70 HRB	
	304	FL-304–210N ^a	< 0,08	18 to 20	8 to 12	—	—	0,2 to 0,6	Bal-ance	2	210	—	6,4	300	260	< 1	105	0,25	5	260	770	105	125/5	61 HRB	
	304	FL-304–260N ^b	< 0,08	18 to 20	8 to 12	—	—	0,2 to 0,6	Bal-ance	2	260	—	6,9	480	310	8	140	0,27	34	320	n.m	160	140/5	68 HRB	
Austenitic	316	FL-316–170N ^a	< 0,08	16 to 18	10 to 14	2 to 3	—	0,2 to 0,6	Bal-ance	2	170	—	6,4	280	230	< 1	105	0,25	7	250	740	75	115/5	59 HRB	
	316	FL-316–260N ^b	< 0,08	16 to 18	10 to 14	2 to 3	—	0,2 to 0,6	Bal-ance	2	260	—	6,9	480	310	13	140	0,27	65	320	n.m	130	125/5	65 HRB	
	316L	FL-316–150 ^c	< 0,03	16 to 18	10 to 14	2 to 3	—	< 0,03	Bal-ance	2	150	—	6,9	390	210	21	140	0,27	88	220	n.m	115	75/5	45 HRB	
Ferritic	410L	FL-410–140 ^f	< 0,03	11,5 to 13,5	—	—	< 0,03	< 0,03	Bal-ance	2	140	—	6,9	330	180	16	165	0,27	68	190	n.m	125	80/5	45 HRB	
	430L	FL-430–170 ^f	< 0,03	16 to 18	—	—	< 0,03	< 0,03	Bal-ance	2	170	—	7,1	340	210	20	170	0,27	108	230	n.m	170	80/5	45 HRB	
	434L	FL-434–170 ^f	< 0,03	16 to 18	—	0,75 to 1,25	< 0,03	< 0,03	Bal-ance	2	170	—	7,0	340	210	15	165	0,27	88	230	n.m	150	95/5	50 HRB	
Martensitic	410	FL-410–620H ^d	0,10 to 0,25	11,5 to 13,5	—	< 0,03	0,2 to 0,6	Bal-ance	2	—	620	6,5	720	e	< 1	125	0,25	3	640	780	240	300/10	23 HRC		

Table 17 (continued)

Type	Grade	Normative values									Informative values												
		Chemical composition									Tensile yield strength min MPa	Ultimate tensile strength min MPa	Density g/cm ³	Tensile strength R _m MPa	Tensile yield strength R _{p0.2} MPa	Elongation A ₂₅ %	Young's modulus GPa	Poisson's ratio	Unnotched Charpy impact J	Compressive yield strength (0.1 %) MPa	Transverse rupture strength MPa	Rotating fatigue limit 90 % sur- vivals MPa	Apparent hardness
		C com- bined	Cr	Ni	Mo	S	N	Fe	Total other ele- ments max.														
		%	%	%	%	%	%	%	%	R _{p0.2} MPa	R _m MPa	ρ	R _m MPa	R _{p0.2} MPa	A ₂₅ %	GPa		J	(0.1 %) MPa	MPa	MPa	HV	Rockwell

n.m = not measurable.

The corrosion properties of sintered stainless steel are not necessarily the same as those of wrought stainless steels. In general, the austenitic materials can be ranked as type 316L being the best, followed by 304 and then 303. These materials as a group are all better than any of the martensitic or ferritic materials. Type 434 has the best corrosion properties of the latter group.

Sintering may also affect corrosion resistance, so that grade -FL 316-150 may be more resistant than the grades sintered in nitrogen-containing atmospheres.

Before using any sintered stainless steel, a corrosion test under expected environmental conditions is recommended.

NOTES: Property data were obtained under the following conditions:

^a Grades -FL-303-170N, -FL-304-210N and -FL-316-170N sintered in a nitrogen-containing atmosphere, e.g. dissociated ammonia at 1 150 °C.

^b Grades -FL-303-260N, -FL-304-260N and -FL-316-260N sintered in a nitrogen-containing atmosphere, e.g. dissociated ammonia at 1 290 °C.

^c Grade -FL-316-150 sintered in a nitrogen-free atmosphere, e.g. hydrogen or vacuum backfilled with argon at 1 290 °C.

^d Grade FL-410-620H sintered in a nitrogen-containing atmosphere, e.g. dissociated ammonia at 1 150 °C, hardened by rapid cooling, and tempered at 180 °C for 1 h.

^e Tensile yield strength and ultimate tensile strength are approximately the same for heat-treated materials.

^f Grades -FL-410-140, -FL-430-170 and -FL-434-170 sintered in a nitrogen-free atmosphere, e.g. hydrogen or vacuum backfilled with argon at 1 290 °C

^g Machined test pieces according to ISO 3928.

Table 18 — Non-ferrous materials for structural parts: copper-based alloys

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	Apparent hardness	
	Sn	Zn	Ni	Cu	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	HV5	Rockwell
Brass	—	Balance	—	77 to 80	2	75	7,6	160	90	9	85	0,31	37	80	360	50	73 HRH
	—	Balance	—	77 to 80	2	80	8,0	240	120	18	100	0,31	61	100	480	68	82 HRH
	—	Balance	—	68 to 72	2	100	7,6	190	110	14	80	0,31	31	120	430	72	84 HRH
	—	Balance	—	68 to 72	2	110	8,0	230	130	17	90	0,31	52	130	590	84	92 HRH
Bronze	8,5 to 11,0	—	—	Balance	2	90	7,2	150	110	4	60	0,31	5	140	310	68	82 HRH
Nickel silver	—	Balance	16 to 20	62 to 66	2	120	7,9	230	140	11	95	0,31	33	170	500	82	90 HRH

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

The letter R indicates that the material has been re-pressed.

Annex A (normative)

Designation system

A.1 Designation of materials

The designation system to be used for sintered materials specified in this document is in accordance with ISO/IEC Directives, Part 2:2021. The objective is that the designation shall give an indication of the chemical composition of the sintered material and an indication of the way the raw material has been prepared.

A.2 Description block

The description block shall contain the letter P, denoting powder metallurgical materials.

A.3 Identity block

The identity block shall contain the number of this document, i.e. ISO 5755, followed by the individual item block.

A.4 Individual item block

A.4.1 First group

The first group of the individual item block shall consist of one to three letters describing the base metal and ways of adding alloying elements:

- F = Plain iron powder or iron powder with admixed alloying additives;
- FD = Iron powder with diffusion-alloyed additives;
- FL = Pre-alloyed steel powder;
- FLA = Pre-alloyed steel powder with admixed alloying additives (hybrid-alloy steels);
- FLD = Pre-alloyed steel powder with diffusion-alloyed additives (hybrid-alloy steels);
- FX = Copper-infiltrated steel;
- C = Copper powder with admixed alloying additives;
- CL = Pre-alloyed copper-based powder.

