American Gear Manufacturers Association

Technical Resources

Technical Publications Catalog

January 2010

AGMA
Catalog of Technical Publications

TABLE OF CONTENTS

American Gear Manufacturers Association

AGMA is a voluntary association of companies, consultants and academicians with a direct interest in the design, manufacture, and application of gears and flexible couplings. AGMA was founded in 1916 by nine companies in response to the market demand for standardized gear products; it remains a member- and market-driven organization to this day. AGMA provides a wide variety of services to the gear industry and its customers and conducts numerous programs which support these services. Some of these services and programs are:

- **STANDARDS:** AGMA develops all U.S. gear related standards through an open process under the authorization of the American National Standards Institute (ANSI).
- **ISO PARTICIPATION:** AGMA is Secretariat to TC60, the committee responsible for developing all international gear standards. TC60 is an ISO (International Organization of Standardization) committee.
- **MARKET REPORTS AND STATISTICS:** AGMA's Operating Ratio Report, Wage & Benefit Survey, and Monthly Market Trend Reports help you stay competitive by giving you up-to-date information on the gear industry.
- **THE MARKETING AND STATISTICAL COUNCILS** enhance your competitiveness by sharing information and by developing creative solutions to common industry problems.
- **THE PUBLIC AFFAIRS COUNCIL** gives you an active voice in Washington, promoting the gear industry to our nation's legislators and regulators.
- **GEAR EXPO:** This is the only trade show dedicated solely to the gear industry.
- **TECHNICAL COMMITTEE MEETINGS** are the core of the open AGMA standard writing process keeping members abreast of new developments while ensuring that AGMA standards are kept current.
- **THE AGMA TRAINING SCHOOL FOR GEAR MANUFACTURING** uses current technology to offer hands-on training in hobbing, shaping, and inspection. At the "Gear School", operators learn how to maximize their productivity. Enrollment is open to all.
- **NEWS DIGEST,** AGMA's quarterly newsletter, offers you timely, useful information you can use immediately.

If you would like additional information about our programs, or on how to become a member of AGMA, please contact AGMA Headquarters.

American Gear Manufacturers Association
500 Montgomery Street, Suite 350
Alexandria, VA 22314-1560

Phone: (703) 684-0211
FAX: (703) 684-0242
E-Mail: tech@agma.org
website: www.agma.org

Leading the Gear Industry Since 1916

How to Purchase Documents

Unless otherwise indicated, all current AGMA Standards, Information Sheets and papers presented at Fall Technical Meetings are available for purchase, in electronic form, through the AGMA website, www.agma.org.

Index of AGMA Standards and Information Sheets by Number

Italicizing denotes a current standard

Number	Page	Title or reference
110.04		Replaced by 1010-E95
112.05		Incorporated into 1012-G05
114.02		Replaced by 910-C90
115.01		Replaced by 933-A03
116.01		Incorporated into 1012-G05
118.01		Replaced by 906-A94
120.01		Withdrawn
121.02		Replaced by 120.01
122.02		Replaced by 120.01
123.01		Replaced by 120.01
124.01		Replaced by 120.01
141.01		Withdrawn
151.02		Replaced by 420.04
170.01		Replaced by 6002-B93
201.02		Withdrawn
202.03		Replaced by 2005-D03
203.03		Withdrawn
207.06		Replaced by 1003-G93
208.03		Replaced by 2005-D03
209.04		Replaced by 2005-D03
210.02		Replaced by 218.01
211.02A		Replaced by 420.04
212.02		Replaced by 2003-B97
215.02		Replaced by 218.01 & 2003-B97
216.01		Replaced by 2003-B97
216.01A		Replaced by 420.04
217.01		Withdrawn
218.01		Replaced by 2001-D04 & 908-B89
220.02		Replaced by 218.01
221.02A		Replaced by 420.04
222.02		Replaced by 2003-B97
223.01A		Replaced by 420.04
223.02		Replaced by 2003-B97
224.01		Incorporated into 240.01
225.01		Replaced by 226.01
226.01		Replaced by 908-B89
230.01		Replaced by 2007-C00
231.52		Replaced by 2002-B88
234.01		Replaced by 390.03a
235.02		Replaced by 2000-A88
236.05		Replaced by 390.03a
237.01		Replaced by 390.03
239.01		Replaced by 2000-A88
239.01A		Replaced by 390.03a
240.01		Replaced by 2004-B89
241.01		Incorporated into 240.01
242.02		Incorporated into 240.01
243.01		Incorporated into 240.01
243.51		Incorporated into 240.01
243.61		Incorporated into 240.01
243.71		Incorporated into 240.01
244.02		Incorporated into 240.01
245.01		Incorporated into 240.01
246.01		Incorporated into 240.01
246.02A		Replaced by 926-A99
247.01		Incorporated into 240.01
248.01		Incorporated into 240.01
249.01		Incorporated into 240.01
250.04		Replaced by 9005-E02

Obsolete documents should not be used, please use replacements. Most obsolete and superseded documents are available for puchase. Contact AGMA Headquarters for price and availability.

