

Study of the Correlation Between Theoretical and Actual Gear Fatigue Test Data on a Polyamide

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American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

DSM Engineering Plastics is a producer of nylon plastic materials used for gears. In the past two years, they have been running fatigue tests on actual molded gears in order to provide design data. This experiment used spur gears that are fully lubricated and temperature controlled. Testing for the materials has been done at DSM Research, while the gear tests are being conducted at the University of Berlin. The purpose of the testing is to see if there is a good correlation between fatigue data, generated on test bars, versus the actual fatigue performance in a gear.

In order to do this, the theories of gear calculations to get root stresses also had to be examined. Advanced FEA showed that there are corrections needed to account for high loading or high temperatures in plastic gears. This corroborates other work within the industry.

With proper corrections to get accurate root stresses, there can be shown good correlation between tensile bar fatigue and actual spur gear fatigue.

The chemistry of various nylons used in gears is explained. A high crystalline nylon has been found which is an excellent material for gears in demanding applications and can withstand high torques and operating temperatures. The material has a crystallinity of 70%, which results in very good wear properties and excellent retention of mechanical properties (strength, stiffness, and fatigue) especially at elevated temperatures.

Several commercial gear applications are currently utilizing these properties. These will be shown to demonstrate the benefits and manufacturability of this material.

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Introduction

Plastic gears have gained in their use and are now seen in the home, office, and automobile. They have gained acceptance due to manufacturing methods such as injection molding which produces economical yet very reproducible gears. Noise reduction and corrosion resistance are also reasons why plastic gears are used. Plastic gears are now not only used for light loaded applications such as printers and toys, but for highly loaded or elevated temperature environments, such as automotive starter gears, turbo actuators, electronic throttle control, etc.

With the higher demands it would be desirable to have increased predictive ability especially with regards to long term endurance capability. To this end, a study was done to look at fatigue on actual plastic gears and relate that to tensile bar fatigue. Tensile fatigue is quicker and easier to generate. The materials suppliers usually have this data already available. It is also independent of geometry as the stress on tensile specimens is simply the load divided by the cross sectional area. The goal is to have a method where root stresses could be calculated and compared to the more readily available tensile fatigue for prediction of gear life.

Critical to this predictive capability then is the methods for calculation of gear tooth root bending stress. Finite Element Analysis (FEA) and semi-analytic (e.g. ISO standards, KISSsoft) must be compared and validated for use in heavily loaded or high temperature plastic gears.

Methods

The portion of the fatigue study that is on the actual plastic gears was conducted at the University of Berlin in Germany, while the tensile bar fatigue was

performed at DSM Engineering Plastics in Geleen, the Netherlands. The gear test parameters were selected to minimize wear and thus isolate the failure mode in the gear to true fatigue. The test rig is a 2 closed-loop (4-square) tester with dip lubrication. The oil lubrication is maintained at 140 C. This is typical automotive under hood temperatures and motor oil was utilized as the lubricant. The gears are spur with the driver being steel and the driven plastic. They are both module of 2, face width of 12 mm, with a 20 degree pressure angle. A standard profile according to DIN 867 was used.

The FEA was conducted on the same gear pair using a commercially available software package, MSC.MARC. The gears were modeled as 2 discs with 4 teeth each, under plain strain conditions. 80,000 first order quads were used, with mesh refinements in the tooth and at the surfaces in order to also capture contact stresses, see figures 1, 2 and 3. Linear elastic modeling was used for the initial runs.

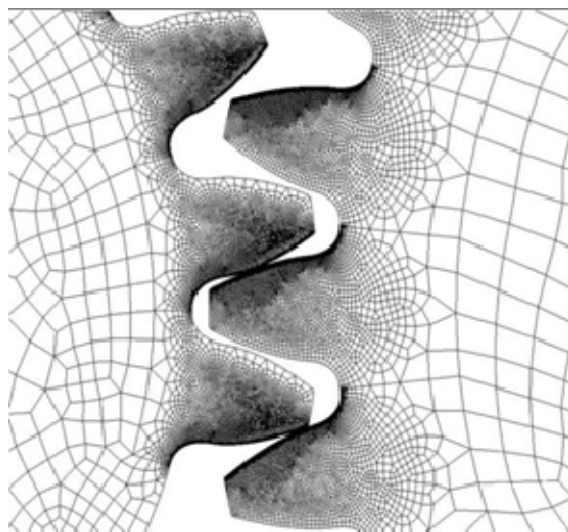


Figure 1. Finite element mesh