A.4.2 Second group

The second group of the individual item block shall consist of two to six alphanumeric characters with two digits for the content of dissolved (combined) carbon without a decimal comma (except for copper-based materials and stainless steels, see examples under [A.6](#)), e.g. 03 = 0,3 % C. The third position in this group will be the capital letter assigned to the alloying element with the highest content (if any) followed by the nominal content given as integers, e.g. 1 = 0,5 % to 1,4 %, 2 = 1,5 % to 2,4 %, 10 = 10 % of the element in question. Finally, this group ends with the capital letter assigned to the alloying element with the second highest content (if any) but without any indication of the content.

A.4.3 Third group

A.4.3.1 General

The third group of the individual item block shall show the value of the minimum yield strength (or minimum tensile strength for heat-treated materials) listed as MPa, followed, if appropriate, by the letter H indicating heat-treated material, or letters SH for sinter-hardened material.

The individual item block shall start with a hyphen and the groups within the block shall be separated by a hyphen.

A.4.3.2 Special case for hybrid-alloy steels

For these materials, where the pre-alloying is explained in the second group of the individual item block, an extra group shall be included after the second group showing the alloying elements that have been added by admixing (FLA-) or diffusion-alloying (FLD-). First, the capital letter for the added element with the highest content followed by the content given with an integer and then the second added element (if any) without any indication of the content. In this case, the third group mentioned under this subclause becomes the fourth group.

A.5 Letters assigned to alloying elements

Letters assigned to alloying elements shall be as follows:

- C = Copper;
- Cr = Chromium;
- G = Graphite;
- M = Molybdenum;
- N = Nickel;
- P = Phosphorus;
- T = Tin;
- Z = Zinc.

A.6 Examples of the designation system

The description block (see [A.2](#)) and the identity block (see [A.3](#)) are not used in the tables of material specifications in this document. They should be used on purchase and technical documentation where any possibility of ambiguity exists.

EXAMPLE 1 **C-T10-K110** is a copper-based alloy with 10 % added tin, and a radial crushing strength, *K*, of 110 MPa.

EXAMPLE 2 **F-08C2-620H** is an iron-based material with 0,8 % carbon, 2 % copper and a minimum tensile strength of 620 MPa in the heat-treated condition.

EXAMPLE 3 **FD-05N4C-420** is an iron-based alloy with 0,5 % carbon and diffusion-alloyed additions of nickel (4 %) and copper having a minimum yield strength of 420 MPa.

EXAMPLE 4 **FL-05N2M-860H** is a pre-alloyed nickel (2 %) and molybdenum steel with 0,5 % carbon and a minimum tensile strength of 860 MPa in the heat-treated condition.

EXAMPLE 5 **FX-08C20-410** is a copper-infiltrated iron-based material with 0,8 % carbon and a minimum yield strength of 410 MPa.

EXAMPLE 6 **FL-304-260N** is a type 304 stainless steel, sintered in a nitrogen-containing atmosphere and having a minimum yield strength of 260 MPa. (Further information on the designation of stainless steels can be found in [Table 16](#).)

EXAMPLE 7 **FLA-05M1N-N1-360** is a hybrid-alloy steel based on pre-alloyed molybdenum (1 %) and nickel steel to which elemental nickel (1 %) has been added. It has 0,5 % carbon and a minimum yield strength of 360 MPa.

EXAMPLE 8 **FLD-05M2-N4C-500** is a hybrid-alloy steel based on pre-alloyed molybdenum (1,5 %) to which nickel (4 %) and copper have been diffusion alloyed. It has 0,5 % carbon and a minimum yield strength of 500 MPa.

The description block (see [A.2](#)) and the identity block (see [A.3](#)) are not used in the tables of material specifications in this document. They should be used on purchase and technical documentation where any possibility of ambiguity exists. Hence, **P-ISO 5755-FL-05Cr3M-670** is an example of a purchase order entry showing the International Standard number block in conjunction with the individual item block.

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Annex B
(informative)

Microstructures

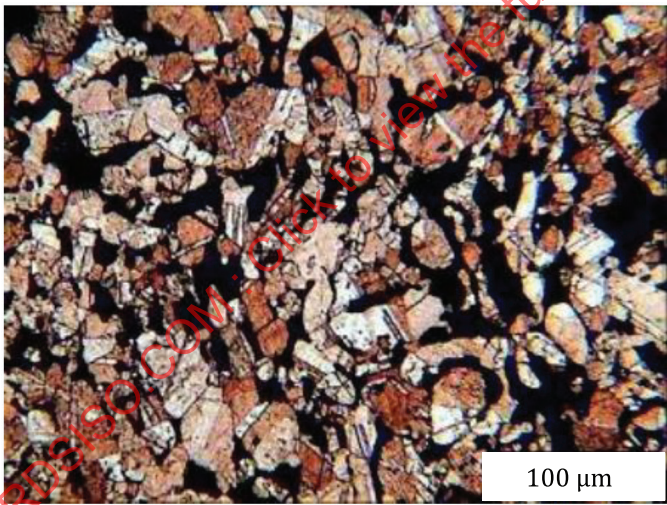
B.1 General

For the preparation of samples for metallographic examination, reference should be made to ISO/TR 14321.

In the micrographs given in this annex, there are examples of typical microstructures of sintered materials, but all are not exact compositions of materials of this document.

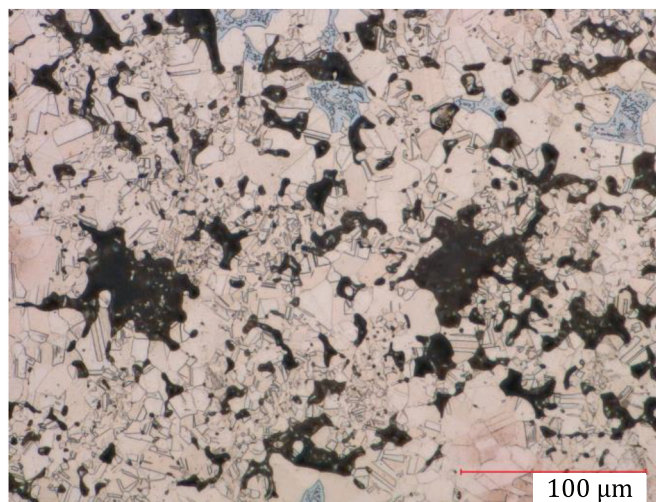
B.2 Bronze and bronze with graphite materials for bearings — [Table 1](#)

In 90-10 copper-tin bronze bearings, the structure should be ideally alpha bronze with no grey copper-tin compounds and with a minimum of reddish copper-rich areas (see [Figure B.1](#)). In any case, grey copper-tin compounds are often present in microstructure (see [Figure B.2](#)).