Number	Page	Title or reference
251.02		Replaced by 9005-E02
254.01		Incorporated into 250.04
254.04		Incorporated into 251.02
255.03		Replaced by 6001-D97
260.02		Replaced by 6001-D97
265.01		Replaced by 6001-D97
271.03		Replaced by 420.04
291.01		Replaced by 420.04
295.04		Replaced by 6025-D98
297.01		Replaced by 6025- D98
298.01		Replaced by 6025- D98
299.01		Replaced by 914-A04
321.05		Replaced by 6004-F88
323.01		Replaced by 6005-B89
330.01		Replaced by 2005-D03
331.01		Replaced by 2008-C01
341.02		Replaced by 6022-C93
342.02		Replaced by 6035-A02
360.02		Withdrawn
370.01		Replaced by 917-B97
374.04		Withdrawn
390.03		Replaced by 390.03a & 2000-A88
390.03a		Replaced by 2009-B01 and 2011-A98
411.02		Replaced by 911-A94
420.04		Replaced by 6010-F97
421.06		Replaced by 6011-i03
422.03		Withdrawn
423.01		Replaced by 420.04
424.01		Withdrawn
425.01		Replaced by 420.04
426.01		Replaced by 6000-B96
427.01		Incorporated into 6011-H98
430.03		Replaced by 420.04
431.01		Withdrawn
440.04		Replaced by 6034-A87
441.04		Replaced by 6035-A02
442.01		Replaced by 6035-A02
460.05		Replaced by 6019-E89
461.01		Replaced by 6035-A02
480.06		Replaced by 6021-G89
481.01		Replaced by 6021-G89
510.03		Replaced by 9009-D02
511.02		Replaced by 9002-A86
512.01		Replaced by 9002-A86
513.01		Replaced by 9002-A86
514.02		Withdrawn
515.02		Replaced by 9000-C90
516.01		Replaced by 9008-B00
600.01		Replaced by 904-B89
900-H06	*10*	*Style Manual for the Preparation of Standards, Information Sheets and Editorial Manuals*
901-A92	*10*	*Procedure for the Preliminary Design of Minimum Volume Gears*
904-C96	*10*	*Metric Usage*
906-A94		Withdrawn
908-B89	*10*	*Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth*
909-A06	*10*	*Specifications for Molded Plastic Gears*
910-C90	*10*	*Formats for Fine-Pitch Gear Specification Data*
911-A94	*10*	*Design Guidelines for Aerospace Gearing*
912-A04	*10*	*Mechanisms of Gear Tooth Failure*
913-A98	*11*	*Method for Specifying the Geometry of Spur and Helical Gears*
914-B04	*11*	*Gear Sound Manual - Part I: Fundamentals of Sound as Related to Gears; Part II: Sources, Specifications and Levels of Gear Sound; Part III: Gear Noise Control*
915-1-A02	*11*	*Inspection Practices - Part 1: Cylindrical Gears - Tangential Measurements*
915-2-A05	*11*	*Inspection Practices - Part 2: Cylindrical Gears - Radial Measurements*

Obsolete documents should not be used, please use replacements. Most obsolete and superseded documents are available for puchase. Contact AGMA Headquarters for price and availability.

Number	Page	Title or reference
915-3-A99	*11*	*Inspection Practices - Gear Blanks, Shaft Center Distance and Parallelism*
917-B97	*11*	*Design Manual for Parallel Shaft Fine-Pitch Gearing*
918-A93	*11*	*Numerical Examples Demonstrating the Procedures for Calculating Geometry Factors for Spur and Helical Gears*
920-A01	*11*	*Materials for Plastic Gears*
921-A97		Replaced by 6006-A03
922-A96	*11*	*Load Classification and Service Factors for Flexible Couplings*
923-B05	*11*	*Metallurgical Specifications for Steel Gearing*
925-A03	*12*	*Effect of Lubrication on Gear Surface Distress*
926-C99	*12*	*Recommended Practice for Carburized Aerospace Gearing*
927-A01	*12*	*Load Distribution Factors - Analytical Methods for Cylindrical Gears*
929-A06	*12*	*Calculation of Bevel Gear Top Land and Guidance on Cutter Edge Radius*
930-A05	*12*	*Calculated Bending Load Capacity of Powder Metallurgy (P/M) External Spur Gears*
931-A02		Replaced by 10064-5-A06
932-A05	*12*	*Rating the Pitting Resistance and Bending Strength of Hypoid Gears*
933-A03	*12*	*Basic Gear Geometry*
935-A05	*12*	*Recommendations Relative to the Evaluation of Radial Composite Gear Double Flank Testers*
938-A05	*12*	*Shot Peening of Gears*
939-A07	*13*	*Austempered Ductile Iron for Gears*
1003-H07	*13*	*Tooth Proportions for Fine-Pitch Spur and Helical Gears*
1006-A97	*13*	*Tooth Proportions for Plastic Gears*
1010-E95	*13*	*Appearance of Gear Teeth - Terminology of Wear and Failure*
1012-G05	*13*	*Gear Nomenclature, Definitions of Terms with Symbols*
1102-A03	*13*	*Tolerance Specification for Gear Hobs*
1103-H07	*13*	*Tooth Proportions for Fine-Pitch Spur and Helical Gears (Metric Edition)*
1106-A97	*13*	*Tooth Proportions for Plastic Gears*
1328-1		Replaced by 2015-1-A01
1328-2		Replaced by 2015-2-A06
2000-A88		Replaced by 915-1-A02, 915-2-A05, 2015-1-A01, and 2015-2-A06
2001-D04	*14*	*Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*
2002-B88	*14*	*Tooth Thickness Specification and Measurement*
2003-B97	*14*	*Rating the Pitting Resistance and Bending Strength of Generated Straight Bevel, Zerol Bevel, and Spiral Bevel Gear Teeth*
2004-C08	*14*	*Gear Materials, Heat Treatment and Processing Manual*
2005-D03	*14*	*Design Manual for Bevel Gears*
2007-C00	*14*	*Surface Temper Etch Inspection After Grinding*
2008-C01	*14*	*Assembling Bevel Gears*
2009-B01	*14*	*Bevel Gear Classification, Tolerances, and Measuring Methods*
2010-A94		Replaced by 18653-A06
2011-A98	*14*	*Cylindrical Wormgearing Tolerance and Inspection Methods*
2015-1-A01	*15*	*Accuracy Classification System - Tangential Measurements for Cylindrical Gears*

Obsolete documents should not be used, please use replacements. Most obsolete and superseded documents are available for puchase. Contact AGMA Headquarters for price and availability.

Obsolete documents should not be used, please use replacements. Most obsolete and superseded documents are available for puchase. Contact AGMA Headquarters for price and availability.

Number	Page	Title or reference
9002-B04	*18*	*Bores and Keyways for Flexible Couplings (Inch Series)*
9003-B08	*18*	*Flexible Couplings - Keyless Fits*
9004-B08	*19*	*Flexible Couplings - Mass Elastic Properties and Other Characteristics*
9005-E02	*19*	*Industrial Gear Lubrication*
9008-B00	*19*	*Flexible Couplings – Gear Type – Flange Dimensions, Inch Series*
9009-D02	*19*	*Flexible Couplings - Nomenclature for Flexible Couplings*
9103-B08	*19*	*Flexible Couplings - Keyless Fits (Metric Edition)*
9104-A06	*19*	*Flexible Couplings - Mass Elastic Properties and Other Characteristics (Metric Edition)*
9112-A04	*19*	*Bores and Keyways for Flexible Couplings (Metric Series)*

Number	Page	Title or reference
10064-1		Replaced by 915-1-A02
10064-2		Replaced by 915-2-A05
10064-5-A06	*19*	*Code of Inspection Practice - Part 5: Recommendations Relative to Evaluation of Gear Measuring Instruments*
14179-1	*20*	*Gear Reducers - Thermal Capacity Based on ISO/TR 14179-1*
17485-A08	*20*	*Bevel Gears - ISO System of Accuracy*
Supplement to 17485-A08	20	*Supplemental Tables for ANSI/AGMA ISO 17485-A08, Bevel Gears - ISO System of Accuracy - Tolerance Tables*
18653-A06	*20*	*Gears - Evaluation of Instruments for the Measurement of Individual Gears*
23509-A08	*20*	*Bevel and Hypoid Gear Geometry*

Obsolete documents should not be used, please use replacements. Most obsolete and superseded documents are available for puchase. Contact AGMA Headquarters for price and availability.

