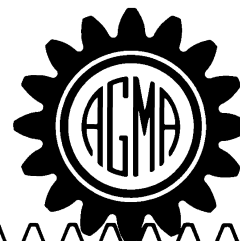


Evaluation of the Scuffing Resistance of Isotropic Superfinished Precision Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

Evaluation of the Scuffing Resistance of Isotropic Superfinished Precision Gears

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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

The high performance required from aerospace gears places stringent requirements upon the metallurgical quality, geometry, and surface finish of mating parts. In an effort to meet their mission requirements, aerospace gears are often engineered to operate near the upper bounds of their theoretical design allowables. Due to this, scuffing is a primary failure mode for aerospace gears.

It was previously shown that specimens having an isotropic superfinish using chemically accelerated vibratory finishing had an improved performance in Rolling/Sliding Contact Fatigue (R/SCF) testing. Isotropic superfinishing improved R/SCF resistance up to nine times that of baseline test specimens. These tests also demonstrated the ability to successfully carry 30 percent higher loads for at least three times the life of the baseline samples.[1]

A study was then conducted on actual gears having an isotropic superfinish. This study showed isotropic superfinishing technology increased a gear's resistance to contact fatigue by a factor of three, and increased bending fatigue resistance by at least 10 percent. [2] This increase in gear performance translates to reduced operation and sustainment costs, and also offers the potential for weight reduction in new transmission designs.

The present paper will discuss an additional study which is underway to determine and compare the scuffing resistance of isotropic superfinished aerospace gears to that of baseline ground gears. Sample gears were made from case carburized SAE 9310. These tests were conducted using a method that progressively increases lubricant temperature until scuffing occurs, rather than the traditional load increasing method used in FZG testing rigs. The results of the current testing reveals that isotropic superfinished SAE 9310 specimens show at least a 40° F higher lubricant temperature at the point of scuffing compared to as-ground baseline gears. Based on these results and the previous studies, it was concluded that this isotropic superfinishing technology should be incorporated in all future aerospace gear designs. A later paper will report on similar scuffing testing performed on AMS 6308 gears due to run-outs achieved by both the baseline and isotropic superfinished samples during the current procedure.

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Introduction

The high performance required from aerospace gears places stringent requirements upon the metallurgical quality, geometry, and surface finish of mating parts. In an effort to meet these requirements, mating parts are often designed to operate near the upper bounds of their theoretical design strength envelope. Precision grinding after heat treatment is a standard practice used in the aerospace industry in order to obtain the necessary final tolerances demanded by the need to provide higher power density levels, without increasing component size or weight.

Friction and wear between two sliding surfaces are in large part dependent upon the finish of the surface. In particular, the roughness of the surface has a strong influence on the coefficient of friction. Overcoming friction, especially in high performance applications, involves stringent lubrication requirements. Examples of applications requiring exceptional surface finish include gears and bearings. A new surface finishing technology, known as Isotropic Superfinish (ISF[®]), has proven to be effective at reducing gear wear while at the same time reducing lubrication requirements. This revolutionary technology was developed for military helicopter applications as part of both the Instrumented Factory for Gears (INFAC) and Power Transfer Systems Manufacturing (PTSM) programs, sponsored by the US Army Aviation and Missile Command (AMCOM) at Redstone Arsenal. Initial testing performed by Alion Science and Technology Corporation (formerly IIT Research Institute), under the Army MANTECH program (DAAJ09-95-C-0546), demonstrated that the isotropic superfinish process improved performance in Rolling/Sliding Contact Fatigue (R/SCF) specimens. This testing revealed that superfinished samples yielded improvements of up to 9 times the contact fatigue life as compared to baseline test specimens. Isotropic superfinished specimens have also demonstrated the ability to

successfully carry 30 percent higher loads for at least 3 times the life of the baseline samples^{NO TAG}.

These promising INFAC results led to the comparison testing of actual aerospace quality gears in both baseline (final ground) and isotropic superfinish conditions. This second project, conducted under the PTSM Program was titled, Engineered and Superfinished Surfaces for Precision Aerospace Applications (Manufacturing Technology Report, October 30, 2002, Contract No. DAAH23-00-C-R232). This project demonstrated the ability of isotropic superfinishing to increase a gear's resistance to contact fatigue by a factor of 3, and to increase bending fatigue resistance by at least 10 percent. This increase in gear performance translates to reduced operation and sustainment costs and offers the potential for weight reduction in new transmission designs. However, the effect of the isotropic superfinish process on scuffing resistance of gears remained unknown. This lack of knowledge was an obstacle to implementation of the process. Consequently, it was determined that data on scuffing resistance must be obtained.

