
**Sintered-metal injection-moulded
materials — Specifications**

*Matériaux métalliques frittés pour moulage par injection —
Spécifications*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22068 was prepared by Technical Committee ISO/TC 119, *Powder metallurgy*, Subcommittee SC 5, *Specifications for powder metallurgical materials (excluding hardmetals)*.

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Sintered-metal injection-moulded materials — Specifications

1 Scope

This International Standard specifies the requirements for the chemical composition and the mechanical and physical properties of sintered-metal injection-moulded materials.

It is intended to provide design and materials engineers with necessary information for specifying materials in components manufactured by means of the Metal Injection Moulding (MIM) process only.

It does not apply to structural parts manufactured by other powder metallurgy routes, such as press-and-sinter or powder-forging technologies.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 3369, *Impermeable sintered metal materials and hardmetals — Determination of density*

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

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales, A, B, C, E, F, G, H, K, N, T)*

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

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

IEC 60404-4, *Magnetic materials — Part 4: Methods of measurement of d.c. magnetic properties of magnetically soft materials*

ASTM D2638, *Standard Test Method for Real Density of Calcined Petroleum Coke by Helium Pycnometer*

ASTM D4892, *Standard Test Method for Density of Solid Pitch (Helium Pycnometer Method)*

3 Terms and definitions

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

3.1 tensile strength

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

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, expressed in MPa

3.3 elongation

A_{25}
plastic elongation, expressed as a percentage of the original gauge length of the specimen

NOTE The elastic strain at the 0,2 % yield strength must be subtracted from the total elongation to give the plastic elongation.

3.4 density

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

3.5 hardness

resistance of a PM material to indentation, tested under specified conditions

4 Test methods for normative properties

4.1 General

The following test methods shall be used to determine the normative properties given in Tables 1 to 6.

4.2 Chemical composition

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.

4.3 Density

The density shall be determined in accordance with ISO 3369 or by gas pycnometer measurement in accordance with ASTM D2638 or ASTM D4892 as stipulated at the time of enquiry and order.

4.4 Tensile strength

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

4.5 Tensile yield strength

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

4.6 Elongation

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

4.7 Magnetic properties

The maximum permeability and magnetic induction at an applied field of 1 990 A/m (25 Oe) shall be determined in accordance with IEC 60404-4.

5 Other test methods

5.1 Hardness

The hardness shall be determined in accordance with ISO 4498, ISO 6507-1 and ISO 6508-1.

5.2 Corrosion resistance

Four corrosive media and test methods (see 5.2.1 to 5.2.4) are used to rate the corrosion resistance of MIM stainless-steel alloys.

5.2.1 Sulfuric acid test

The standard un-notched Charpy test specimens (10 mm × 5 mm × 55 mm) are immersed in a 2 % by mass sulfuric acid solution at room temperature for 1 000 h. Three replicates are tested. The loss in mass for each is determined in accordance with MPIF Standard 62, and then converted into mass loss per surface area per day in units of gram per square decimetre day [g/(dm²)(day)].

5.2.2 Copper sulfate test

The test specimens or test parts are immersed in a copper sulfate solution (dissolve 1 g of cupric sulfate crystals in a mixture of 22,5 ml of distilled water and 2,5 g of sulfuric acid) for 6 min (± 30 s) at a temperature of 17 to 20 °C. Specimens that show no sign of copper plating are classified as passing this test (see ASTM F1089).

5.2.3 Boiling water test

The test specimen or test parts are immersed in distilled water, then brought to a boil and held for (30 ± 1) min. After the 30 min exposure remove from the heat source and let the specimens remain in the water for 3 h ± 15 min. The specimens are then removed and left to dry in still air for 2 h ± 10 min. Specimens that show no visible corrosion are classified as passing this test (see ASTM F1089).

5.2.4 Salt spray test

Criteria for the salt spray test in accordance with ISO 9227 shall be determined between the manufacturer and the customer.

6 Information and explanatory notes

6.1 Minimum value concept

This International Standard has adopted the concept of minimum mechanical and magnetic property values. These values may be used for determining the material most suited for a particular application if the part is manufactured by means of the MIM process.

6.2 Minimum mechanical property values

The minimum values for the MIM materials are expressed in terms of ultimate tensile strength, yield strength (0,2 % offset), and percent elongation to fracture. Values are reported for structural materials in both the as-sintered and heat-treated condition (where applicable).

The tensile properties used for establishing this International Standard were obtained from tensile specimens prepared according to ISO 2740. Tensile properties obtained from test specimens prepared by machining of non-standard specimens, or from non-standard specimens directly, may differ from those prepared according to ISO 2740. Evidence of mechanical properties for a particular component shall therefore be based on the tensile properties measured using specimens prepared according to ISO 2740. These specimens shall be manufactured from the same batch of material as the components, have the same density and be sintered and heat treated (if required) along with the components.