Gear Software
(for ANSI/AGMA 2001 and ISO 6336)

AGMA's *Gear Rating Suite*

Beginning with AGMA's ISO6336 Software , which was developed and tested over several years by a group of AGMA men and women working closely with the developers of the international standard, the software addresses ISO 6336 method B, the most comprehensive, analytical calculation method. It has gained international acceptance since its release in 1998 and enables you to:

- determine gear capacity in accordance with the ISO 6336 standard quickly and accurately;
- compare your own design and practices with ISO 6336 results;
- understand your competitor's ratings.

The manual alone is worth the price! In addition to explaining the software, this handy document is a great tool for learning how to use ISO 6336, guiding you through the complexities and teaching you the correct inputs, especially in the exacting areas of tooth geometry and tooling.

Two of the most recognized standards in the world today for determining the rating of spur and helical gears are ANSI/AGMA 2001-C95 and ISO 6336. Now for the first time, software to calculate ratings in accordance with each standard is available in one package from AGMA. Entitled the ***Gear Rating Suite***, the software allows the user to input data once for each gearset, and obtain ratings to both standards. Among the many features of the software package are:

- An in-depth User's Manual, and all required AGMA and ISO standards.
- User friendly I/O that provides an intuitive user interface, with drop-down boxes, look-up tables, and graphical guides used to assist in data entry.
- Dual input units which allow the user to switch between SI and inch units.
- Error and warning messages are provided within both the input and rating routines to help identify problems.
- A help program is incorporated within the software.
- Long and short form outputs are provided.

In addition to the gear rating routines and aids, the package also provides:

- A Geometry Checker for checking input data to ensure they are within allowable ranges. The Geometry Checker will help identify data entry errors and unusual gear designs.
- Tolerance worksheets which allow the user to calculate tooth tolerances from quality numbers, convert quality numbers between AGMA and ISO, and to display tolerances for adjacent grades.

The potential of the ***Gear Rating Suite*** to improve your efficiency and save you time in performing these rigorous calculations makes this a "must have" tool for all gear engineers.

Obsolete documents should not be used, please use replacements. Most obsolete and superseded documents are available for puchase. Contact AGMA Headquarters for price and availability.

Index of AGMA Standards and Information Sheets by Topic

Aerospace

AGMA 911-A94 *Design Guidelines for Aerospace Gearing*

AGMA 926-C99 *Recommended Practice for Carburized Aerospace Gearing*

Calibration and Measurement Uncertainty

AGMA 935-A05 *Recommendations Relative to the Evaluation of Radial Composite Gear Double Flank Testers*

ANSI/AGMA 2116-A05, *Evaluation of Double Flank Testers for Radial Composite Measurement of Gears*

AGMA ISO 10064-5-A06, *Code of Inspection Practice - Part 5: Recommendations Relative to Evaluation of Gear Measuring Instruments*

ANSI/AGMA 18653-A06, *Gears - Evaluation of Instruments for the Measurement of Individual Gears*

Couplings

AGMA 922-A96 *Load Classification and Service Factors for Flexible Couplings*

ANSI/AGMA 9000-C90 *Flexible Couplings - Potential Unbalance Classification*

ANSI/AGMA 9001-B97 *Flexible Couplings - Lubrication*

ANSI/AGMA 9002-B04 *Bores and Keyways for Flexible Couplings (Inch Series)*

ANSI/AGMA 9003-B08 *Flexible Couplings - Keyless Fits*

ANSI/AGMA 9004-B08 *Flexible Couplings - Mass Elastic Properties and Other Characteristics*

ANSI/AGMA 9008-B00 *Flexible Couplings – Gear Type – Flange Dimensions, Inch Series*

ANSI/AGMA 9009-D02 *Flexible Couplings - Nomenclature for Flexible Couplings*

ANSI/AGMA 9103-B08 *Flexible Couplings - Keyless Fits (Metric Edition)*

ANSI/AGMA 9104-A06 *Flexible Couplings - Mass Elastic Properties and Other Characteristics (Metric Edition)*

ANSI/AGMA 9112-A04 *Bores and Keyways for Flexible Couplings (Metric Series)*

Design and Assembly - Bevel

AGMA 929-A06 *Calculation of Bevel Gear Top Land and Guidance on Cutter Edge Radius*

ANSI/AGMA 2005-D03 *Design Manual for Bevel Gears*

ANSI/AGMA 2008-C01 *Assembling Bevel Gears*

ANSI/AGMA ISO 17485-A08 *Bevel Gears - ISO System of Accuracy*

ANSI/AGMA ISO 23509-A08 *Bevel and Hypoid Gear Geometry*

Design - Fine Pitch

AGMA 910-C90 *Formats for Fine-Pitch Gear Specification Data*

AGMA 917-B97 *Design Manual for Parallel Shaft Fine-Pitch Gearing*

Design - Spur and Helical

AGMA 901-A92 *A Rational Procedure for the Preliminary Design of Minimum Volume Gears*