Background

The isotropic superfinish process is a commercially available process that when applied to helicopter transmission gears, can result in improved gear tooth bending and contact fatigue resistance as well as reduced noise, vibration, and operating temperatures. [3] [4] The isotropic superfinish process provides a uniform surface finish by reducing the peaks on the surface through the use of chemically accelerated vibratory finishing.

A detailed description of chemically accelerated vibratory finishing using high density, non-abrasive media has been published in the past. [5] The following is a brief summary of the technique. The isotropic superfinish is produced in vibratory finishing bowls or tubs. An active chemistry is used in the vibratory machine in conjunction with high density,

non-abrasive ceramic media. When introduced into the machine, this active chemistry produces a stable, soft conversion coating on the surface of the metal gears being processed. The rubbing motion across the gears developed by the machine and media effectively wipes the conversion coating off the “peaks” of the gears’ surfaces, but leaves the “valleys” untouched. No finishing occurs where media is unable to contact or rub. The conversion coating is continually re-formed and rubbed off during this stage producing a surface smoothing mechanism. This process is continued in the vibratory machine until the surfaces of the gears are free of asperities or until the surface attains the desired level of finish. At this point, the active chemistry is rinsed from the part and the gears are dipped in rust preventive.

The Army ManTech projects discussed above have also shown that the isotropic superfinish process is robust and suitable for production environments. It does not require any unusual or financially significant unique tooling, fixtures, or equipment. The budgetary cost for a “Turn Key” isotropic superfinish processing system is between \$45,000 and \$75,000. The gear performance benefits of this process, coupled with its suitability and affectability for shop floor use supports additional testing of isotropic superfinish gears to help pave the way for implementation of the technology in Army weapon systems.

As such, Sikorsky Aircraft Corporation and REM Chemicals, Inc., teaming with the United States Army and Navy, conducted a 200-hour endurance test on the H-60 tail and intermediate gearboxes with the isotropic superfinish process applied to the bevel gears. Testing included documentation of noise and vibration levels along with determination of the effects on gearbox temperature. Results of the H-60 tests are not publicly available at this time (AATD RDS-21 Program, Agreement Number DAAH10-01-2-0032). Sikorsky also ran an in-house test on an S-76C+ main gearbox final stage spur bull gear and mating two pinions that had been isotropic superfinish processed. Results show a 3.7 dB noise reduction for the 2nd Stage Bevel Gear, and a 7.0 dB noise reduction for the 3rd Stage Bull Gear (at 1 x Bull gear clash frequency), and a 5° F drop in oil out temperature as a result.

Additional testing is scheduled under the AATD RDS-21 and the Coating Enables High Power Den-

sity Transmissions (NIST) programs to further demonstrate and document the improvements in gear tooth life in bending and Hertzian contact. Gear tooth root surface finish improvement has been shown to increase the bending fatigue allowable. Isotropic superfinish for bearings will also be investigated under the RDS-21 program in the future. However, there was still a need for a program that would determine the scuffing resistance of the isotropic superfinish on gear tooth surfaces. With improved scuffing resistance criteria, new transmission designs with isotropic superfinish gears can be optimized for gear tooth strength and lubrication requirements, which will improve overall power density.

Objectives

The objective of this PTSM Project was to determine and compare the scuffing resistance of isotropic superfinished precision aerospace gears to that of conventionally processed baseline samples. Sample gears were made from SAE 9310 gear steel for this study. It was expected that this project would result in the quantification of the scuffing resistance of isotropic superfinished precision gears. It was further expected that the results of this project would lead to the implementation of the isotropic superfinish technology, if the scuffing resistance of the superfinished gears was shown to be equivalent or superior to those gears that were conventionally processed.

Research Approach

Alion Science and Technology Corporation, REM Chemicals, Inc. and Sikorsky Aircraft Corporation agreed to participate in this project as a team. Alion Science and Technology Corporation was responsible for project management, REM Chemicals Inc. for the isotropic superfinishing of the test gears and Sikorsky Aircraft Corporation for test gear procurement, testing and data analysis. The original test plan was as follows:

Fabrication

Sikorsky Aircraft Corporation was responsible to fabricate a total of twenty four (24), 4-inch pitch diameter test gears, per the agreed upon drawing. Aero Gear Corporation of Windsor, CT was selected as the manufacturer to fabricate the gears for these tests. The test gears were manufactured to the following specifications: