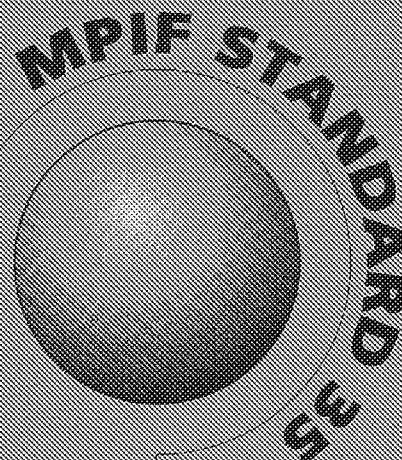




Materials Standards

for

P/M SELF-LUBRICATING BEARINGS

1998 edition



Documents

Document Standard 35

MPIF Standard 35

Materials
Standards
for P/M
Self-
Lubricating
Bearings*

*For structural parts made by the P/M (powder metallurgy) process, see MPIF Standard 35, "Materials Standards for P/M Structural Parts."

*For P/M components made by the metal injection molding (MIM) process, see MPIF Standard 35, "Materials Standards for Metal Injection Molded Parts".

Table of Contents

EXPLANATORY NOTES AND RECOMMENDED PRACTICES	
Minimum Value Concept	2
Grade Selection	2
Nomenclature	2
Chemistry	3
Microstructure	3
Oil Impregnation	3
Porosity	4
Oil Content by Volume, As Received	4
Density	4
Radial Crushing Force	5
Storage	5
Surface Finish	5
SI Units	5
Comparable Standards	5
DATA TABLES	
Bronze Bearings (Low, Medium, High Graphite)	6
Iron and Iron-Carbon Bearings	7
Iron-Copper Bearings	8
Iron-Copper-Carbon Bearings	9
Diluted Bronze Bearings	10
Iron-Graphite Bearings	11
ENGINEERING INFORMATION - ENGLISH UNITS	
Typical Loads	12
Press Fits	13
Interference Fits	13
Running Clearances	13
Dimensional Tolerances	13
Plain Cylindrical	13
Flange	14
Thrust	14
ENGINEERING INFORMATION - SI UNITS	
Typical Loads	15
Press Fits	16
Interference Fits	16
Running Clearances	16
Dimensional Tolerances	16
Plain Cylindrical	16
Flange	17
Thrust	17
SI Units for P/M	



Materials Standards for P/M Self-Lubricating Bearings

Price: \$15.00

Issued 1965
Revised 1974, 1976, 1986, 1990 and 1998

Scope

MPIF Standard 35 is issued to provide the design and materials engineer with the information necessary for specifying P/M materials which have been developed by the P/M parts manufacturing industry. This section of Standard 35 deals with self-lubricating bearings and bushings made by the powder metallurgy process. A bearing may be defined as a machine part in which another component such as a journal or rod turns or slides. A bushing is normally a removable cylinder used to control the size of an opening or to resist abrasion or to serve as a guide. This section does not apply to P/M structural parts or metal injection molded products which are covered in other sections. The same materials may appear in more than one section depending upon their common use, i.e., some structural materials may also be used in bearing applications and vice versa.

The use of any MPIF Standard is entirely voluntary. MPIF Standards are issued and adopted in the public interest. They are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper material for his particular product. Existence of MPIF Standards does not in any respect preclude any member or non-member of the Federation from manufacturing or selling products which use materials or testing procedures not included in this Standard. Other materials may be available commercially which are not covered in this Standard at this time.

By publication of these Standards, no position is taken with respect to the validity of any patent rights nor does the Metal Powder Industries Federation undertake to ensure anyone utilizing the Standards against liability for infringement of any Letters Patent or accept any such liability.

Neither MPIF nor any of its members assumes or accepts any liability resulting from use or non-use of any MPIF Standard. In addition, MPIF does not accept any liability or responsibility for the compliance of any product with any standard, the achievement of any minimum or typical values by any supplier, or for the results of any testing or other procedure undertaken in accordance with any standard.

MPIF Standards are subject to periodic review and may be revised. Users are cautioned to refer to the latest edition.

Both the purchaser and the manufacturer should, in order to avoid possible misconceptions or misunderstandings, agree on the following conditions prior to the manufacture of a P/M part: minimum strength value, grade selection, chemistry, proof testing, typical property values and processes, which may affect the part application.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publisher.