AGMA 913-A98 *Method for Specifying the Geometry of Spur and Helical Gears*

Design - Wormgear

ANSI/AGMA 6022-C93 *Design Manual for Cylindrical Wormgearing*

Drive Components

ANSI/AGMA 6001-E08 *Design and Selection of Components for Enclosed Gear Drives*

ANSI/AGMA 6101-E08 *Design and Selection of Components for Enclosed Gear Drives (Metric Edition)*

Enclosed Drives

AGMA ISO 14179-1 *Gear Reducers - Thermal Capacity Based on ISO/TR 14179-1*

ANSI/AGMA 6013-A06 *Standard for Industrial Enclosed Gear Drives*

ANSI/AGMA 6113-A06 *Standard for Industrial Enclosed Gear Drives (Metric)*

ANSI/AGMA 6123-B06 *Design Manual for Enclosed Epicyclic Gear Drives (Metric)*

Failure Modes

AGMA 912-A04, *Mechanisms of Gear Tooth Failure*

ANSI/AGMA 1010-E95 *Appearance of Gear Teeth - Terminology of Wear and Failure*

High Speed Units

ANSI/AGMA 6011-I03 *Specification for High Speed Helical Gear Units*

Inspection and Tolerances

AGMA 915-1-A02 *Inspection Practices - Part 1: Cylindrical Gears - Tangential Measurements*

AGMA 915-2-A05 *Inspection Practices - Part 2: Cylindrical Gears - Radial Measurements*

AGMA 915-3-A99 *Inspection Practices - Gear Blanks, Shaft Center Distance and Parallelism*

ANSI/AGMA 1102-A03, *Tolerance Specification for Gear Hobs*

ANSI/AGMA 2002-B88 *Tooth Thickness Specification and Measurement*

ANSI/AGMA 2007-C00 *Surface Temper Etch Inspection After Grinding*

ANSI/AGMA 2009-B01 *Bevel Gear Classification, Tolerances, and Measuring Methods*

ANSI/AGMA 2011-A98 *Cylindrical Wormgearing Tolerance and Inspection Methods*

ANSI/AGMA 2015-1-A01 *Accuracy Classification System - Tangential Measurements for Cylindrical Gears*

ANSI/AGMA 2015-2-A06 *Accuracy Classification System - Radial Measurements for Cylindrical Gears*

ANSI/AGMA 2111-A98 *Cylindrical Wormgearing Tolerance and Inspection Methods (Metric)*

Supplemental Tables for AGMA 2015/915-1-A02 *Accuracy Classification System - Tangential Measurement Tolerance Tables for Cylindrical Gears*

Lubrication

ANSI/AGMA 9005-E02 *Industrial Gear Lubrication*

Materials

AGMA 920-A01 *Materials for Plastic Gears*

AGMA 923-B05 *Metallurgical Specifications for Steel Gearing*

AGMA 938-A05, *Shot Peening of Gears*

ANSI/AGMA 939-A07, *Austempered Ductile Iron for Gears*

ANSI/AGMA 2004-C08 *Gear Materials, Heat Treatment and Processing Manual*

ANSI/AGMA 6033-C08 *Materials for Marine Propulsion Gearing*

ANSI/AGMA 6133-C08 *Materials for Marine Propulsion Gearing (Metric)*

Metric Usage

AGMA 904-C96 *Metric Usage*

Mill Drives

ANSI/AGMA 6014-A06 *Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment*

ANSI/AGMA 6114-A06 *Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment (Metric)*

Nomenclature

AGMA 933-A03 *Basic Gear Geometry*

ANSI/AGMA 1012-G05 *Gear Nomenclature, Definitions of Terms with Symbols*

Plastics Gears

AGMA 909-A06 *Specifications for Molded Plastic Gears*

AGMA 920-A01 *Materials for Plastic Gears*

ANSI/AGMA 1006-A97 *Tooth Proportions for Plastic Gears*

ANSI/AGMA 1106-A97 *Tooth Proportions for Plastic Gears*

Powder Metallurgy Gears

AGMA 930-A05 Calculated Bending Load Capacity of Powder Metallurgy (P/M) External Spur Gears

ANSI/AGMA 6008-A98 *Specifications for Powder Metallurgy Gears*

Proportions

ANSI/AGMA 1003-H07 *Tooth Proportions for Fine-Pitch Spur and Helical Gears*

ANSI/AGMA 1006-A97 *Tooth Proportions for Plastic Gears*

ANSI/AGMA 1103-H07 *Tooth Proportions for Fine-Pitch Spur and Helical Gears (Metric Edition)*