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B2-1	Cu-10 %Sn	Atomized Cu-10 %Sn	750 °C, 30 min.	Alcoholic FeCl ₃

Figure B.1 — Microstructure B2-1



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B2-2	Cu-10 %Sn	Mixture of electrolytic Cu and atomized Sn	780 °C, 20 min.	Alcoholic FeCl ₃

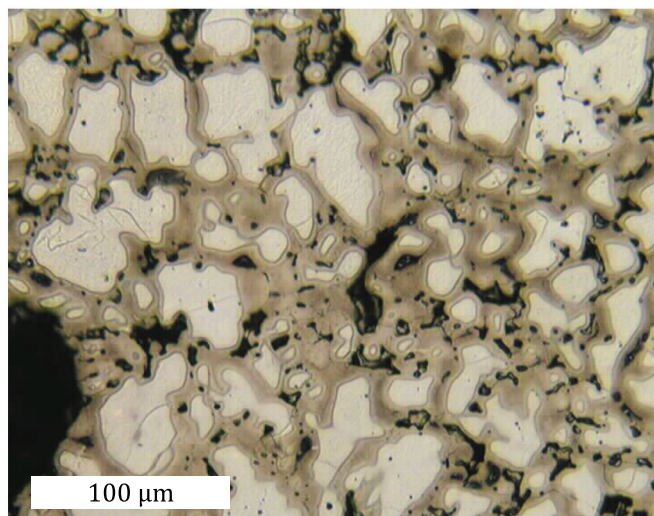
Figure B.2 — Microstructure B2-2

B.3 Iron, iron-copper, iron-bronze, iron-carbon-graphite materials for bearings

In iron-copper bearings, microstructure is ferritic, and the copper should have melted and flowed into the surrounding pores (see [Figure B.3](#)). With copper contents > 2 % some free copper may be visible, but with 2 % or less copper, free copper is generally not present. Free copper is also present in the microstructure of bearings sintered below the copper melting temperature (see [Figure B.4](#)). Bearings should show a minimum of original particle boundaries.

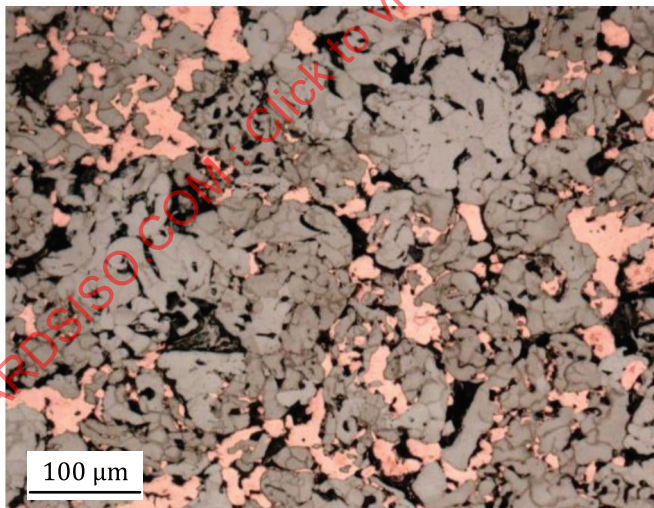
The microstructure of iron-bronze combines the appearances of iron and bronze structures.

Iron-graphite material should exhibit either free graphite in its microstructure or a free graphite/combined carbon mixture depending on the manufacturing process (see [Figure B.5](#)).



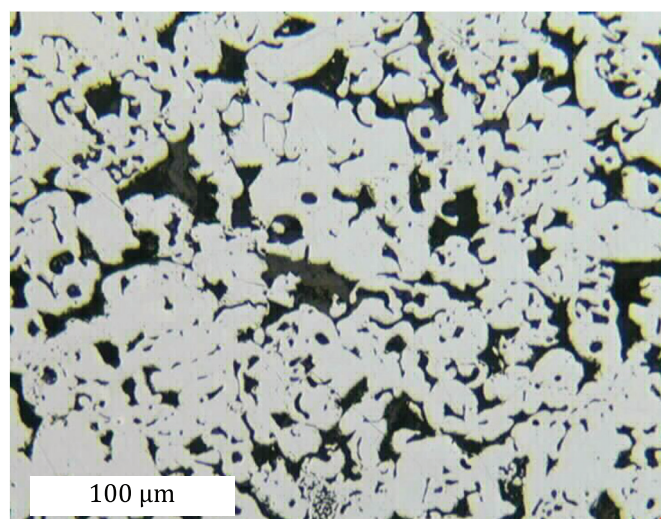
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B3-1	Fe-2 %Cu	Mixture of sponge Fe powder and diffusion Fe-Cu powder	1 120 °C, 30 min	Nital 1 %

Figure B.3 — Microstructure B3-1



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B3-2	Fe-22 %Cu-0,5 %C	Mixture of sponge Fe powder and atomized Cu powder under 150 μm	1 000 °C, 30 min	Nital 1 %

Figure B.4 — Microstructure B3-2

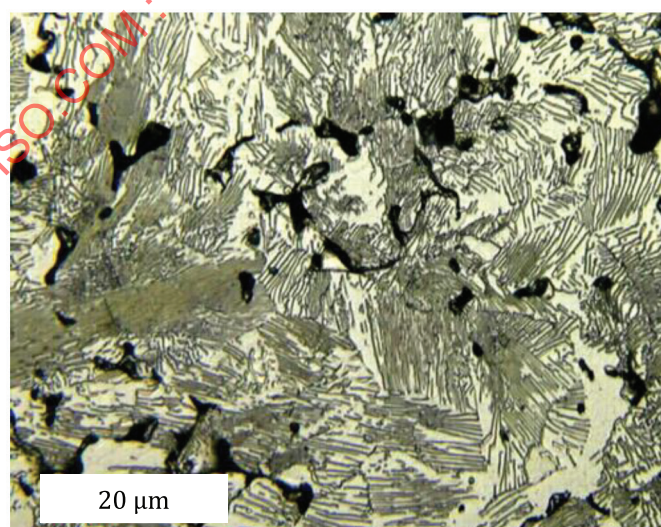


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B3-3	Fe-3 %C	Sponge Fe powder	1 000 °C, 30 min	Nital 1 %

Figure B.5 — Microstructure B3-3

B.4 Iron and carbon steel materials for structural parts

Microstructure is a mixture of ferrite and pearlite (see [Figure B.6](#)). The carbon content of a sintered structure can be estimated metallographically from the area fraction of pearlite where 100 % pearlite is equivalent to approximately 0,8 % carbon. Carbon dissolves rapidly in iron and it is therefore unusual to see uncombined graphite after about 5 min sintering at 1 040 °C.

