Gear Fatigue Testing

In this study, a new state-of-the-art gear contact durability test machine is developed to eliminate some key limitations, issues and inconveniences associated with conventional FZG machines. Based on lessons learned from prior in-house studies using conventional FZG machines, a number of requirements are specified. A new four-square concept is designed and fabricated to gain various advantages with respect to foot-print, temperature regulation, and long-lasting auxiliary components. The mechanical layout and out-of-the-loop torque application methodology are described along with the heat management and lubrication systems. Various new safety provisions are highlighted, in addition to a streamlined interim gear inspection procedure during long-cycle contact fatigue tests performed on these new machines. For demonstration purposes, the proposed machines are used to conduct an example contact fatigue test program to evaluate a stress-life curve of ground spur gears made of a typical automotive gear steel. The test procedures, test conditions and the test specimens are described. Various results containing digital images of the gear teeth, surface wear and roughness progression over the fatigue life of the gears are detailed. A detailed statistical analysis is presented to define a stress-life curve and confidence intervals. This example fatigue study confirms the suitability of the new machines to perform high-fidelity gear contact fatigue experiments.

Fatigue Testing and Analysis: Theory and Practice presents the latest, proven techniques for fatigue data acquisition, data analysis, and test planning and practice. More specifically, it covers the most comprehensive methods to capture the component load, to characterize the scatter of product fatigue resistance and loading, to perform the fatigue damage assessment of a product, and to develop an accelerated life test plan for reliability target demonstration. This book is most useful for test and design engineers in the ground vehicle industry. Fatigue Testing and Analysis introduces the methods to account for variability of loads and statistical fatigue properties that are useful for further probabilistic fatigue analysis. The text incorporates and demonstrates approaches that account for randomness of loading and materials, and covers the applications and demonstrations of both linear and double-linear damage rules. The reader will benefit from summaries of load transducer designs and data acquisition techniques, applications of both linear and non-linear damage rules and methods, and techniques to determine the statistical fatigue properties for the nominal stress-life and the local strain-life methods. Covers the useful techniques for component load measurement and data acquisition, fatigue properties determination, fatigue analysis, and accelerated life test criteria development, and, most importantly, test plans for reliability demonstrations Written from a practical point of view, based on the authors' industrial and academic experience in automotive engineering design Extensive practical examples are used to illustrate the main concepts in all chapters

Fatigue Test and Analysis of the F-100 Landing Gear. Appendices A and B.

Evaluation of Advanced Lubricants for Aircraft Applications Using Gear Surface Fatigue Tests

Heat Treating

Analysis of Micropitting on Prototype Surface Fatigue Test Gears

In this study, tooth bending fatigue lives of spur gears are studied both experimentally and theoretically. the primary focus id given to long-cycle fatigue performance of gears loaded under fully released codnitions (e.g. a sun or ring gear in a planetary gear set) and under fully reversed conditions (e.g. planet gears in a planetary gear set). As no experimental data as well as no experimental set-up existed to quantify the differences in fatigue lives of a gear subjected to these two different loading conditions, the main task of this investigation is to develop such an experimental methodology that enables such evaluations.For this, a new test gear geometry whose liekely failure mode is tooth breakage under long-cycle fatigue condtions is designed and developed. Novel gear fatigue test machinesthat are capable of testing gear soecimens under both fulled reversed and fully released loading conditions are designed and fabricated. Vibration-based diagnostics systems are devised to facilitate immediate suspension of tests at the onset of tooth conditions that have the least amount of dynamic influences, and to quantify unavoidable dynamic root stress factors at these operating condtions. The experimental metodology developed here is employed to conduct long-cycle fatigue experiments to generate stress-life curves for both fully released adn fully reversed loading conditions. These setd of data are analyzed statisticaly and compated to each other to estavlidj a filly reversed to fully release stress ratio that would result in tje same tooth bending fatigue life. This empirical ratio is implemented with kinematics of planetary gear sets to define ring-to-sun and planet-to-sun stress ratios as a function of desired gear set life such that each gear component has the same life expectancy. On the modeling side, multi-mesh deformable-body gear contact models of the test gears are developed under both loading conditions to predict stress tensor time histories along the root fillets. With available independently collected basic material data, measured residual stress profiles, and predicted stress time histories, representative multiaxial fatigue models are implemented to generate theoretical stress-life curves for both loading conditions. Comparisons of these predictions to measurements indicate that the models are reasonably accurate under fully reversed loading conditions while they overpredict fully released fatigue lives. At the end, recommendations are made towards further improvement of the theoretical and experimental methodologies presented in this work.