Defects introduced during the MIM processing of particular components may limit the tensile properties. Non-destructive evaluation of the parts can be necessary to ensure that the minimum property specifications according to this International Standard are met, if proof testing is not used.

6.3 Proof testing

The practical method for demonstrating the strength of a component is through static or dynamic testing stipulated by the supplier and/or user of the MIM part. This proof test should be as closely related to the actual function of the part as possible, as provided by break load, bend test, pull test, etc. For example, it may be agreed that the break load should be greater than a given value. If that load is exceeded in proof tests, the minimum strength is demonstrated. In an alternative method, the first batch of parts can also be tested in service and demonstrated to be acceptable. The static or dynamic load to fracture is determined separately and these data are statistically analysed to determine a minimum break load for future production batches. Exceeding that minimum load on future lots of these parts is proof that the specified strength requirement has been met.

6.4 Chemical composition

The chemical composition of each material lists the principal alloying elements by minimum and maximum percentage. Other elements include the total other elements by difference and are listed as a maximum value in mass percent.

6.5 Density and residual porosity

MIM materials are normally processed to near full density. If not otherwise specified, MIM materials contain less than 5 % residual porosity. The pores are finely dispersed, mainly within the grains, well rounded and have no access to the surface of the component, which means that MIM materials are impermeable to gases or liquids.

6.6 Heat treatment

Many MIM materials may be heat treated to increase strength, hardness and wear resistance. Ferrous MIM parts which contain at least 0,3 % carbon can be quench-hardened and tempered. Tempering is required after quenching for stress relief and optimization of strength and toughness. These two properties can be varied over a wide range using different tempering temperatures. The hardness level obtained after heat treatment

shall be stated for quenched and tempered steels. Case hardening (carburizing or carbo-nitriding) can also be applied to ferrous MIM materials with less than 0,3 % carbon to obtain high surface hardness.

The mechanical properties listed in this International Standard for the heat-treated condition are minimum values obtained at the practical lowest and highest apparent hardness levels attained with different tempering temperatures.

Martensitic stainless steels (MIM-420) and precipitation-hardened stainless steels (MIM-174PH) can also be heat treated for increased strength and hardness.

MIM materials respond well to conventional heat-treating practices and procedures in gas atmosphere or in a vacuum.

7 Designation of materials

7.1 Designation system

The designation system to be used for metal injection-moulded materials specified in this International Standard is in accordance with the ISO/IEC Directives, Part 2:2004.

7.2 Description block

The description block shall contain the letters MIM, denoting powder metallurgy materials made using the metal injection-moulding process.

7.3 Identity block

The identity block shall contain the number of this International Standard, ISO 22068, followed by the individual item block.

7.4 Individual item block

The coding system utilizes two different methods: for unique MIM alloys that do not exist as wrought compositions the material designation is an abbreviated code for the alloy composition where the major element is listed first, followed by the minor alloying elements, preceded by the numerical mass percentage value. If the material is a low-alloy steel containing carbon, the C designation is the last element listed with no numerical value given. The range of carbon required for the alloy is listed in the data table. For example, the alloy Fe-2 %Ni has the designation Fe2Ni; if this alloy has carbon added, the material designation code is Fe2NiC. For alloys that have recognized wrought composition codes, these material designations codes are used to identify the equivalent MIM alloy. For example, the stainless steels use a corresponding wrought steel grade wherever possible, e.g. 316L stainless steel or 420 stainless steel. Following the material designation code is a hyphen and then the numeric value of the yield strength in MPa units, e.g., MIM-Fe2NiC-205.

Heat-treated steels and stainless steels include in the material designation an "H" following the material code to signify a heat-treated material. The complete code has three or four numerals preceding the "H" where these numbers are the normative tensile yield strength value, in MPa units. For example, MIM-4340- 750H designates a heat-treated, low-alloy steel with nominally 0,4 % carbon, 2 % nickel, 1 % chromium and a minimum tensile yield strength of 750 MPa.

In the case of the soft-magnetic alloys, the two or three digit number following the material code is the normative maximum permeability value multiplied by 0,01, not the minimum tensile strength as in structural steels or stainless steels. For example, the MIM-Fe3Si-55 designation indicates a steel alloy with no carbon and 3 % silicon with a normative maximum permeability value of 5 500.

The identity block is not used in the tables of materials specifications in this International Standard. It should be used on purchase and for technical documentation where any possibility of ambiguity exists. Hence **MIM-ISO22068-Fe2NiC-205** is an example of a purchase order entry showing the identity block in conjunction with the individual item block.