ANSI/AGMA 1106-A97 *Tooth Proportions for Plastic Gears (Metric Edition)*

Rating: Spur, Helical and Bevel Gears

AGMA 908-B89 *Information Sheet-Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth*

AGMA 918-A93 *A Summary of Numerical Examples Demonstrating the Procedures for Calculating Geometry Factors for Spur and Helical Gears*

AGMA 925-A03 *Effect of Lubrication on Gear Surface Distress*

AGMA 927-A01 *Load Distribution Factors - Analytical Methods for Cylindrical Gears*

AGMA 932-A05 *Rating the Pitting Resistance and Bending Strength of Hypoid Gears*

ANSI/AGMA 2001-D04 *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*

ANSI/AGMA 2003-B97 *Rating the Pitting Resistance and Bending Strength of Generated Straight Bevel, ZEROL Bevel, and Spiral Bevel Gear Teeth*

ANSI/AGMA 2101-D04 *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth (Metric Edition)*

ANSI/AGMA 6032-A94 *Standard for Marine Gear Units: Rating*

ANSI/AGMA ISO 6336-6-A08 *Calculation of Load Capacity of Spur and Helical Gears - Part 6: Calculation of Service Life Under Variable Load*

Sound and Vibration

AGMA 914-B04 *Gear Sound Manual - Part I: Fundamentals of Sound as Related to Gears; Part II: Sources, Specifications and Levels of Gear Sound; Part III: Gear Noise Control*

ANSI/AGMA 6000-B96 *Specification for Measurement of Linear Vibration on Gear Units*

ANSI/AGMA 6025-D98 *Sound for Enclosed Helical, Herringbone, and Spiral Bevel Gear Drives*

Style Manual

AGMA 900-G00 *Style Manual for the Preparation of Standards and Editorial Manuals*

Thermal

AGMA ISO 14179-1 *Gear Reducers - Thermal Capacity Based on ISO/TR 14179-1*

Vehicle

ANSI/AGMA 6002-B93 *Design Guide for Vehicle Spur and Helical Gears*

Wind Turbine Units

ANSI/AGMA/AWEA 6006-A03 *Standard for Design and Specification of Gearboxes for Wind Turbines*

Wormgears

ANSI/AGMA 6034-B92 *Practice for Enclosed Cylindrical Wormgear Speed Reducers and Gearmotors*

ANSI/AGMA 6035-A02 *Design, Rating and Application of Industrial Globoidal Wormgearing*

ANSI/AGMA 6135-A02 *Design, Rating and Application of Industrial Globoidal Wormgearing (Metric)*

AGMA Standards and Information Sheets

Many standards require additional documents for their proper use. A list of these standards are normally supplied after the scope, in the normative references section of a document. Be sure to inquire whether the standard you need requires other documents listed herewith.

AGMA 900-H06 ***Style Manual for the Preparation of Standards, Information Sheets and Editorial Manuals***

Presents the requirements for preparing AGMA standards, editorial manuals, and other technical literature. A new annex "ISO symbols used in metric documents", has been added, which includes a comprehensive listing of the symbols used in ISO gear rating standards. **Revision of AGMA 900-G00.**

ISBN: 1-55589-775-4 Pages: 38

AGMA 901-A92 ***A Rational Procedure for the Preliminary Design of Minimum Volume Gears***

Presents a simple, closed-form procedure as a first step in the minimum volume spur and helical gearset design. Includes methods for selecting geometry and dimensions, considering maximum pitting resistance, bending strength, and scuffing resistance, and methods for selecting profile shift.

ISBN: 1-55589-579-4 Pages: 37

AGMA 904-C96 ***Metric Usage***

Serves as a guide in preparing AGMA metric standards.

ISBN: 1-55589-681-2 Pages: 20

AGMA 908-B89 ***Information Sheet - Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth***

Gives the equations for calculating the pitting resistance geometry factor, I, for external and internal spur and helical gears, and the bending strength geometry factor, J, for external spur and helical gears that are generated by rack-type tools (hobs, rack cutters or generating grinding wheels) or pinion-type tools (shaper cutters). Includes charts which provide geometry factors, I and J, for a range of typical gear sets and tooth forms.

ISBN: 1-55589-525-5 Pages: 78

AGMA 909-A06, Specifications for Molded Plastic Gears

The objective of this information sheet is to inform the plastic gear designer of the importance to clearly and thoroughly define the gear specifications to the plastic gear producer. It discusses the specifications for gear tooth geometry, inspection, other gear features and manufacturing considerations for involute external and internal spur and helical gears. Suggested data forms are provided in the annexes.

