Schedule of Events

Sunday, October 22
11 a.m. - 5 p.m.
Registration

6:30 p.m. - 8 p.m.
Welcoming Reception

Monday, October 23
7 a.m. - 5 p.m.
Registration

7 a.m. - 8 a.m.
Continental Breakfast

8 a.m. - 11:30 a.m.
Technical Session I
Optimizing Design

12 p.m. - 2 p.m.
Annual Awards Luncheon

2 p.m. - 5 p.m.
Technical Session II
Standards & Micropitting

Tuesday, October 24
7 a.m. - 12 p.m.
Registration

7 a.m. - 8 a.m.
Continental Breakfast

8:30 a.m. - 11:30 p.m.
Technical Session III
Application Analysis

1 p.m. - 4 p.m.
Technical Session IV
Bevel Gears Plus

AGMA Fall Technical Meeting
October 22-24, 2006
Grovesnor Resort • Orlando, Fla.

Grovesnor Resort
1850 Hotel Plaza Boulevard
Lake Buena Vista, FL 32830-2202
(800) 624-4109 or (407) 828-4444

Rate
$85 (Single/Double)

Cut-Off Date
September 17

FTM attendees are responsible for making their own hotel and travel reservations. To obtain the preferred rate, be sure to mention the AGMA Fall Technical Meeting when making your reservations.

Registration Fees
Member Registrant $545
Member Spouse/Guest $75
Nonmember Registrant $835
Nonmember Spouse/Guest $125
Students (w/ technical papers) $95
Students (admission only) $25

Ways to Register
Online: www.agma.org
Phone: (703) 684-0211
Fax: (703) 684-0242
Mail: AGMA, 500 Montgomery St., Suite 350,
Alexandria, VA 22314-1581

Learn from the Gear Industry's Best

Session I - Optimizing Design

The Effects of Super Finishing on Bending Fatigue

Gregory Blake, Rolls-Royce Indianapolis

Super finishing is a technology that public literature suggests has potential for increased power density. A study was designed and conducted to characterize this technology's benefit to bending fatigue. Two AMS6265 sample groups were created: one without and one with super finish. Bending fatigue was characterized using Single Tooth Bending Fatigue (STF) and RR Moore rotating beam methods. The STF specimen was designed such that the tooth geometry replicated the normal cross section of Rolls Royce spiral bevel gears. Two unique heat lots of material were used; each was processed

through manufacturing as a separate machining batch. Thus, a minimum of two carburization and hardening lots, two shot peen batches and two super finishing cycles (if applicable) were processed per sample group. A detailed metallurgical evaluation of the specimens was performed to characterize the material and make comparison to actual spiral bevel gears. Analysis of the STF and RR Moore test data concluded no statistical difference between the bending fatigue strength of the two populations.

Isotropic Superfinishing of S-76C+ Main Transmission Gears

Bruce Hansen, Sikorsky Aircraft Corporation; Mike Salerno, Lane Winkelmann, REM Chemicals, Inc.

Isotropic superfinishing is a chemically accelerated vibratory finishing process that is capable of generating surface finishes with an Arithmetic Mean Roughness (Ra) less than 3 microinches. This process was applied to the third stage spur bull gear and mating pinions along with the second stage bevel gears of a Sikorsky S-76C+ main gearbox. The gearbox completed the standard Acceptance Test Procedure (ATP) and a 200-hour endurance test. During these tests noise, vibration, and operating temperatures were shown to be significantly reduced due to lower friction. This technology has since been flight certified and integrated into the S-76C+ with several aircraft in commercial service. A description of the tests, performance data and a general description of the process will be presented.

Detailed Procedure for the Optimum Design of an Epicyclic Transmission Using Plastic Gears

Dr. Isaias Regalaco, Alfredo Hernandez, CIATEQ

This paper shows all the steps to get an optimum (volume based) design for an epicyclic transmission using plastic materials. The design was developed using the tooth proportions proposed in ANSI/AGMA 1006-A97, Tooth Proportions for Plastic Gears, and took into account the recommendations given in ANSI/AGMA 6023-A88, Design Manual for Enclosed Epicyclic Gear Drives, and ANSI/AGMA 2101-C95, Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth, for the effect of changing the number of planets, the bending fatigue and contact strength of the plastic materials, and the temperature effects on the size of the gears. The design procedure starts with a preliminary analysis of the performance of the gears in a proposed (not optimized) transmission, going step by step to an optimum design for the given load conditions and expected minimum life.