Surface pitting fatigue life tests were conducted with five lubricants, using spur gears made from a single lot of consumable-electrode vacuum melted (CVM) AISI 9310 steel. The gears were case carburized and hardened to a Rockwell C-60 and finish ground. The gear pitch diameter was 8.89 cm (3.5 in.). The lot of gears was divided into five groups, each of which was tested with a different lubricant. The test lubricants can be classified as synthetic polyol-esters with various viscosities and additive packages. Test conditions included a bulk gear temperature of 350 K (170 F), a maximum Hertz stress of 1. 71 GPa (248 ksi) at the pitch line, and a speed of 10,000 RPM. The following results were obtained. The lubricant with a viscosity that provided a specific film thickness greater than one and with an additive package produced far greater surface fatigue lives than lubricants with a viscosity that provided specific film thickness less than one. A low viscosity lubricant with an additive package produced gear surface fatigue lives equivalent to a similar base stock lubricant with 30 percent higher viscosity but without an additive package. Lubricants with the same viscosity and similar additive packages gave equivalent gear surface fatigue lives.

A Symposium

Gear Single Tooth Bending Fatigue Test

Software for Statistical Analysis of Weibull Distributions with Application to Gear Fatigue Data: User Manual with Verification

Power Transmissions

The Weibull distribution has been widely adopted for the statistical description and inference of fatigue data. This document provides user instructions, examples, and verification for software to analyze gear fatigue test data. The software was developed presuming the data are adequately modeled using a two-parameter Weibull distribution. The calculations are based on likelihood methods, and the approach taken is valid for data that include type I censoring. The software was verified by reproducing results published by others.

This section describes the experimental stress analysis phase of the landing gear fatigue investigation. The objectives of the experimental phase were: determine the peak stress points and associated stress concentration factors for fatigue analysis, and to investigate the relative merits of strain gages and photoelastic coatings for obtaining surface distributions near geometrical discontinuities on curved landing gear surfaces.

Surface Fatigue Life and Failure Characteristics of EX-53, CBS 1000M, and AISI 9310 Gear Materials

Surface Fatigue Lives of Case-Carburized Gears With an Improved Surface Finish

Fatigue Test and Analysis of the F-100 Landing Gear. Appendix C.

ASME 63-WA-199

Analytical and experimental studies were performed to investigate the effect of gear rim thickness on crack propagation life. The FRANC (FRacture ANalysis Code) computer program was used to simulate crack propagation. The FRANC program used principles of linear elastic fracture mechanics, finite element modeling, and a unique re-meshing scheme to determine crack tip stress distributions, estimate stress intensity factors, and model crack propagation. Various fatigue crack growth models were used to estimate crack propagation life based on the calculated stress intensity factors. Experimental tests were performed in a gear fatigue rig to validate predicted crack propagation results. Test gears were installed with special crack propagation gages in the tooth fillet region to measure bending fatigue crack growth. Good correlation between predicted and measured crack growth was achieved when the fatigue crack closure concept was introduced into the analysis. As the gear rim thickness decreased, the compressive cyclic stress in the gear tooth fillet region increased. This retarded crack growth and increased the number of crack propagation cycles to failure.

A diagnostic tool was developed for detecting fatigue damage to spur gears, spiral bevel gears, and rolling element bearings. This diagnostic tool was developed and evaluated experimentally by collecting oil debris data from fatigue tests performed in the NASA Glenn Spur Gear Fatigue Rig, Spiral Bevel Gear Test Facility, and the 500hp Helicopter Transmission Test Stand. During each test, data from an online, in-line, inductance type oil debris sensor was monitored and recorded for the occurrence of pitting damage. Results indicate oil debris alone cannot discriminate between bearing and gear fatigue damage.

Fatigue Test and Analysis of the F-100 Landing Gear. Appendix D.

Evaluation of High-contact-ratio Spur Gears with Profile Modification

Including Advances in Surface Engineering, an International Symposium in Honor of Professor Tom Bell, and Professor Jerome B. Cohen Memorial Symposium on Residual Stresses in the Heat Treatment Industry : Proceedings of the 20th Conference, 9-12 October 2000, St. Louis, Missouri

Investigation of the Effects of Manufacturing Variations and Materials on Fatigue Crack Detection Methods in Gear Teeth

Previous research provides qualitative evidence that an improved surface finish can increase the surface fatigue lives of gears. To quantify the influence of surface roughness on life, a set of AISI 9310 steel gears was provided with a near-mirror finish by superfinishing. The effects of the superfinishing on the quality of the gear tooth surfaces were determined using data from metrology, profilometry, and interferometric microscope inspections. The superfinishing reduced the roughness average by about a factor of 5. The superfinished gears were subjected to surface fatigue testing at 1.71-GPa (248-ksi) Hertz contact stress, and the data were compared with the NASA Glenn gear fatigue data base. The lives of gears with superfinished teeth were about four times greater compared with the lives of gears with ground teeth but with otherwise similar quality.

All of the critical technical aspects of gear materials technology are addressed in this new reference work. Gear Materials, Properties, and Manufacture is intended for gear metallurgists and materials specialists, manufacturing engineers, lubrication technologists, and analysts concerned with gear failures who seek a better understanding of gear performance and gear life. This volume complements other gear texts that emphasize the design, geometry, and theory of gears. The coverage begins with an overview of the various types of gears used, important gear terminology, applied stresses and strength requirements associated with gears, and lubrication and wear. This is followed by in-depth treatment of metallic (ferrous and nonferrous alloys) and plastic gear materials. Emphasis is on the properties of carburized steels, the material of choice for high-performance power transmission gearing.

Impact of the Fully Reversed Loading Condition on Gear Tooth Bending Strength
Handbook of Fatigue Testing
Pitting Fatigue Characteristics of AISI M-50 and Super Nitralloy Spur Gears
NASA Technical Paper

The fatigue life of a gear tooth can be thought of as the sum of the number of cycles required to initiate a crack, N(sub i), plus the number of cycles required to propagate the crack to such a length that fracture occurs, N(sub p). The factors that govern crack initiation are thought to be related to localized stress or strain at a point, while propagation of a fatigue crack is a function of the crack tip parameters such as crack shape, stress state, and stress intensity factor. During a test there is no clear transition between initiation and propagation. The mechanisms of initiation and propagation are quite different and modeling them separately produces a higher degree of accuracy, but then the question that continually arises is 'what is a crack?' The total life prediction in a fracture mechanics model presently hinges on the assumption of an initial crack length, and this length can significantly affect the total life prediction. The size of the initial crack is generally taken to be in the range of 0.01 in. to 0.2 in. Several researchers have used various techniques to determine the beginning of the crack propagation stage. Barhorst showed the relationship between dynamic stiffness changes and crack propagation. Acoustic emissions, which are stress waves produced by the sudden movement of stressed materials, have also been successfully used to monitor the growth of cracks in tensile and fatigue specimens. The purpose of this research is to determine whether acoustic emissions can be used to define the beginning of crack propagation in a gear using a single-tooth bending fatigue test. Wheitner, Jeffrey A. and Houser, Donald R. Unspecified Center ACOUSTIC EMISSION; ACOUSTIC MEASUREMENT; BENDING FATIGUE; CRACK PROPAGATION; FATIGUE LIFE; FATIGUE TESTING MACHINES; FRACTURE MECHANICS; GEAR TEETH; NONDESTRUCTIVE TESTS; BEND TESTS; CRACKS; DETECTION; FATIGUE TESTS; STIFFNESS; STRESS WAVES...

Contact fatigue failure is a common problem experienced in many applications such as bearings, gears, and railway tracks. In recent years, research companies have developed finishing processes that aim to improve components' contact fatigue life. Preliminary rolling contact fatigue tests have shown that superfinishing processes could potentially improve a component's contact fatigue life by 300 %. However, before these technologies can move from the laboratories to industrial platforms, more tests are needed to verify the claim. The objective of the work herein is to discuss the completion and verification of a sliding-rolling contact fatigue (S-RCF) test rig. This project is funded by the U.S. Army to assess the real benefit of superfinishing on the contact fatigue life of gears used in helicopter transmission boxes. The proposed tester design uses three rollers around a specimen, a hydraulic loading mechanism, and two servo motors. This configuration of the S-RCF tester allows for shorter testing time, more flexible testing parameters such as any combination of slide-roll ratio between the surfaces, any operating speed, and dry or lubricated testing conditions. Failure is detected with a state-of-the-art eddy current crack detection system, which can also be used to monitor and investigate crack growth for different materials, levels of superfinish, and operating conditions. Preliminary tests on a common gear material (AISI 8620 steel) were performed to assess the mechanical limits as well as the control software performance. This paper presents the detailed development and validation of the tester. It discusses issues involved with servo controllers, electronic gear ratio, and their ability to provide precise speed and slip ratios.

A Hydraulic Fatigue Testing Machine for Gear Teeth. [With Illustrations.].

Development of a Sliding-Rolling Contact Fatigue Tester

Fatigue Test and Analysis of the F-100 Landing Gear

Fatigue Testing and Analysis

A static strength analysis is performed using revised and up-dated ground loads for the new F-100 landing gear, as redesigned under the direction of OOAMA, Hill Air Force Base, Ogden, Utah. No zero or negative margins of safety are found. The fatigue life of the redesigned portions of the gear is found to meet the requirement of 7,000 hours of trouble free service upon the basis of the results of full scale fatigue tests. A computer program using Miner's Rule is used to predict the laboratory fatigue failures which did occur as well as to predict a service life for sections not having a laboratory failure history. Strain gages and photostress were used to obtain experimental stress concentration factors.

Results of using vibration based methods to detect gear tooth fatigue cracks are presented. An experimental test rig was used to fail a number of spur gear specimens through bending fatigue. The gear tooth fatigue crack in each test was initiated through a small notch in the fillet area of a tooth on the gear. The primary purpose of these tests was to verify analytical predictions of fatigue crack propagation direction and rate as a function of gear rim thickness. The vibration signal from a total of three tests was monitored and recorded for gear fault detection research. The damage consisted of complete rim fracture on the two thin rim gears and single tooth fracture on the standard full rim test gear. Vibration-based fault detection methods were applied to the vibration signal both on-line and after the tests were completed. The objectives of this effort were to identify methods capable of detecting the fatigue crack, and determine how far in advance of total failure positive detection was given. Results showed that the fault detection methods failed to respond to the fatigue crack prior to complete rim fracture in the thin rim gear tests. In the standard full rim gear test all of the methods responded to the fatigue crack in advance of tooth fracture; however, only three of the methods responded to the fatigue crack in the early stages of crack propagation.