ISBN: 1-55589-889-8 Pages: 25

AGMA 910-C90 ***Formats for Fine-Pitch Gear Specification Data***

Consists of a series of printed forms for gear drawings that contain the appropriate data the gear designer must tabulate for the gear manufacturer. Includes a series of definitions of the various tabulated items. Appendix contains blank, pre-printed forms that can easily be copied for the user's drawings.

ISBN: 1-55589-571-9 Pages: 29

AGMA 911-A94 ***Guidelines for Aerospace Gearing***

Covers current gear design practices as they are applied to air vehicles and spacecraft. Goes beyond the design of gear meshes. Presents the broad spectrum of factors which combine to produce a working gear system, whether it be a power transmission or special purpose mechanism. Covers only spur, helical and bevel gears. (Does not cover wormgears, face gears, and various proprietary tooth forms). **Replaces AGMA 411.02.**

ISBN: 1-55589-629-4 Pages: 97

AGMA 912-A04, ***Mechanisms of Gear Tooth Failure***

This information sheet describes many of the ways in which gear teeth can fail and recommends methods for reducing gear failure. It provides guidance for those attempting to analyze gear failures. It should be used in conjunction with ANSI/AGMA 1010-E95 in which the gear tooth failure modes are defined. They are described in detail to help investigators understand failures and investigate remedies. This information sheet does not discuss the details of disciplines such as dynamics, material science, corrosion or tribology. It is hoped that the material presented will facilitate communication in the investigation of gear operating problems. **Supplement to ANSI/AGMA 1010-E95.**

ISBN: 1-55589-838-6 Pages: 22

AGMA 913-A98 ***Method for Specifying the Geometry of Spur and Helical Gears***

Provides information to translate tooth thickness specifications which are expressed in terms of tooth thickness, center distance or diameter into profile shift coefficients. It describes the effect that profile shift has on the geometry and performance of gears.

Annexes are provided which contain practical examples on the calculation of tool proportions and profile shift.
ISBN: 1-55589-714-2 Pages: 25

AGMA 914-B04, ***Gear Sound Manual - Part I: Fundamentals of Sound as Related to Gears; Part II: Sources, Specifications and Levels of Gear Sound; Part III: Gear Noise Control***

This information sheet discusses how noise measurement and control depend upon the individual characteristics of the prime mover, gear unit, and driven machine, as well as their combined effects in a particular acoustical environment. It indicates certain areas that might require special attention. This document is a revision of AGMA 299.01 to include updated references and a discussion of Fast Fourier Transform analysis. **Replaces AGMA 299.01.**
ISBN: 1-55589-820-3 Pages: 37

AGMA 915-1-A02 ***Inspection Practices - Part 1: Cylindrical Gears - Tangential Measurements***

Provides a code of practice and measuring methods dealing with inspection relevant to tangential element and composite deviations of cylindrical involute gears (measurements referred to single flank contact). **Replaces elemental measurement section of AGMA 2000-A88.**
ISBN: 1-55589-798-3 Pages: 39

AGMA 915-2-A05 ***Inspection Practices - Part 2: Cylindrical Gears - Radial Measurements***

This information sheet discusses inspection of cylindrical involute gears using the radial (double flank) composite method, with recommended practices detailed. Also included is a clause on runout and eccentricity measurement methods. This information sheet is a supplement to the standard ANSI/AGMA 2015-2-A06. It replaced AGMA ISO 10064-2 and **replaces double flank composite measurement section of AGMA 2000-A88.**
ISBN: 1-55589-843-2 Pages: 24

AGMA 915-3-A99 ***Inspection Practices - Gear Blanks, Shaft Center Distance and Parallelism***

Provides recommended numerical values relating to the inspection of gear blanks, shaft center distance and parallelism of shaft axes. Discussions include such topics as methods for defining datum axes on components; the use of center holes and mounting surfaces during manufacturing and inspection; and, recommended values of in-plane and out-of-plane deviations of shaft parallelism. **Modified adoption of ISO/TR 10064-3:1996.**
ISBN: 1-55589-738-X Pages: 9

AGMA 917-B97 ***Design Manual for Parallel Shaft Fine-Pitch Gearing***

Provides guidance for the design of spur and helical gearing of 20 through 120 diametral pitch including internal and rack forms. Manual contains such specialized subjects as inspection, lubrication, gear load calculation methods, materials, including a wide variety of plastics. **Replaces AGMA 370.01.**
ISBN: 1-55589-694-4 Pages: 84

AGMA 918-A93 ***A Summary of Numerical Examples Demonstrating the Procedures for Calculating Geometry Factors for Spur and Helical Gears***