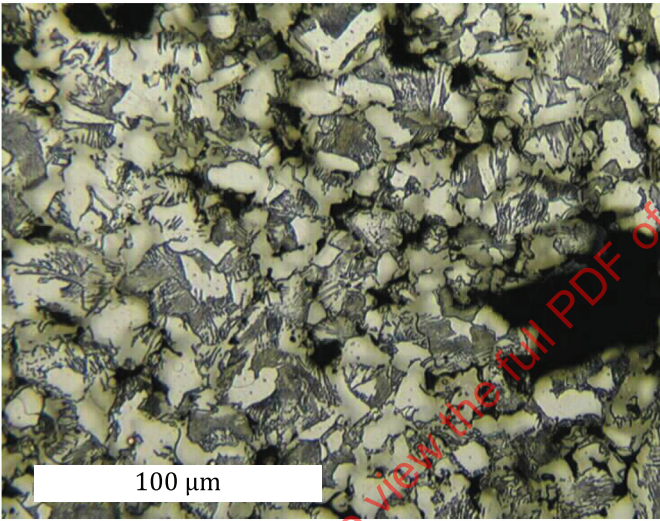


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B4	Fe-0,7 %C	Atomized Fe powder	1 120 °C, 30 min	Nital 2 %

Figure B.6 — Microstructure B4

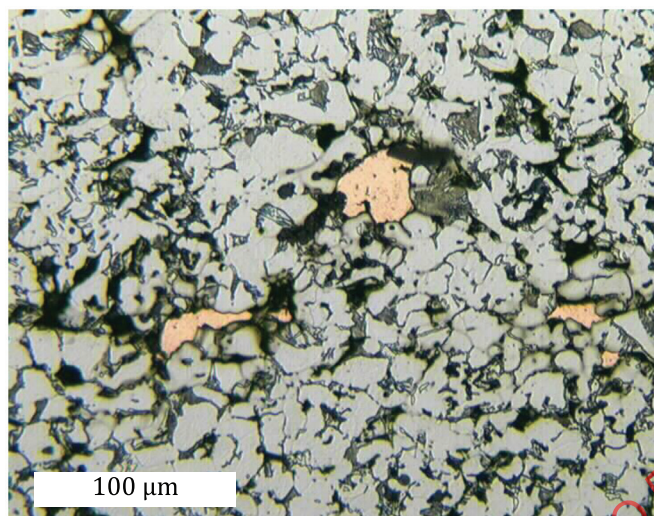
B.5 Copper steel and copper-carbon steel materials for structural parts

Microstructure is a mixture of ferrite and pearlite, with some cementite in grain boundaries due to the carbon diffusion inhibition caused by copper. The combined carbon content may be estimated metallographically from the microstructure in similar way as described in B.4. Admixed copper powder melts at approximately 1 083 °C, flows between the iron particles and into pores, helping the sintering mechanism. Normally, sintered alloys with 2 % or less copper show little or no undissolved copper (see Figure B.7). At higher percentages the copper will be seen as a separate phase (see Figure B.8) or as precipitated fine free copper (see Figure B.9), depending on the sintering conditions. Copper dissolves in iron but does not penetrate to the centre of the larger iron particles. When copper melts it diffuses or migrates leaving pores behind in place of the copper particles; if copper powder with coarse particle size is used, the pores will be coarser and can be easily seen.



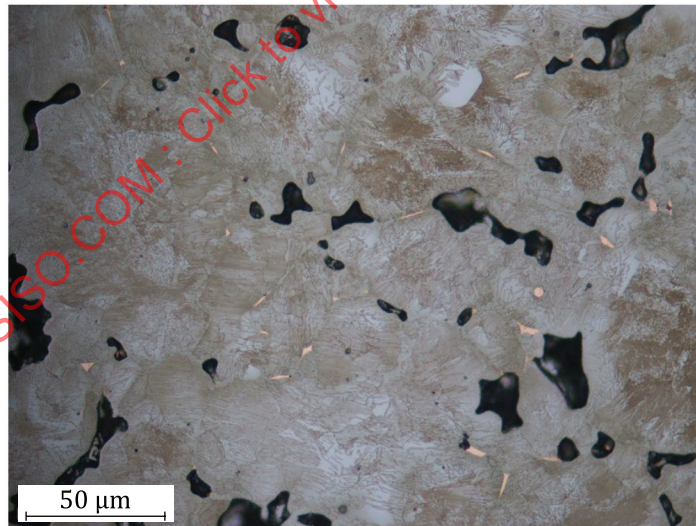
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B5-1	Fe-2,0 %Cu-0,5 %C	Mixture of atomized Fe powder and atomized Cu powder under 150 μm	1 120 °C, 30 min	Nital 1 %

Figure B.7 — Microstructure B5-1



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B5-2	Fe-2,0 %Cu-0,5 %C	Mixture of sponge Fe powder and atomized Cu powder under 150 μm	1 050 °C, 30 min	Nital 1 %

Figure B.8 — Microstructure B5-2

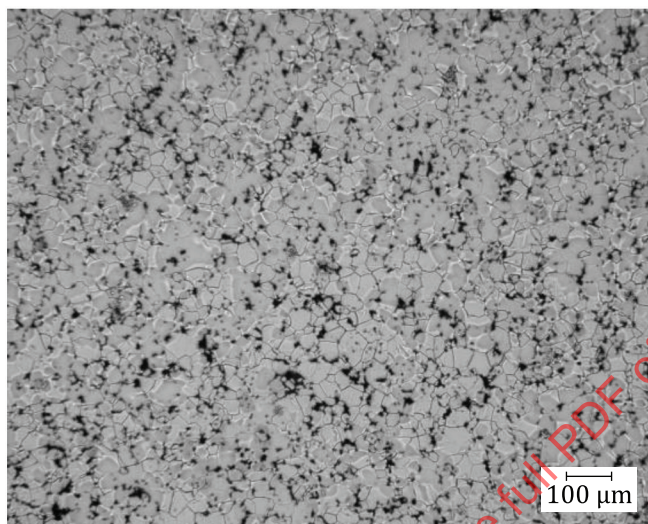


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B5-3	Fe-4,0 %Cu-0,5 %C	Mixture of atomized Fe powder and atomized Cu powder under 150 μm	1 120 °C, 30 min	Nital 1 %

Figure B.9 — Microstructure B5-3

B.6 Phosphorus steels for structural parts

Phosphorus steels with less than 0,1 % carbon have predominantly ferritic microstructure. When etched in 4 % nital it is possible to distinguish areas with high (lighter) and low (darker) phosphorus content (see [Figure B.10](#)). As carbon is increased, grey or dark areas of fine lamellar pearlite can be seen with light etching areas of ferrite. By adding copper a network of copper-rich areas can be found in the microstructure. Well-rounded pores also characterize phosphorus steels due to the liquid phase sintering mechanism.

