AMERICAN GEAR MANUFACTURERS ASSOCIATION

Materials for Plastic Gears

AGMA 920-01

AGMA INFORMATION SHEET

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American Gear Manufacturers Association

Materials for Plastic Gears
AGMA 920-A01

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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 nor any comparative evaluations of plastic types. Such specific information is left to be provided by material suppliers and gear manufacturers.

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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 920-A01, *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.

Suggestions for improvement of this document will be welcome. They should be sent to the American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314.

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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 1a. 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 1b). However, for ductile polymers, the material will experience another increase in creep strain rate