Copyright Metal Powder Industries Federation
Provided on license with MPIF
ISBN No. 1-878954-66-0
Full document details: MPIF 35 1998

Licensee=, User=,
Not for Resale.

Published by
Metal Powder Industries Federation
105 College Road East
Princeton, New Jersey 08540-6692 U.S.A.
Tel: (609) 452-7700
Fax: (609) 987-8523
E-mail: info@mpif.org



Explanatory Notes and Recommended Practices

Minimum Value Concept

The Metal Powder Industries Federation has adopted the concept of *minimum* values of properties for P/M materials. These values such as oil content and radial crushing force may be used in designing for a P/M bearing application. Composition, density, and in some cases, radial crushing force, also have maximum values listed. It is seen as an advantage of the process that equivalent properties can be developed by varying chemical composition, particle configuration, density and/or processing techniques.

The minimum value is the value that will be statistically exceeded by all bearings in a production lot as defined by the manufacturer and the purchaser. **The manufacturer and the purchaser should agree on the sampling plan.**

The purchaser should select and specify the combination of P/M material and properties most suitable for a specific application. The data provided define values for listed materials and display minimum properties. Other improvements in performance characteristics may be attained through more complex processing. To select a material optimum in both properties and cost-effectiveness, it is essential that the application be discussed with the P/M manufacturer.

Utilization of MPIF Standard 35 to specify a P/M bearing means that unless the purchaser and manufacturer have agreed otherwise, the material will have at least the minimum value specified in the Standard.

(See **P/M Bearing Materials Properties** on pages 6-11).

Grade Selection

Before a particular grade of material can be selected, a careful analysis is required of the design of the bearing and its end use, including dimensional tolerances. In addition, the final property requirements of the finished bearing should be considered, e.g., density, porosity, compressive strength, corrosion resistance, wear resistance, oil content, oil type, surface finish and any other requirements pertinent to the application. It is recommended that all of the above aspects be subjects of discussion between the manufacturer and the purchaser prior to final grade selection.

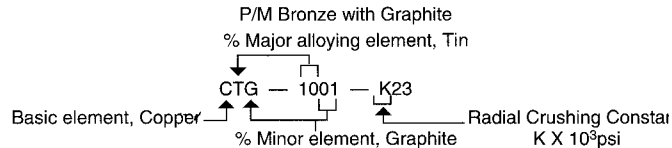
In addition to the bearing materials standardized herein, there are other proprietary materials available for specific applications.

(See **Powder Metallurgy Design Manual** published by the Metal Powder Industries Federation for design recommendations and other information pertinent to the proper use of P/M self-lubricating bearings.)

Nomenclature

The four digits following the prefix letter code refer to the composition of the material.

In nonferrous materials, the first two numbers in the four digit series designate the percentage of the major alloying constituent. The last two numbers of the four-digit series designate the percentage of the minor alloying constituent. The percentages of other minor elements excluded from the code are represented in the "Chemical Composition" which appears with each standard material. Illustration of P/M nonferrous material designation coding:



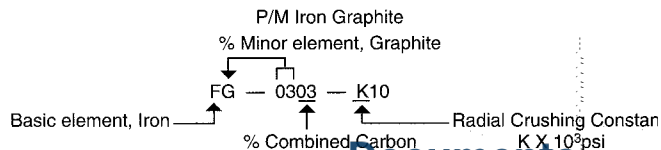
In ferrous materials, the major alloying elements (except combined carbon) are included in the prefix letter code. Other elements are excluded from the code but are represented in the "Chemical Composition" which appears with each standard material. The first two digits of the four-digit code indicate the percentage of the major alloying constituent present.

Combined carbon content in ferrous materials is designated by the last two numbers in the four-digit series. The ranges of carbon that are metallurgically combined are indicated in the coding systems below:

Carbon Ranges	Code Designation
0.0% - 0.3%	00
0.3% - 0.6%	05
0.6% - 0.9%	08

Carbon Ranges for Iron-Graphite Bearings	Code Designation
0.0% - 0.5%	03
0.5% - 1.0%	08

Illustration of P/M ferrous material designation coding:



The two-digit suffix represents the minimum K factor.

expressed in 10³ psi, that the user can expect from the P/M material possessing that chemistry. The letter K indicates a bearing grade material.