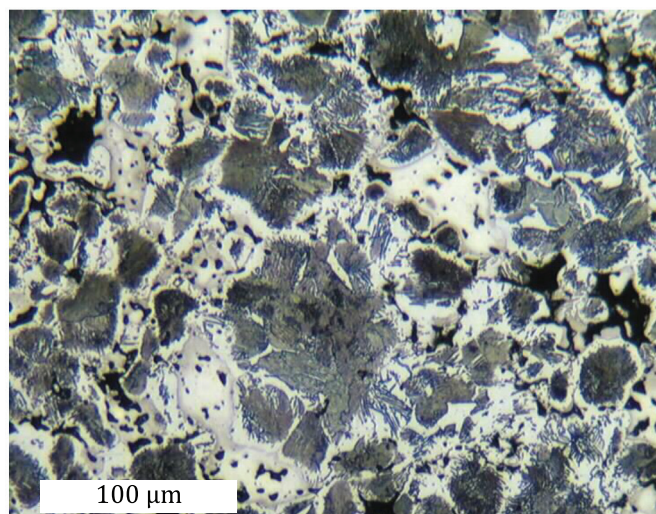


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B6	Fe-0,45 %P	Mixture of atomized Fe powder and Fe-P rich master alloy	1 120 °C, 30 min	Nital 4 %

Figure B.10 — Microstructure B6

B.7 Nickel steels for structural parts

The fine nickel powder admixed with iron and graphite does not completely diffuse during sintering around 1 100 °C. As-sintered nickel steels show light coloured austenitic nickel-rich islands with needles of martensite or bainite around their edges (see [Figure B.11](#)). This heterogeneous microstructure is normal. Sintering at temperatures above 1 150 °C will reduce the volume-fraction of nickel-rich islands. In the heat-treated condition the nickel-rich islands are light coloured, austenitic at their centre and with martensitic needles at the edges (viewed at 1 000X). The matrix is martensite and, depending on quenching rate, 0 to 35 % fine pearlite.

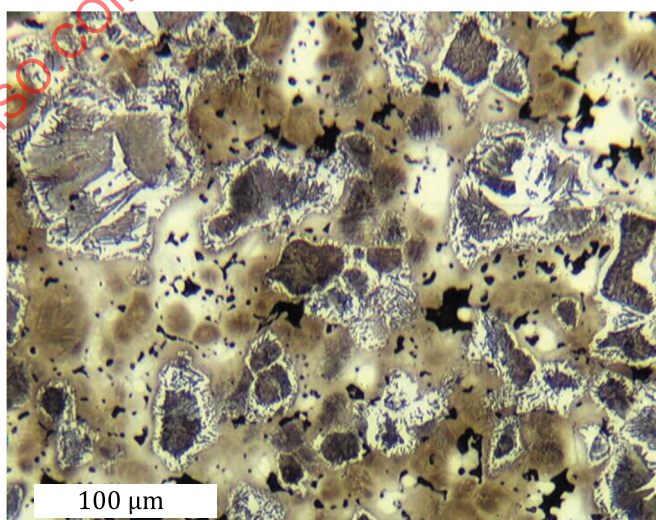


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B7	Fe-3 % Ni-0,6 %C	Mixture of atomized Fe powder and Ni powder	1 120 °C, 30 min	Picral 4 %

Figure B.11 — Microstructure B7

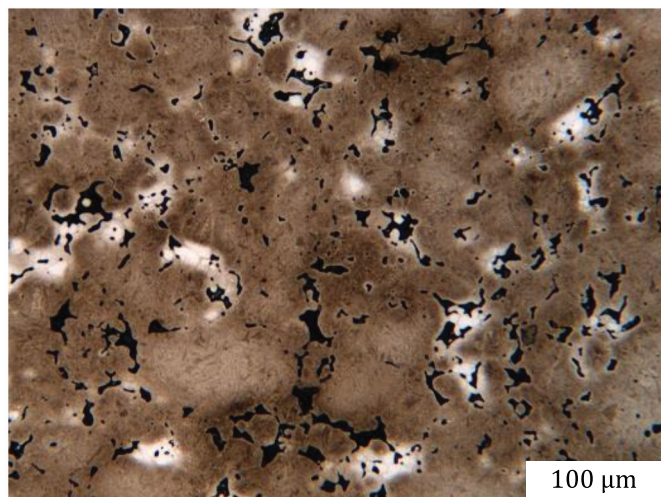
B.8 Diffusion-alloyed nickel-copper-molybdenum steels for structural parts

These materials are produced from diffusion-alloyed powders with the addition of elemental graphite. These materials produce a heterogeneous microstructure. As-sintered diffusion-alloyed steels show a microstructure similar to the nickel steels in B.7, but with a greater proportion of bainite and martensite (see Figure B.12). After heat treatment, microstructures are similar to those of heat-treated nickel steels (see Figure B.13).



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B8-1	Fe-1,75 %Ni-1,5 %Cu-0,5 %Mo-0,5 %C	Diffusion-alloyed powder	1 120 °C, 30 min	Picral 4 %

Figure B.12 — Microstructure B8-1

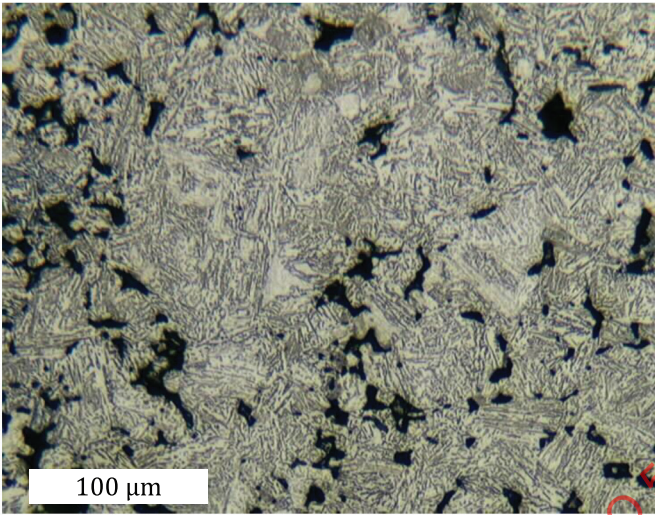


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B8-2	Fe-1,75 %Ni-1,5 %Cu-0,5 %Mo-0,8 %C	Diffusion-alloyed powder	1 120 °C, 30 min + Quenched and tempered	Picral 4 %

Figure B.13 — Microstructure B8-2

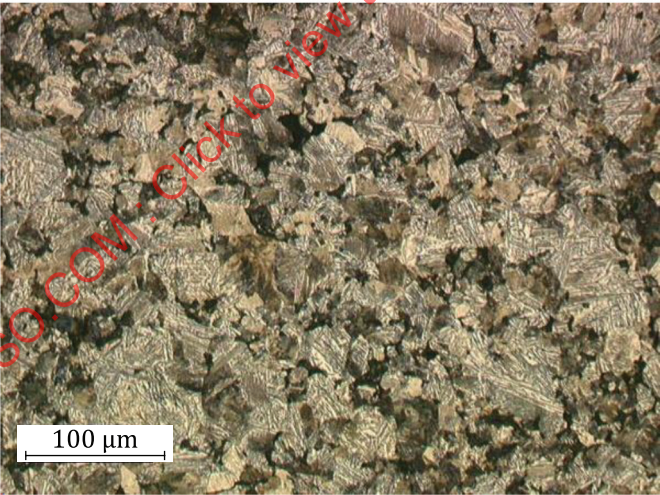
B.9 Pre-alloyed steels for structural parts

These materials are produced from prealloyed steel powders with the addition of elemental graphite and occasionally copper powder. Alloying elements used in prealloyed steels are Ni, Mo, Cr and Mn in low and moderate content, which increase the material hardenability. Microstructures show typically fine pearlite, bainite, or mixtures of both constituents depending on the material chemical composition and the cooling rate during sintering, and without the Ni-rich areas typical of diffusion-alloyed materials (see [Figures B.14](#) and [B.15](#)). After heat treatment or sinterhardening, the prealloyed steels exhibit a uniform martensitic microstructure or mixtures bainite-martensite (see [Figure B.16](#) and [B.17](#)).



