



American  
Gear Manufacturers  
Association

**AGMA 920-B15**  
(Revision of AGMA 920-A01)

## **AGMA Information Sheet**

# **Materials for Plastic Gears**

**American  
Gear  
Manufacturers  
Association**

***Materials for Plastic Gears***

AGMA 920-B15

**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 920-B15, *Materials for Plastic Gears*, published by the American Gear Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, Virginia 22314, <http://www.agma.org>.]

**ABSTRACT**

The purpose of this document is to aid the gear designer in understanding the unique physical, mechanical and thermal behavior of plastic materials. The use of plastic materials for gear applications has grown considerably due to cost and performance issues. Growing markets include the automotive, business machine, and consumer-related industries. Topics covered include general plastic material behavior, gear operating conditions, plastic gear manufacturing, tests for gear related material properties, and typical plastic gear materials. There are no quantitative details on material properties or any comparative evaluations of plastic types. Such specific information is left to be provided by material suppliers and gear manufacturers.

Published by

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

Copyright © 2015  
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: 1-55589-048-3

## Contents

Foreword .....	v
1 Scope.....	1
2 General nature of plastic materials.....	1
2.1 Elastic and viscoelastic behavior .....	1
2.2 Response to load .....	1
2.3 Effect of rate of load application .....	2
2.4 Effect of temperature .....	2
2.5 Effect of moisture .....	3
3 Gear operating conditions and related material properties .....	3
3.1 General operating conditions.....	3
3.2 Special operating conditions.....	5
3.3 Vibration and noise .....	8
4 Gear manufacturing and related material properties.....	9
4.1 Manufacture by machining.....	9
4.2 Injection molding process .....	11
5 Tests for gear related material properties .....	13
5.1 Strength properties .....	13
5.2 Wear and frictional characteristics.....	21
5.3 Thermal properties.....	23
5.4 Environmental properties.....	25
5.5 Miscellaneous properties .....	26
6 General description of plastic materials .....	28
6.1 Classification.....	28
6.2 Additives .....	31
6.3 Available forms .....	32
7 Plastic materials widely used for gears .....	33
7.1 Engineering thermoplastics .....	33
7.2 Thermosets.....	34
8 Material selection procedure .....	34
8.1 Environmental considerations.....	35
8.2 Mechanical considerations .....	37
8.3 Regulatory requirements .....	38
8.4 Manufacturing considerations.....	38
8.5 Cost considerations .....	38
8.6 Quality.....	40

## Annexes

Annex A Bibliography.....	42
---------------------------	----

## Tables

Table 1 – Additives in plastics for molded gears .....	32
Table 2 – Plastic materials for molded gears.....	34
Table 3 – Plastic materials for machined gears .....	34

## Figures

Figure 1 – Representative creep behavior of ductile plastic .....	2
Figure 2 – Representative creep behavior of non-ductile plastic.....	2
Figure 3 – Effect of strain rate and temperature on stress-strain curves.....	2
Figure 4 – Typical fatigue curve (NOTE: Linear scale used for stress axis.).....	3
Figure 5 – Effect of temperature on stress vs. strain for acetal (POM) .....	5
Figure 6 – Effect of moisture on stress vs. strain for nylon 6-6 (PA 6,6) at 23°C .....	6
Figure 7 – Polymer impact strength as a function of temperature .....	8
Figure 8 – Simple gear with three gates .....	12
Figure 9 – ASTM D638 Type 1 tensile specimen .....	13
Figure 10 – Typical DMA curves normalized at 23°C .....	15
Figure 11 – Tensile DMA .....	16
Figure 12 – DMA, amorphous polymers .....	17
Figure 13 – DMA, semi-crystalline polymer .....	17
Figure 14 – Flexural fatigue specimen.....	19
Figure 15 – Representations of creep – strain vs. time .....	21
Figure 16 – Representations of creep – creep modulus vs. time .....	21
Figure 17 – Representations of creep – isochronous stress vs. strain.....	21
Figure 18 – ASTM D-3702 thrust washer wear and friction test.....	22
Figure 19 – Two-dimensional representation of crystalline and amorphous thermoplastics.....	29
Figure 20 – Modulus behavior vs. temperature of crystalline and amorphous resins, neat and glass fiber reinforced .....	30

## 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 920-B15, *Materials for Plastic Gears*.]

Plastic materials differ considerably from metals in performance and processing. Many of the important differences, especially those that are critical to gear applications, are not widely recognized. This is partly because many plastic materials specialists are not familiar with gear requirements. Similarly, many gear specialists are not familiar with plastic material characteristics. Hence the need for reference material which will help bridge these gaps.