Examples of P/M Material Designation Coding

Material	Nominal Composition by Percent	Complete Code for Material, Composition and Minimum K x 10 ³ psi
P/M Bronze	Cu-90, Sn-10	CT-1000-K26
P/M graphited Bronze	Cu-86, Sn-10, G-4	CTG-1004-K10
P/M Iron	All Fe	F-0000-K23
P/M Iron-Copper	Fe-90, Cu-10	FC-1000-K40
P/M Iron-Graphite	Fe-97.25 Graphite 2.5	
	Comb. Carbon 0.25	FG-0303-K10
P/M Diluted Bronze	Fe-60, Cu-36, Sn-4	FCTG-3604-K16

Prefix Letter Code

A Aluminum	G Free graphite
C Copper	M Manganese
CT Bronze	N Nickel
CNZ Nickel Silver	P Lead
CZ Brass	S Silicon
F Iron	SS Stainless Steel (prealloyed)
FC Iron-Copper or Copper Steel	T Tin
FD Diffusion Alloyed Steel	U Sulfur
FL Prealloyed Ferrous material except Stainless Steel	Y Phosphorus
FN Iron-Nickel or Nickel Steel	Z Zinc
FX Copper Infiltrated Iron or Steel	

Chemistry

The chemistry of each material lists the principal elements by minimum and maximum percentage by weight. "Other Elements" includes the total other elements by difference and is reported as a maximum percentage. These may include other minor elements added for specific purposes and the normal amount of extraneous constituents found in the individual ingredients.

The chemistry specification for P/M self-lubricating materials describes the materials in the as-sintered condition. Subsequent operations such as sizing, machining, tumbling, or oil impregnation can change the results of the chemical analysis. An as-sintered part can be checked for chemistry with no interference as long as the sampling procedure (chip drilling) does not introduce contamination such as oil or oxide. In some instances, impregnants, whether for sizing or lubrication purposes, may be partially removed using Soxhlet extraction (ASTM B 328).

Parts that have been sized, tumbled, machined or impregnated will be contaminated with carbonaceous materials that must be removed prior to carbon determination. There is no known way to remove completely some such interfering materials; thus an accurate carbon content cannot be measured. Combined carbon in iron can be measured by metallographic estimate of the area fraction of pearlite: 100% pearlite is equivalent to approximately 0.8% carbon.

Microstructure

The examination of the microstructure of a P/M bearing can serve as a diagnostic tool and reveal the degree of sintering and other metallurgical information critical to the powder metallurgy process. Several observations common to most sintered materials are briefly described below.

In selecting a section of a P/M part for microstructural analysis, an interior plane parallel to the pressing direction is preferred for mounting and polishing. Coarse and fine polishing should be continued until all of the pores are opened to view and the area fraction of porosity represents the density of the part. For example, an 80% dense bearing should show approximately 20% of its area as pores.

Low density materials such as those designed for self lubrication should be impregnated with mounting resin during preparation of the specimen for microstructural examination. This will help prevent distortion of the voids during machining or polishing. Sintered bearings are always first examined in the unetched condition. In an average sinter there will be very few or no original particle boundaries seen at 200X. Bearings should have their oil removed by Soxhlet extraction so that it will not interfere with microscopic examination. Examination of the unetched inside diameter surfaces should show surface porosity.

In 90-10 copper-tin bronze bearings, the structure should be alpha bronze with no gray copper-tin compounds and with a minimum of reddish copper-rich areas. In iron-copper bearings, the copper should have melted and flowed into the surrounding small pores. With 5% to 10% copper, the copper will be visible as melted regions. With 2% copper or less, free copper is generally not present. Bearings should show a minimum of original particle boundaries. The microstructure of "diluted" 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 upon manufacturing process. To preserve graphite for metallographic examination, rough grind on 400 and 600 grit SiC paper, then polish for 2-6 minutes with moderate pressure, 250 rpm lap, one micrometer grit diamond on a short-napped cloth.

Definitions and Equations

Oil Impregnation

The controlled, interconnected pore structure in low density P/M parts or bearings permits their impregnation with lubricating oil. This provides self-lubricating properties. When friction heats the part, the oil expands and flows to the bearing surface. In operation, the oil is "pumped" from the bearing as the shaft rotates. On cooling, the oil returns into the metal's pores by capillary action. Conventional P/M bearings can absorb from 10 to 30% by volume of oil. Impregnation is achieved by vacuum techniques or by soaking the parts in heated oil. (See pages 12 and 15 for further engineering information on this subject).