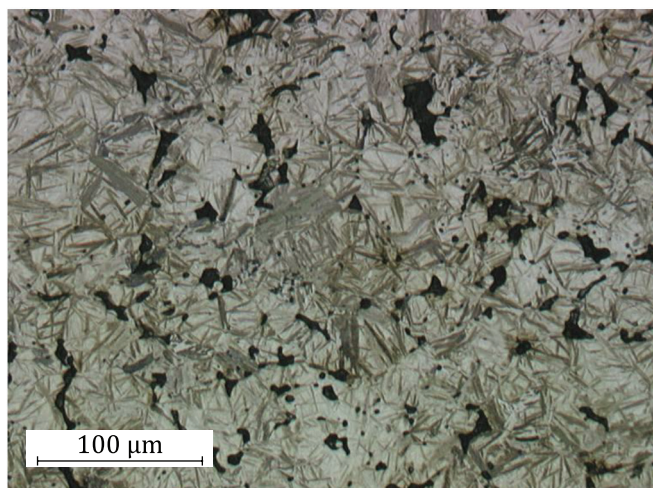
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B9-1	Fe-1,5 %Mo-0,5 %C	Atomized	1 120 °C, 30 min	Nital 1 %

Figure B.14 — Microestructure B9-1



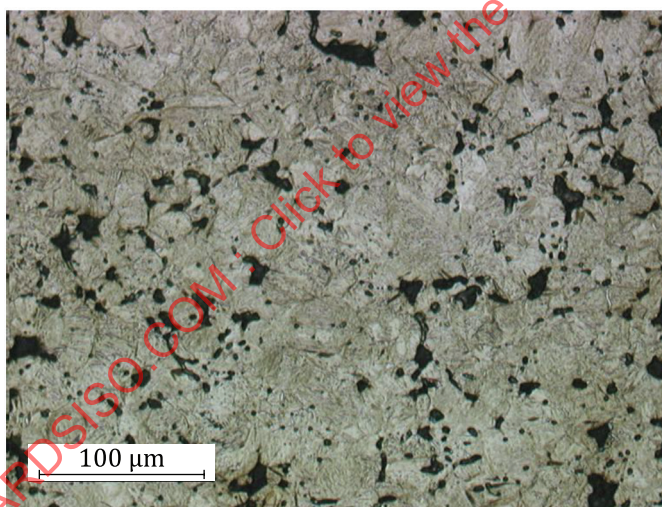
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B9-2	Fe-1,8 %Ni-0,55 %Mo-0,8 %C	Atomized	1 120 °C, 30 min	Nital 1 %

Figure B.15 — Microestructure B9-2



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B9-3	Fe-3 %Cr-0,5 %Mo-0,5 %C	Atomized	1 120 °C, 30 min	Nital 2 %/Picral 4 %

Figure B.16 — Microestructure B9-3



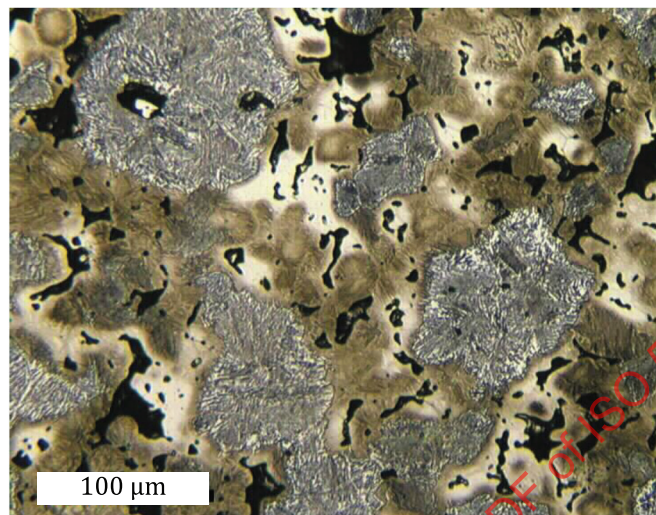
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B9-4	Fe-3 %Cr-0,5 %Mo-0,5 %C	Atomized	1 120 °C, 30 min, cooling 2 °C/s	Nital 2 %/Picral 4 %

Figure B.17 — Microestructure B9-4

B.10 Hybrid-alloy steels

These materials are produced from pre-alloyed powder with elemental or diffusion-alloyed additions (such as nickel and/or copper). The resultant as-sintered microstructure consists of a heterogeneous mixture similar to the admixed or diffusion-alloyed steels with a difference in the form of the eutectoid product (see [Figure B.18](#)). Due to the prealloyed base powder, the eutectoid is not the same as the fine pearlite of the plain iron-carbon system. The carbide plates are coarser and spaced in such a manner that the proeutectoid ferrite is not clearly defined. Therefore, it is difficult to estimate the

combined carbon content metallographically. Alloys containing copper additions may show bainite and/or martensite in the as-sintered structure. After heat treatment, the hybrid-alloy steels exhibit a martensitic microstructure with nickel-rich areas in those alloys containing admixed or diffusion-alloyed nickel heterogeneous mixture similar to B8-2 (see [Figure B.13](#)) with a difference in the form of eutectoid product.

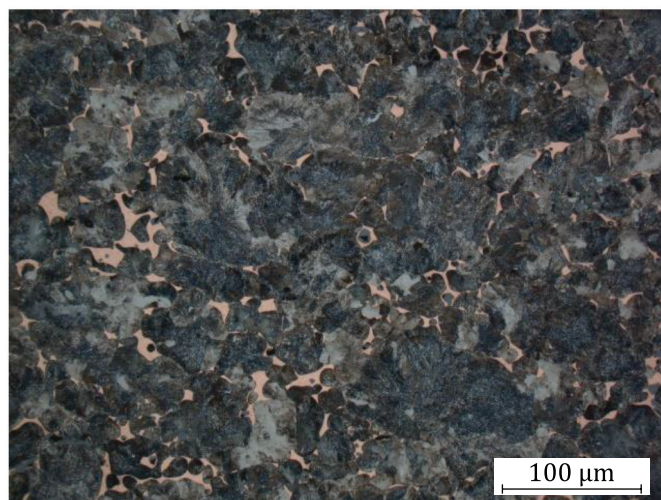


Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B10	Fe-4 %Ni-2 %Cu-0,5 %Mo-0,6 %C	Diffusion-alloyed powder based on atomized Fe-1,5 %Mo	1 120 °C, 30 min	Picral 4 %

Figure B.18 — Microstructure B10

B.11 Copper or copper-alloy-infiltrated steels for structural parts

The copper-rich phase can be seen clearly in the microstructure (see [Figure B.19](#)). Cu fills the pores by capillary action, it will first fill the finer interconnected pores. Some pores may not be fully Cu-infiltrated. Cu-infiltration of a component can be carried out partially or totally. The combined carbon content is based on the iron phase only, similar to B4.



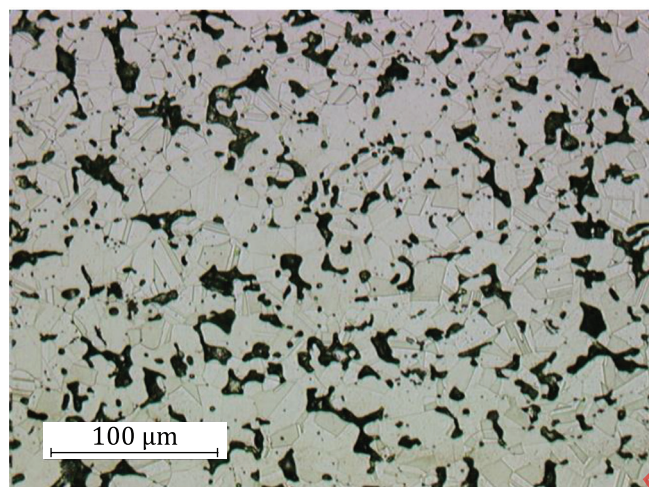
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B11	Fe-11 %Cu-0,8 %C	Atomized Fe powder	1 120 °C, 30 min	Nital 1 %

Figure B.19 — Microstructure B11

B.12 Austenitic, ferritic and martensitic stainless steels for structural parts

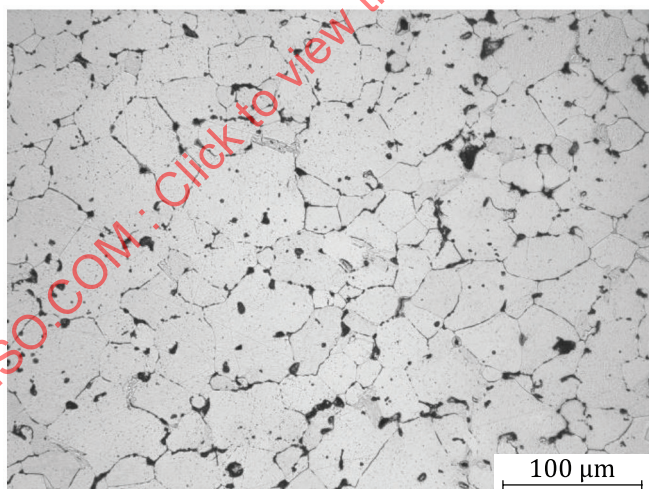
The -FL303, -FL304 and -FL316 grades are austenitic with some evidence of twin formation (see [Figure B.20](#)). In the 316L type there should be little or almost no evidence of original particle boundaries, chromium carbides, nitrides or oxides.

The -FL410, -FL430 and -FL434 grades are ferritic in the as-sintered condition. There should be no clear evidence of prior particle boundaries, oxides or carbides. Even minor residual carbon or nitrogen will appear in the microstructure (see [Figure B.21](#)). The -FL410 heat-treated grade is fully martensitic after sintering or sinter-hardening. It also can be hardened separately but, in either case, it is generally tempered for optimum toughness (see [Figure B.22](#)).



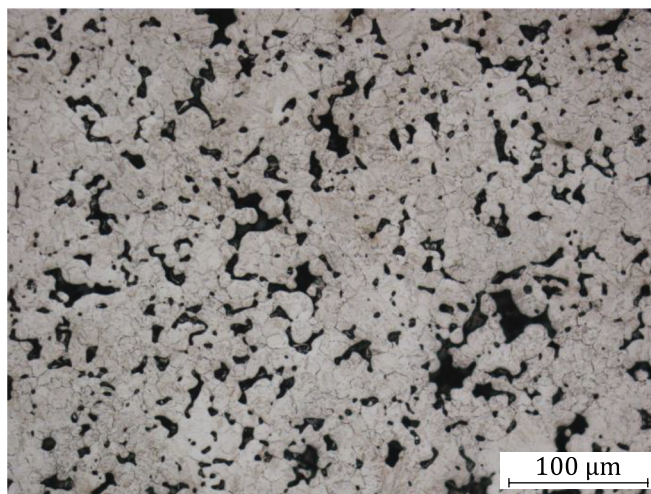
Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B12-1	Fe-17 %Cr-12 %Ni-2 %Mo	Atomized	1 250 °C	Glyceregia

Figure B.20 — Microestructure B12-1



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B12-2	Fe-17 %Cr-1 %Mo	Atomized	1 250 °C	Vilella

Figure B.21 — (Microestructure B12-2)



Microstructure	Chemical composition	Type of powder	Sintering conditions	Etching agent
B12-3	Fe-11 %Cr	Atomized	1 250 °C	Vilella

Figure B.22 — (Microstructure B12-3)

B.13 Copper-based alloys for structural parts

Brass, bronze and nickel-silver shows alpha-phase microstructure same as microstructure B2-1 (see [Figure B.1](#)) but with less porosity. They should be sintered to the point where very few original particle boundaries are observable.

Annex C (informative)

Equivalence of standards of powder metallurgy materials

Tables C.1 to C.5 present the equivalence between standards published by different organizations related to powder metallurgy materials.

Table C.1 — Materials for bearings

Material category according to ISO 5755	Material sub-category	Reference standards or equivalences				
		ISO 5755:2012	DIN 30910-3:2004-11	MPIF Std 35:2019	ASTM B783-19	JIS Z 2550:2016
Non-ferrous materials for bearings: bronze and bronze with graphite	Bronze	C-T10-K110	—	CT-1000-K19	CT-1000-K19	C-T10-K110
		C-T10-K140	Sint-A50	CT-1000-K26	CT-1000-K26	C-T10-K140
		C-T10-K180	Sint-B50	CT-1000-K37	CT-1000-K37	C-T10-K180
		—	Sint-C50	CT-1000-K40	CT-1000-K40	—
	Bronze with graphite	C-T10G-K90	—	—	—	C-T10G-K90
		C-T10G-K110	—	—	—	C-T10G-K110
		C-T10G-K120	Sint-A51	CTG-1001-K17	CTG-1001-K17	C-T10G-K120
		C-T10G-K170	—	—	—	C-T10G-K170
		C-T10G-K160	Sint-B51	CTG-1001-K23	CTG-1001-K23	C-T10G-K160
		—	—	CTG-1001-K30	CTG-1001-K30	—
		—	Sint-C51	CTG-1001-K34	CTG-1001-K34	—
		C-T10G-K115	—	—	—	C-T10G-K115
		—	—	CTG-1004-K10	CTG-1004-K10	—
		—	—	—	—	—
		—	—	CTG-1004-K15	CTG-1004-K15	—
	Bronze-Lead-Graphite	—	—	—	CTG-1001-K23-MOD	—
	Iron	F-00-K170	Sint-A00	F-0000-K15	F-0000-K15	F-00-K170
		F-00-K220	Sint-B00	F-0000-K23	F-0000-K23	F-00-K220
		—	Sint-C00	—	—	—
	Iron-carbon	—	—	F-0005-K20	F-0005-K20	—
		—	—	F-0005-K28	F-0005-K28	—
		—	—	F-0008-K20	F-0008-K20	—
		—	—	F-0008-K32	F-0008-K32	—
	Iron-copper	—	Sint-A10	FC-0200-K20	FC-0200-K20	—
		FC-00C2-K200	Sint-B10	—	—	FC-00C2-K200
		FC-00C2-K250	Sint-C10	FC-0200-K34	FC-0200-K34	FC-00C2-K250
		—	—	FC-1000-K20	FC-1000-K20	—
		—	—	FC-1000-K30	FC-1000-K30	—
		—	—	FC-1000-K40	FC-1000-K40	—
		F-03C22-K150	—	—	—	F-03C22-K150
		—	Sint-A20	FC-2000-K25	FC-2000-K25	—