Planetary Servo Gearheads

Dr. Gerhard G. Antony, Neugart USA LP

Modern automated machines are increasingly using flexible, high dynamic servomotors because of their ability to speed up and automate the complex motions performed by these machines. Planetary gearheads are frequently used in conjunction with servomotors to match the inertias, lower the motor speed, boost the torque, and at the same time provide a sturdy mechanical interface for pulleys, cams, drums and other mechanical components.

Continued on page 22

Continued from page 21

This paper addresses topics such as: reasons why the planetary gear systems are the preferred choice for "servo applications"; what influences the positioning accuracy repeatability of a planetary servo gear; rating practices to establish a transparent "comparability" of different torques; and, an introduction of a simple, reliable method to determine the required gearbox torque rating for a servo-application based on motor torque data.

Session II
Standards & Micropitting

Development of a Gear Rating Standard – A Case Study of AGMA 6014-A06

Frank C. Uherek, Rexnord Geared Products

The AGMA Mill Gearing Committee recently completed AGMA 6014 dealing with the rating of gears for grinding mill and kiln service. In the development of this standard, the committee took a different approach to determining the end result of the standard writing process. Through review of previous standards, performance history for long life (over 20 years) applications, and considering the extreme gear size for these applications, the committee achieved consensus on a new rating method which was derived from ANSI/AGMA 2001-D04. A factor comparison between 6014 and 2001 is presented, as well as their interaction, to explain the goal of the committee to develop a document that reflects actual field experience of in-service operating gear sets.

An Analytical Approach to the Prediction of Micropitting on Case Carburised Gears

D. Barnett, Renold Gears; J.P. Elderkin, MTM Precision; Lt. W. Bennett, MoD (Navy)

Micropitting is one area of gear failure that has become more predominant over recent years, mainly because of its effect on gear noise and transmission error. This paper will outline an approach to analysing micropitting by looking at the critical factors for a given gear design. A practical calculation procedure, which incorporates a three-dimensional spring model, was used to predict the micropitting wear rate and the position that wear would take place on test gear pairs. Case studies have been included that directly compare the predicted levels of micropitting with those actually measured. A simplified formulation suitable for manual calculations will also be discussed.

Improvement of Standardized Test Methods for Evaluating the Influence of the Lubricant on Micropitting and Pitting Resistance of Case Carburized Gears

Prof. Dr.-Ing. B.-R. Höhn, Dr.-Ing. P. Oster, Dr.-Ing. T. Radev, Dipl.-Ing. G. Steinberger, Dr.-Ing. T. Tobie, Gear Research Centre (FZG), Technical University of Munich

Micropitting and pitting are fatigue failures which occur on the flanks of highly stressed, case carburized gears. The fatigue resistance of a gear flank depends on the lubricant used. The performance of lubricants in regard to micropitting and pitting can be evaluated by standardized test methods.

The FVA-FZG-micropitting test consists of two parts: a load stage test followed by an endurance test. The result of the load stage test is a test stage failure load. The endurance test provides information on the progress of the damage after higher numbers of load cycles. The test requires relatively high costs and is quite time consuming. Therefore an analogous short test method was developed to classify candidate lubricants, and supplement the existing test. The results of the standardized short test method correlate well with the ones of the full micropitting test.

The FVA-FZG-pitting test is a single stage test with limited-life fatigue loads using standardized test gears, which are ground without controlled profile or helix modifications. Although the flank roughness is restricted, the appearance of micropitting can cause a wide statistical spread of pitting test life. Thus, there was potential improvement in the reproducibility of test results and the test relevance. In the developed single stage test, the test gears were superfinished to prevent micropitting, and have flank modifications for improved test relevance.

The paper describes the new developed test procedures and shows basic examples of test results.