Proceedings of the International Conference on Power Transmissions 2016 (ICPT 2016), Chongqing, P.R. China, 27-30 October 2016

Full-Scale Fatigue Testing of Components and Structures

Single Tooth Gear Bending Fatigue Test

Spinoff 2007

Experimental tests were performed on the OH-58A helicopter main-rotor transmission in the NASA Lewis 500-hp Helicopter Transmission Test Stand. The testing was part of a joint Navy/NASA/Army lubrication program to develop a separate lubricant for gearboxes that would improve life and load-carrying capacity. The goal of the experiments was to develop a testing procedure using a MIL-L-23699 base reference oil to fail certain transmission components, and then to run identical tests with improved lubricants and demonstrate improved performance. The tests were directed at failing components that have given the Navy problems because of marginal lubrication. These failures included mast-shaft bearing micropitting, sun gear and planet bearing fatigue, and spiral bevel gear scoring. More than 900 hr of total run time were accumulated for these tests. Some success was achieved in developing a testing procedure to produce sun gear and planet bearing fatigue failures. Only marginal success was achieved in producing mast-shaft bearing micropitting and spiral bevel gear scoring.

The F-100 Aircraft Structural Integrity Program was designed to fatigue test the basic wing, fuselage and empennage structure of the air vehicle. In conjunction with these tests, actual nose and main gears were used as loading jigs to introduce ground loads into the structure. Consequently, the major portion of the test effort on the landing gear was completed on that program. The incomplete testing of the nose gear was concluded on the F-100 Landing Gear Fatigue Test Program. The results of the gear tests conducted on both programs are presented in this section of the report.

Rolling Contact Fatigue Testing of Bearing Steels

Detecting Gear Tooth Fatigue Cracks in Advance of Complete Fracture

Damage Assessment by Acoustic Emission (AE) During Landing Gear Fatigue Testing

Gear Materials, Properties, and Manufacture

Spinoff is NASA's annual premiere publication featuring successfully commercialized NASA technology. For more than 40 years, the NASA Commercial Technology Program has facilitated the transfer of NASA technology to the private sector, benefitting global competition and the economy. The resulting commercialization has contributed to the development of commercial products and services in the fields of health and medicine, industry, consumer goods, transportation, public health, computer technology, and environmental resources. Since 1976, Spinoff has featured between 40 and 50 of these commercial products annually.

This book presents papers from the International Conference on Power Transmissions 2016, held in Chongqing, China, 27th-30th October 2016. The main objective of this conference is to provide a forum for the most recent advances, addressing the challenges in modern mechanical transmissions. The conference proceedings address all aspects of gear and power transmission technology and a range of applications. The presented papers are catalogued into three main tracks, including design, simulation and testing, materials and manufacturing, and industrial applications. The design, simulation and testing track covers topics such as new methods and designs for all types of transmissions, modelling and simulation of power transmissions, strength, fatigue, dynamics and reliability of power transmissions, lubrication and sealing technologies and theories, and fault diagnosis of power transmissions. In the materials and manufacturing track, topics include new materials and heat treatment of power transmissions, new manufacturing technologies of power transmissions, improved tools to predict future demands on production systems, new technologies for ecologically sustainable productions and those which preserve natural resources, and measuring technologies of power transmissions. The proceedings also cover the novel industrial applications of power transmissions in marine, aerospace and railway contexts, wind turbines, the automotive industry, construction machinery, and robots.

Gear Crack Propagation Investigations

Theory and Practice

A new high-speed, high-cycle, gear-tooth bending fatigue test capability

Investigation of Gear and Bearing Fatigue Damage Using Debris Particle Distributions

Full-scale Fatigue Testing of Components and Structures presents the approaches to the testing of full-scale components or structures. The book begins by examining the necessity or desirability of full-scale fatigue testing. Subsequent chapters are devoted to the discussion of fatigue testing done on aircraft structures, railway components, helicopter rotor heads, artillery gun structures, and bridge components. The role of full-scale fatigue testing on automotive components and systems, structural testing in nuclear engineering, and the use of a structural fatigue testing laboratory for other tests are covered as well. Engineers, materials scientists, and researchers in the field of fatigue testing will find the book very useful.

Development of a Full-scale Transmission Testing Procedure to Evaluate Advanced Lubricants

Development of a New Test Machine for Experimental Contact Fatigue Investigations of Spur Gears

An Investigation of Gear Mesh Failure Prediction Techniques