Table C.1 (continued)

Material category according to ISO 5755	Material sub-category	Reference standards or equivalences				
		ISO 5755:2012	DIN 30910-3:2004-11	MPIF Std 35:2019	ASTM B783-19	JIS Z 2550:2016
Ferrous materials for bearings: iron, iron-copper, iron-bronze and iron-carbon graphite		—	Sint-B20	FC-2000-K30	FC-2000-K30	—
		—	—	FC-2000-K40	FC-2000-K40	—
		F-03C22G-K150	—	—	—	F-03C22G-K150
		F-03C22G-K200	—	—	—	F-03C22G-K200
		F-03C25T-K120	—	—	—	F-03C25T-K120
	Iron-copper-carbon	—	—	FC-0205-K20	FC-0205-K20	—
		—	—	FC-0205-K35	FC-0205-K35	—
		—	—	FC-0208-K25	FC-0208-K25	—
		—	Sint-B11	FC-0208-K40	FC-0208-K40	—
		—	—	FC-0508-K35	FC-0508-K35	—
		—	—	FC-0508-K46	FC-0508-K46	—
		—	—	FC-2008-K44	FC-2008-K44	—
		—	—	FC-2008-K46	FC-2008-K46	—
		—	Sint-A22	—	—	—
		—	Sint-B22	—	—	—
	Iron-bronze	—	—	FDCT-1802-K22	FDCT-1802-K22	—
		—	—	FDCT-1802-K31	FDCT-1802-K31	—
		—	—	FDCT-1802-K39	FDCT-1802-K39	—
		F-03C36T-K90	—	FCTG-3604-K16	FCTG-3604-K16	F-03C36T-K90
		F-03C36T-K120	—	FCTG-3604-K22	FCTG-3604-K22	F-03C36T-K120
		F-03C45T-K70	—	—	—	F-03C45T-K70
		F-03C45T-K100	—	—	—	F-03C45T-K100
		—	—	CFTG-3606-K14	CFTG-3606-K14	—
		—	—	CFTG-3606-K22	CFTG-3606-K22	—
	Iron-carbon graphite	F-03G3-K70	—	FG-0303-K10	FG-0303-K10	F-03G3-K70
		F-03G3-K80	—	FG-0303-K12	FG-0303-K12	F-03G3-K80
		—	—	FG-0308-K16	FG-0308-K16	—
		—	—	FG-0308-K22	FG-0308-K22	—

Table C.2 — Iron based structural parts

Material category according to ISO 5755	Material sub-category	Reference standards or equivalences				
		ISO 5755:2012	DIN 30910-4: 2010-03	MPIF Std 35:2019	ASTM B 783-13	JIS Z 2550:2016
Ferrous materials for structural parts: iron and carbon steel	As-sintered	—	—	F-0000-10	F-0000-10	—
		F-00-100	Sint-C00	F-0000-15	F-0000-15	F-00-100
		F-00-120	Sint-D00	—	—	F-00-120
		F-00-140	Sint-E00	F-0000-20	F-0000-20	F-00-140
		F-05-100	—	F-0005-15	F-0005-15	F-05-100
		F-05-140	Sint-C01	F-0005-20	F-0005-20	F-05-140
		F-05-170	Sint-D01	F-0005-25	F-0005-25	F-05-170
		—	—	F-0008-20	F-0008-20	—
		F-08-170	—	F-0008-25	F-0008-25	F-08-170
		F-08-210	Sint-C01	F-0008-30	F-0008-30	F-08-210
		F-08-240	Sint-D01	F-0008-35	F-0008-35	F-08-240
	Heat-treated	F-05-340H	—	F-0005-50HT	F-0005-50HT	F-05-340H
		F-05-410H	—	F-0005-60HT	F-0005-60HT	F-05-410H
		F-05-480H	—	F-0005-70HT	F-0005-70HT	F-05-480H
		—	—	F-0008-55HT	F-0008-55HT	—
		F-08-450H	—	F-0008-65HT	F-0008-65HT	F-08-450H
		F-08-500H	—	F-0008-75HT	F-0008-75HT	F-08-500H
		F-08-550H	—	F-0008-85HT	F-0008-85HT	F-08-550H
Ferrous materials for structural parts: copper steel and copper carbon steel	As-sintered	—	—	FC-0200-15	FC-0200-15	—
		F-00C2-110	—	FC-0200-18	FC-0200-18	F-00C2-110
		F-00C2-140	Sint-C10	FC-0200-21	FC-0200-21	F-00C2-140
		F-00C2-175	Sint-D10	FC-0200-24	FC-0200-24	F-00C2-175
		—	Sint-E10	—	—	—
		—	—	FC-0205-30	FC-0205-30	—
		F-05C2-230	—	FC-0205-35	FC-0205-35	F-05C2-230
		F-05C2-270	Sint-C10	FC-0205-40	FC-0205-40	F-05C2-270
		F-05C2-300	Sint-D10	FC-0205-45	FC-0205-45	F-05C2-300
		—	—	FC-0208-30	FC-0208-30	—
		F-08C2-270	—	FC-0208-40	FC-0208-40	F-08C2-270
		F-08C2-350	Sint-C11	FC-0208-50	FC-0208-50	F-08C2-350
		F-08C2-390	Sint-D11	—	—	F-08C2-390
		F-08C2-410	—	FC-0208-60	FC-0208-60	F-08C2-410
		—	Sint-C21	—	—	—
		—	—	FC-0505-30	FC-0505-30	—
		—	—	FC-0505-40	FC-0505-40	—
		—	—	FC-0505-50	FC-0505-50	—
		—	—	FC-0508-40	FC-0508-40	—
		—	—	FC-0508-50	FC-0508-50	—
		—	—	FC-0508-60	FC-0508-60	—
		—	—	FC-0808-45	FC-0808-45	—
		—	—	FC-1000-20	FC-1000-20	—