An Evaluation of FZG Micropitting Test Procedures and Results for the Crowned AGMA Test Gears

Dr. D. Houser, S. Shon, J. Harianto, The Ohio State University

This paper reports on the surface fatigue testing of gears that were manufactured as a part of the AGMA surface durability testing program. The goal was to develop models for predicting wear. As part of this goal, the study reported upon in this paper focuses on developing an understanding of the stresses and wear predictors using FZG durability tests. Since the focus was on micropitting, the first tests used the method described in FVA Information Sheet No. 54/I-IV. Later, the procedure was modified to account for the much higher contact stress levels that are predicted for the heavily crowned and tip relieved AGMA test gears. This paper provides extensive analysis that includes detailed topography measurements of the tooth profiles, predictions of contact stresses and contact patterns, and discussions regarding factors that affect contact stresses, flash temperatures and local film thickness of the tested gears.

Session III
Application Analysis

Opportunities to Replace Wrought Gears with High Performance PM Gears in Automotive Applications

Ulf Engström, David Milligan, North American Höganäs; Pernilla Johansson, Senad Dizdar, Höganäs AB, Sweden

Powder metallurgy (PM) enables cost effective production of components with complex geometries such as gears. During the last decades the use of PM components in automotive applications has showed a continuous growth. In order to continue this growth, it is important to maintain the strong points of PM, i.e. the net shape capability, while performance is further improved to fulfill more and more demanding requirements. Gears for automotive applications are complex in shape and require both geometrical accuracy and high mechanical performance in terms of tooth durability. By utilizing selective densification of the teeth, these performance requirements can be met at a low added cost. In this paper a PM process consisting of compaction, sintering, surface densification, and finally heat treatment has been studied to assess the feasibility of producing high performance gears by powder metallurgy. Helical and spur gears were used in the study where the densification, as well as the resulting gear quality and durability, were tested.

Fabrication, Assembly and Test of a High Ratio, Ultra-Safe, High Contact Ratio, Double Helical Compound Planetary Transmission for Helicopter Applications

Frederick W. Brown, Mark J. Robuck, Mark Kozachyn, John R. Lawrence, Timothy E. Beck, The Boeing Company

An ultra-safe, high ratio planetary transmission, for application as a helicopter main rotor final drive, has been designed, fabricated and tested under the

Continued on page 24

Continued from page 21

sponsorship of National Rotorcraft Technology Cen ter - Rotorcraft Industry Technology Association (NRTC/RITA). The improvements offered by this new planetary transmission are reduced weight, reduced noise and improved fail-safety and efficiency. This paper discusses the fabrication, assem bly and testing of the improved planetary transmission.

An existing helicopter rotor transmission planetary drive served as the baseline for comparison to the improved transmission design. The existing system utilizes a two-stage conventional spur gear planetary design with fixed internal ring gears. The new double helical planetary (DHP) system design uses a compound planetary arrangement with innovations such as staggered planets and high combined contact ratio gearing in a unique configuration. Double helical gears in the planet/ring meshes balance axial tooth forces, so that axial planet bearing reactions are not required. The spur gear sun/planet meshes are staggered to achieve a compact spatial arrangement. The sun gear is fully floating. Demonstration testing of a full scale prototype DHP transmission has recently been completed.

On Tooth Failure Analysis in Small-Teeth-Number Gearing: An Analytical Approach

Dr. Stephen P. Radzevich, Eaton Corporation

This paper pertains to the analytical study of the major reasons that cause tooth failure in gearing having small numbers of teeth. For the analysis of gear tooth failure, tooth contact stresses and the combined shear stresses are investigated. The study is based on in-depth analysis of gear tooth loading, accounting for load variations with time and other gear parameters in various phases of tooth meshing. The contact and shear stresses are caused by simultaneous impact of (a) contact stresses together with (b) stresses caused by the pinion and gear tooth profile sliding. While developed for use in gearing with low numbers of teeth, the method is also recommended for the accurate computation of stresses in gearing having more teeth. The reported results of the research could be used to extend the existing AGMA 908-B89 document to gears having less than 12 teeth.

A Crane Gear Failure Analysis – Case Study, Observations, Lessons Learned, Recommendations

Raymond J. Drago, Drive Systems Technology, Inc.

