



American
Gear Manufacturers
Association

Technical Resources

AGMA Information Sheet

Metallurgical Specifications for Powder Metallurgy, PM, Steel Gearing

American
Gear

Manufacturers
Association

Metallurgical Specifications for Powder Metallurgy, PM, Steel Gearing
AGMA 942-A12

CAUTION NOTICE: AGMA technical publications are subject to constant improvement, revision, or withdrawal as dictated by experience. Any person who refers to any AGMA technical publication should be sure that the publication is the latest available from the Association on the subject matter.

[Tables or other self-supporting sections may be referenced. Citations should read: See AGMA 942-A12, *Metallurgical Specifications for Powder Metallurgy, PM, Steel Gearing*, published by the American Gear Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, Virginia 22314, <http://www.agma.org>.]

Approved August 16, 2012

ABSTRACT

This information sheet provides the metallurgical requirements for powder metallurgy (PM) gearing. Four different powder metallurgy processes are identified: as-sintered, through hardened or sinter hardened, carburized case hardened, and induction hardened. In addition, the requirements are coded by process and class number, the latter based on the density of the PM gear teeth. Product requirements are tabulated in four data tables by process and class.

Published by

American Gear Manufacturers Association
1001 N. Fairfax Street, Suite 500
Alexandria, Virginia 22314

Copyright © 2012 by American Gear Manufacturers Association
All rights reserved.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without prior written permission of the publisher.

Printed in the United States of America

ISBN: 978-1-61481-031-5

Contents

Foreword	iv
1 Scope	1
2 Normative references	1
2.1 Gear related specifications	1
2.2 Steel related specifications	1
2.3 Powder metallurgy related specifications	2
3 Definitions	2
4 Procedures	9
4.1 Carbon and surface carbon	10
4.2 Chemical composition	10
4.3 Decarburization	10
4.4 Density	10
4.5 Effective case depth	10
4.6 Hardness	10
4.6.1 Apparent hardness	10
4.6.2 Case hardness	10
4.6.3 Core hardness	11
4.7 Intergranular oxidation	11
4.8 Mechanical testing	11
4.9 Metallography and microstructure analysis	11
4.10 Surface finger oxides	11
4.11 Non-destructive testing	11
4.12 Tooth crush testing	11
5 Metallurgical requirements	11
5.1 As-sintered gearing	13
5.2 Through hardened including sinter hardened gearing	13
5.3 Carburized case hardened gearing	14
5.4 Induction hardened gearing	14
5.5 Guidance in using grade specifications	16
5.5.1 Priority of conflicting standards	16
Bibliography	17

Figures

1 Gear tooth pin crush samples	3
2 Intergranular oxidation in a powder metallurgy gear	4
3 Non-martensitic transformation products (NMTP) in a carburized steel gear	5
4 Non-martensitic transformation products associated with Ni-rich regions (circled) of PM hybrid steel FLN2-4405 at 7.3 g/cm ³ density (nital etch)	5
5 Photomicrograph of PM steel with 7.3 g/cm ³ density illustrating porosity, as shown by arrow (unetched)	6
6 Photomicrograph of surface densification on the (a) tooth flank and the (b) tooth root (unetched)	6
7 Photomicrograph of surface densification in a spur gear (unetched)	7
8 Photomicrograph of PM steel illustrating porosity morphology, as shown by arrow (etched)	7
9 Retained austenite in FX-1008 steel (estimated at 5%, 1% nital, 4% picral etch)	8
10 Retained austenite in FX-1008 steel (estimated at 20%, 1% nital, 4% picral etch)	8
11 Surface finger oxide in a powder forged steel part (unetched)	9

Tables

1 AGMA PM grade classification system	12
2 Metallurgical characteristics for as-sintered gearing	13
3 Metallurgical characteristics for through hardened or sinter hardened gearing	14
4 Metallurgical characteristics for carburized case hardened gearing	15
5 Metallurgical characteristics for induction hardened gearing	16

Foreword

[The foreword, footnotes and annexes, if any, in this document are provided for informational purposes only and are not to be construed as a part of AGMA Information Sheet, 942-A12, *Metallurgical Specifications for Powder Metallurgy, PM, Steel Gearing*.]

This document provides the critical metallurgical characteristics of powder metallurgy, PM, gears that will ensure the metallurgical quality of the teeth. The format of the document has been modeled on AGMA 923-B05, *Metallurgical Specifications for Steel Gearing*, and may be considered a companion document for gear designers seeking the same type of metallurgical features in PM steel gears as found in wrought gears. By using AGMA 923-B05 as a guide the gear designer can easily evaluate a PM material-process system based on the familiar features of wrought steel gears.

This information sheet is dedicated to Howard Sanderow. His participation and inspiration led to the development of this information sheet. His thoroughness and enthusiasm for the powder metallurgy industry, along with his contributions, as well as the contributions of his fellow committee members brought out the best from the committee as a whole.

The first draft of AGMA 942-A12 was made in May, 2007. It was approved by the AGMA membership in August 16, 2012.

Suggestions for improvement of this standard will be welcome. They should be sent to the American Gear Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, Virginia 22314.

PERSONNEL of the AGMA Powder Metallurgy Gearing Committee

Chairman: Paul A. Crawford MTD Products, Inc.
Vice Chairman: Ernie Reiter Web Gear Services Ltd.

ACTIVE MEMBERS

J.R. Hamilton Cloyes Gear & Products, Inc.
S. Haye Lovejoy, Inc.
I. Laskin (Deceased)
R.G. Layland, II Precision Gage Company
D.D. Osti Metal Powder Products Company
R. Rupprecht Metal Powder Products Company
R. Slattery Capstan Atlantic
M.T. Smith Capstan Atlantic

American Gear Manufacturers Association – Metallurgical Specifications for Powder Metallurgy, PM, Steel Gearing

1 Scope

This information sheet recommends powder metallurgy, PM, steel materials and metallurgical quality characteristics for use in specifying PM gearing. It identifies specifications and requirements for various PM steel materials for as-sintered, through hardened or sinter hardened, carburized case hardened, and induction hardened gearing. Characteristics covered include material composition, density, sinter processing (conventional, high temperature and sinter hardening), secondary heat treatments and post heat treatment processing, and their associated inspections. Topics related to gear design and rating such as case depth, stress (bending fatigue and contact fatigue capacity) and quality control systems are not included.

2 Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this information sheet. At the time of publication, the editions were valid. All publications are subject to revision, and the users of this information sheet are encouraged to investigate the possibility of applying the most recent editions of the publications listed.

2.1 Gear related specifications

AGMA 923-B05, *Metallurgical Specifications for Steel Gearing*

AGMA 938-A05, *Shot Peening of Gears*

2.2 Steel related specifications

ASTM A751-11, *Standard Test Methods, Practices and Terminology for Chemical Analysis of Steel Products*

ASTM E3-11, *Standard Guide for Preparation of Metallographic Specimens*

ASTM E18-11, *Standard Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E92-04, *Standard Test Method for Vickers Hardness of Metallic Materials*

ASTM E384-11, *Standard Test Method for Knoop and Vickers Hardness of Materials*

ASTM E407-07, *Standard Practice for Microetching Metals and Alloys*

ASTM E415-08, *Standard Test Method for Atomic Emission Vacuum Spectrometric Analysis of Carbon and Low-Alloy Steel*

ASTM E1019-11, *Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques*

ASTM E1077-01, *Standard Test Method for Estimating the Depth of Decarburization of Steel Specimens*

ASTM E1184-10, *Standard Practice for Determination of Elements by Graphite Furnace Atomic Absorption Spectrometry*