The AGMA Plastics Gearing Committee has brought together technical representatives from plastic material suppliers, gear manufacturers and designers. This document represents their efforts to further this exchange of information. It will not supply answers to many of the questions that arise in the application of plastic materials to gears, but it should encourage inquiry and information exchange.

One issue that requires special attention is the availability of plastic material properties in the form most suitable for plastic gear design. This includes properties that are counterparts of those used in the design of metal gears, and those that are special to plastic materials in these applications. To a very large extent, plastic gear designers have access only to property data taken from ASTM tests as reported by material suppliers even though such tests were created to meet other objectives. It was therefore judged essential to include brief descriptions of these tests supplemented by comments on any limitations of such test data when applied to gears. Various industry initiatives are now underway to develop gear specific property data, which will in time supplement the information provided here.

The first draft of AGMA 920-A01 was made in 1993. It was approved by the AGMA membership in October 2000 and approved for publication by the Technical Division Executive Committee on October 22, 2000.

This edition of the information sheet, AGMA 920-B15, was created to:

- revise definition of  $i$  found in Clause 5.1.3.3;
- renumber figures to meet current style guidelines;
- revise title of Figure 12, which previously appeared as Figure 11 in 920-A01.

The first draft of AGMA 920-B15 was made in January 2015. It was approved by the AGMA Plastics Gearing Committee in October 2015.

Suggestions for improvement of this standard will be welcome. They may be submitted to [tech@agma.org](mailto:tech@agma.org).

**PERSONNEL of the AGMA Plastics Gearing Committee**

Chairman: Richard R. Kuhr .....Richard Kuhr Gear Consulting and Training  
Vice Chairman: Ernie Reiter.....Web Gear Services Ltd.

**ACTIVE MEMBERS**

T. Barry.....Phillips-Moldex Company  
F. Eberle.....Hi-Lex Controls Inc.  
G. Ellis.....ABA-PGT, Inc.  
R.G. Layland .....Precision Gage Company  
T. Padden.....DSM Engineering Plastics  
D. Sheridan .....Celanese Engineered Materials (Michigan)  
Z.P. Smith.....Retired  
B. Stringer .....Gleason Plastic Gears  
E.H. Williams, III.....SABIC Innovative Plastics  
J.H. Winzeler.....Winzeler Gear

## American Gear Manufacturers Association –

# Materials for Plastic Gears

## 1 Scope

This information sheet provides descriptions of plastic materials commonly used in gearing. It relates the general properties of these materials to typical operating conditions of gears. Properties that relate to the manufacturing processes of machining and molding are discussed, including the property of shrink rate in molding. It also describes the types of tests that are customarily used to obtain published values of these properties.

It is intended that this information sheet serve only as an introductory guide to the designer of plastic gears when it comes to selecting candidate materials. The designer is advised to look to material suppliers and plastic gear manufacturers for their expert guidance on selecting materials for specific applications. It is also important to recognize that thorough application testing is often needed to confirm the suitability of a material choice.

Only a limited number of plastic materials are mentioned here as commonly used for gears. Gears have been made from other plastics as well, but generally because some special material property or commercial consideration was judged essential to a particular application. It is also possible that the suitability of other materials for gears has not yet been recognized. Furthermore, new plastic materials are continually being developed and some, no doubt, will prove themselves as important additions to those discussed in this information sheet.

## 2 General nature of plastic materials

Although plastic materials are successfully used in place of metals in load carrying applications such as gears, there are important differences between the two types of materials. These differences generally appear in combination and can have a significant effect on plastic gear performance.

### 2.1 Elastic and viscoelastic behavior

Most structural metals behave as essentially elastic materials. Plastics, on the other hand, behave as a combination of elastic and viscous materials, with the balance varying considerably with the type of plastic, its molecular structure, and the type, quantity, and orientation of any additives. This special nature of plastic materials does not interfere with their use in a very wide range of applications which benefit from their many other special properties. It does, however, require a thorough understanding of reported material properties data and their relationship to the specific application.

### 2.2 Response to load

When load is applied to elastic materials such as steel, the resulting deformation is essentially immediate, constant over time, independent of a wide range of temperature, and fully recoverable when the load is removed. When the material has a viscous component combined with the elastic, the initial deformation will increase with time under load (creep deformation) and will depend to a considerable degree on temperature. When the load is removed, there will be some delayed recovery and, possibly some permanent deformation.

The time dependent deformation of ductile polymers under constant load is quantified in creep testing. A family of curves resulting from varying the constant load (stress) and recording the increasing creep strain is shown in Figure 1. As the polymer is held under constant stress (load) over time, the creep strain initially increases at a rapid rate (primary creep) and then plateaus to a significantly lower creep strain rate (secondary creep). For nonductile polymers the material will experience creep rupture while deforming under secondary creep (see Figure 2). However, for ductile polymers, the material will