Porosity

Porosity is the percentage of void volume in a bearing. It is the complement of density. A bearing which is 85% of theoretical density will have 15% porosity. Porosity in bearings is present as a network of interconnected pores that extend to the surface, like a sponge. Interconnected porosity is important to the performance of self-lubricating bearings and is part of the specification for those types of materials.

It shall be calculated as follows:

$$P_o = \frac{(B-A) \rho_w}{(B-C+E) \times S} \times 100$$

Where:

P_o = interconnected porosity in volume percent.

A = mass of oil-free sample in air, in grams.

B = mass of oil-impregnated sample in air, in grams.

C = mass of oil-impregnated sample suspended and immersed in water, in grams.

S = density of impregnant at the temperature of test, in g/cm³.

E = mass (tare) of suspending wire or basket immersed in water, in grams, and

ρ_w = density of distilled water at the temperature of test.

Note 1. All weighings are made by analytical balance to nearest 0.1%.

Note 2. The effect of the surface tension of water in weighing the test sample should be minimized by the addition of 0.1-0.2 weight % of a wetting agent to the distilled water.

Note 3. The sample mass should be at least 2 grams.

Note 4. Diameter of a fine wire used to suspend samples in water should be 0.005 in. to 0.010 in. (0.12 mm to 0.25 mm). During immersion no air bubbles should adhere to the sample or to the wire.

Note 5. Water density is determined from the following table:

TABLE A. Effect of Temperature on Water Density			
Temperature		Temperature	
°C	ρ_w g/cm ³	°F	ρ_w g/cm ³ *
15	0.9991	60	0.9990
16	0.9989	62	0.9988
17	0.9988	64	0.9986
18	0.9986	66	0.9984
19	0.9984	68	0.9982
20	0.9982	70	0.9980
21	0.9980	72	0.9977
22	0.9978	74	0.9974
23	0.9975	76	0.9972
24	0.9973	78	0.9969
25	0.9970	80	0.9966
26	0.9968	82	0.9963
27	0.9965	84	0.9959
28	0.9962	86	0.9956
29	0.9959		
30	0.9956		

NOTE: The values of ρ_w shown are taken from, "Metrological Handbook 145, Quality Assurance for Measurements", 1990, NIST, p.9.10, and represent the values in air at one atmosphere pressure.

See MPIF Standard 42 for additional details

Oil Content by Volume, As Received

Oil content (P_1) represents the volume percent of oil that fills the porosity of the as-received bearing.

It shall be calculated as follows:

$$P_1 = \frac{(J-A) \rho_w}{(B-C+E) \times S} \times 100$$

Where:

P_1 = oil content of the as-received bearing, in volume percent.

J = mass of the as-received, oil-impregnated sample in air, in grams.

A = mass of oil-free sample in air, in grams.

B = mass of oil-impregnated sample in air, in grams.

C = mass of oil-impregnated sample suspended and immersed in water, in grams.

S = density of impregnant at the temperature of test, in g/cm³.

E = mass (tare) of suspending wire or basket immersed in water, in grams, and

ρ_w = density of distilled water at the temperature of test.

Note 1. All weighings are made by analytical balance to nearest 0.1%.

Note 2. The effect of the surface tension of water in weighing the test sample should be minimized by the addition of 0.1-0.2 weight % of a wetting agent to the distilled water.

Note 3. The sample mass should be at least 2 grams.

Note 4. Diameter of a fine wire used to suspend samples in water should be 0.005 in. to 0.010 in. (0.12 mm to 0.25 mm). During immersion no air bubbles should adhere to the sample or to the wire.

Note 5. Water density is determined from Table A on page 4. See MPIF Standard 42 for additional details.

Density

Density is expressed in grams per cubic centimeter (g/cm³). "Dry density" is the mass per unit volume of an unimpregnated P/M bearing. "Wet density" is the mass per unit volume of a P/M bearing impregnated with oil or other non-metallic materials. Normally, density of structural components is reported on a dry unimpregnated basis and density of bearings on a fully impregnated basis. (See MPIF Standard 42 for additional details.)

A method commonly used is as follows:

$$D_{\text{dry}} = \frac{A \rho_w}{B-C+E}$$

$$D_{\text{wet}} = \frac{B \rho_w}{B-C+E}$$

Where:

D = density, in grams per cubic centimeter.

A = mass of the oil-free sample in air, in grams.

B = mass of the oil-impregnated sample in air, in grams.

C = mass of the oil-impregnated sample suspended and immersed in water, in grams.