8 Material specifications

MIM materials are specified in the Tables 1 to 6. The list represents the current status of standardization. Normative values of tensile strength (UTS), yield strength (YS) and percent elongation to fracture are minimum values for the as-sintered and heat-treated structural alloys. The normative values for the soft-magnetic alloys are the minimum values for density, maximum permeability and maximum induction at 1990 A/m (25 Oe). The steel alloys are listed as low-alloy steels in Tables 1 and 2, the stainless-steel alloys in Table 3 and 4, the soft-magnetic alloys in Table 5 and the titanium alloys in Table 6. The materials in each table are arranged in order of increasing content of alloying elements.

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Table 1 — Low-alloy steels – As-sintered

Grade	Normative values										Informative (typical) properties		
	Chemical composition						Others	Yield strength (0,2 %) min. $R_{p0,2}$ MPa	Elongation min. A_{25} %	Density ρ g/cm ³	Macro-apparent hardness		
	Fe	C	Si	Mn	Ni	Cr					Mo	Rockwell HRB	Vickers HV10
%	%	%	%	%	%	%	%	min.					
MIM-Fe2Ni-110	Bal.	<0,1	<1,0	—	1,5-2,5	—	<1,0	<1,0	110	20	7,6	45	87
MIM-Fe2NiC-205	Bal.	0,4-0,8	<1,0	—	1,5-2,5	—	<0,5	<1,0	205	11	7,6	80	150
MIM-Fe8Ni-210	Bal.	<0,1	<1,0	—	6,5-8,5	—	<0,5	<1,0	210	20	7,6	69	123
MIM-Fe8NiC-300 ^a	Bal.	0,4-0,8	<1,0	—	6,5-8,5	—	<0,5	<1,0	300	6	7,6	90	180
MIM-Fe8NiC-500 ^a	Bal.	0,4-0,8	<1,0	—	6,5-8,5	—	<0,5	<1,0	500	5	7,6	100	250
MIM-4140-400	Bal.	0,35-0,50	<0,4	<0,9	—	0,9-1,2	0,15-0,30	<1,0	400	3	7,4	95	210
MIM-4340-500	Bal.	0,35-0,50	<0,4	<0,8	1,4-2,0	0,7-1,4	0,2-0,3	<1,0	500	4	7,4	100	240
MIM-4605-170	Bal.	0,4-0,6	<1,0	—	1,5-2,5	—	0,2-0,5	<1,0	170	11	7,5	80	150
MIM-52100-450 ^a	Bal.	0,8-1,05	<0,4	<0,8	—	1,35-1,65	—	<1,0	450	3	7,4	95	200
MIM-52100-630 ^a	Bal.	0,8-1,05	<0,4	<0,8	—	1,35-1,65	—	<1,0	630	5	7,4	100	250

^a The mechanical properties depend on the sintering conditions. Faster cooling results in higher strength.

Table 2 — Low-alloy steels – Heat treated

Grade	Normative values										Informative (typical) properties			
	Chemical composition						Others	Yield strength (0,2 %) min. R _{p0,2} MPa	Elongation min. A ₂₅ %	Density ρ g/cm ³	Macro-apparent hardness			
	Fe	C	Si	Mn	Ni	Cr					Mo	Rockwell HRC	Vickers HV10	
MIM-Fe2NiC-700H	Bal.	0,4-0,8	<1,0	—	1,5-2,5	—	<0,5	<1,0	800	700	5	7,6	30	300
MIM-Fe2NiC-1000H	Bal.	0,4-0,8	<1,0	—	1,5-2,5	—	<0,5	<1,0	1 200	1 000	2	7,6	50	510
MIM-Fe8NiC-700H	Bal.	0,4-0,8	<1,0	—	6,5-8,5	—	<0,5	<1,0	800	700	5	7,6	35	345
MIM-Fe8NiC-1100H	Bal.	0,4-0,8	<1,0	—	6,5-8,5	—	<0,5	<1,0	1 300	1 100	2	7,6	50	510
MIM-4140-600H	Bal.	0,35-0,50	<0,4	<0,9	—	0,9-1,2	0,15-0,30	<1,0	750	600	3	7,4	25	265
MIM-4140-1200H	Bal.	0,35-0,50	<0,4	<0,9	—	0,9-1,2	0,15-0,30	<1,0	1 300	1 200	2	7,4	50	510
MIM-4340-750H	Bal.	0,35-0,50	<0,4	<0,8	1,4-2,0	0,7-1,4	0,2-0,3	<1,0	900	750	3	7,4	25	265
MIM-4340-1300H	Bal.	0,35-0,50	<0,4	<0,8	1,4-2,0	0,7-1,4	0,2-0,3	<1,0	1 600	1 300	2	7,4	48	485
MIM-4605-1310H	Bal.	0,4-0,6	<1,0	<0,8	1,5-2,5	—	0,2-0,5	<1,0	1 480	1 310	<1	7,5	48	485
MIM-52100-1250H	Bal.	0,8-1,05	<0,4	<0,8	—	1,35-1,65	—	<1,0	1 500	1 250	1	7,4	50	510