The basic technology of crane design has advanced in many areas including motors, controls, human interface, and wire rope design, among others. One area that has not changed is the design and manufacture of the gearboxes that form major links in the overall crane system. In general, the gearboxes used in cranes have proven themselves to be reliable, capable of delivering years of service with minimal maintenance. Recent crane gear failures, however, gave rise to a reevaluation of the design, configuration, and manufacture of the gearboxes in large cranes. Since crane gearboxes do not operate either for long periods of time or "continuously," as do other geared systems, gear system fatigue characteristics have not been in the forefront of crane gear system operation. Recent studies have indicated that usage rates, loading, and in many cases both, have increased dramatically. In some applications, crane usage has increased by factors of two or three or even more, and unit loading has similarly increased. This much higher usage makes the cumulative effects of fatigue much more important in these typically intermittent use devices. This paper presents a case study of one particular crane gear failure, including failure analysis and resultant remedial actions, along with a discussion of the results and implications from extensive gearbox inspections that were conducted as a result of the initial failure.

Session IV Bevel Gears Plus

Economic Aspects of Vacuum Carburizing

Janusz Kowalewski, Artur Wiechczyski, SECO/ WARWICK Corporation

There is an increased interest in furnaces for vacuum carburizing due to the demand for products with the best overall metallurgical quality and lowest unit cost. Vacuum carburizing technology produces work with minimum distortion, the direct result of being cooled down with gas. The surface metallurgy is superior because the carburization process is carried out in a vacuum environment. Vacuum furnaces systems provide "cold to cold" (cold work going in, cold work coming out) and fully automatic operation that reduces the amount of operator involvement, thus minimizing labor input. Considering upstream and downstream requirements, vacuum carburizing provides a total reduction of processing costs. This technology

differs considerably from traditional gas carburizing both in the equipment used and in the process economy. This paper presents the aspects of vacuum carburizing technology that have an impact on process costs and quality improvements in the final product.

The Optimal High Speed Cutting of Bevel Gears - New Tools and New Cutting Parameters

Dr. Hermann J. Stadtfeld, The Gleason Works

High speed carbide dry cutting went through an evolution with respect to speeds and feeds and the kinematic relationship between cutting blade and work, which eventually resulted in many improvements, available today. The dependency of many important parameters upon the particular situation of a given job often makes it difficult for a manufacturing engineer to establish an optimal cutting scenario. An analysis of the different parameters and their influence to the performance of the cutting process, allows the establishment of five, nearly independent areas of attention: blade geometry and placement in the cutter head; cutting edge micro geometry; surface condition of front face and side relief surfaces; speeds and feeds in the cutting process; and, kinematic relationship between tool and work (climb or conventional cutting, vector feet). This paper presents explanations and guidelines for optimal high speed cutting depending on cutting method, part geometry and manufacturing environment, which also help to choose the right blade system to give the manufacturing engineer detailed information to support optimizing cutter performance, tool life and part quality.

Optimal Tooth Modifications in Spiral Bevel Gears Introduced by Machine Tool Setting Variation

Dr. Vilmos Simon, Budapest University of Technology and Economics

A method for the determination of optimal tooth modifications in spiral bevel gears based on improved load distribution, minimized tooth root stresses and reduced transmission errors is presented. The modifications are introduced into the pinion tooth surface by variation of machine tool settings. This method includes the bending and shearing deflections of gear teeth, local contact deformations of mating surfaces, gear body bending and torsion, deflections of the supporting shafts, and manufacturing and alignment errors of mating members. By applying this optimal set of machine tool setting parameters the maximum tooth contact pressure is reduced by 5.4%, the tooth fillet stresses in the pinion by 8% and the angular position error of the driven gear by 48%, in regard to the spiral bevel gear pair manufactured by machine tool settings determined by the commonly used method.

Certificate for Involute Gear Evaluation Software

Dr. Frank Härtig, Physikalisch-Technische Bundesanstalt

A test for the verification of involute gear software has been developed at the Physikalisch-Technische Bundesanstalt (PTB). This paper shows the critical influence on measurement uncertainty of uncertified involute evaluation software. Besides the test parameter information, the most dominant effects of software errors will be explained. The algorithms developed during this project should influence and help complete the existing standards and their guidelines.