Provides numerical examples for calculating the pitting resistance geometry factor, I, and bending strength geometry factor, J, for typical gearsets that are generated by rack- type tools (hobs, rack cutters or generating grinding wheels) or pinion-type tools (disk-type shaper cutters). **Supplement to AGMA 908-B89.**
ISBN: 1-55589-617-0 Pages: 42

AGMA 920-A01 ***Materials for Plastic Gears***

This document serves to aid the gear designer in understanding the unique physical, mechanical and thermal behavior of plastic materials. Topics covered include general plastic material behavior, gear operating conditions, plastic gear manufacturing, tests for gear related material properties, and typical plastic gear materials.
ISBN: 1-55589-778-9 Pages: 40

AGMA 922-A96 ***Load Classification and Service Factors for Flexible Couplings***

This Information Sheet provides load classifications and related service factors that are frequently used for various flexible coupling applications. Typical applications using smooth prime movers and special considerations involving unusual or more severe loading are discussed. **Replaces AGMA 514.02.**
ISBN: 1-55589-680-4 Pages: 6

AGMA 923-B05 ***Metallurgical Specifications for Steel Gearing***

This document identifies metallurgical quality characteristics which are important to the performance of steel gearing. The AGMA gear rating standards identify performance levels of gearing by heat treatment method and grade number. For each heat treatment method and AGMA grade number, acceptance criteria are given for various metallurgical characteristics identified in this document. **Revision of AGMA 923-A00.**
ISBN: 1-55589-848-3 Pages: 31

AGMA 925-A03 ***Effect of Lubrication on Gear Surface Distress***

This document provides currently available information pertaining to oil lubrication of industrial gears for power transmission applications. It is intended to serve as a general guideline and source of information about gear oils, their properties, and their tribological behavior in gear contacts. Equations provided allow the calculation of specific film thickness and instantaneous contact (flash) temperature for gears in service, and to help assess the potential risk of surface distress (scuffing, micropitting and macropitting, and scoring) involved with a given lubricant choice. **Supplement to ANSI/AGMA 2001-D04.**

ISBN: 1-55589-815-7 Pages: 51

AGMA 926-C99 ***Recommended Practice for Carburized Aerospace Gearing***

Establishes recommended practices for material case and core properties, microstructure and processing procedures for carburized AISI 9310 aerospace gears. This document is not intended to be a practice for any gears other than those applied to aerospace. **Replaces AGMA 246.02a.**

ISBN: 1-55589-758-4 Pages: 9

AGMA 927-A01 ***Load Distribution Factors - Analytical Methods for Cylindrical Gears***

Describes an analytical procedure for the calculation of face load distribution factor. The iterative solution that is described is compatible with the definitions of the term face load distribution of AGMA standards and longitudinal load distribution of the ISO standards. The procedure is easily programmable and flow charts of the calculation scheme, as well as examples from typical software are presented. **Supplement to ANSI/AGMA 2001-D04.**

ISBN: 1-55589-779-7 Pages: 31

AGMA 929-A06 ***Calculation of Bevel Gear Top Land and Guidance on Cutter Edge Radius***

Has the calculations for bevel gear top land and guidance for selection of cutter edge radius for determination of tooth geometry. It integrates various publications with modifications to include face hobbing. It adds top land calculations for non-generated manufacturing methods. It is intended to provide assistance in completing the calculations requiring determination of top lands and cutter edge radii for gear capacity in accordance with ANSI/AGMA 2003-B97. This information sheet is a **supplement to standard ANSI/AGMA 2005-D03**

ISBN: 1-55589-873-4 Pages: 38

AGMA 930-A05 ***Calculated Bending Load Capacity of Powder Metallurgy (P/M) External Spur Gears***

This information sheet describes a procedure for calculating the load capacity of a pair of powder metallurgy external spur gears based on tooth bending strength. Two types of loading are considered: 1) repeated loading over many cycles; and 2) occasional peak loading. It also describes an essentially reverse procedure for establishing an initial design from specified applied loads. As part of the load capacity calculations, there is a detailed analysis of the gear teeth geometry, including tooth profiles and various fillets.

ISBN: 1-55589-845-9 Pages: 78

AGMA 932-A05 ***Rating the Pitting Resistance and Bending Strength of Hypoid Gears***

This information sheet provides a method by which different hypoid gear designs can be compared. The formulas are intended to establish a uniformly acceptable method for calculating the pitting resistance and bending strength capacity of both curved and skewed tooth hypoid gears. They apply equally to tapered depth and uniform depth teeth. Annexes contain graphs for geometry factors and a sample calculation to assist the user. **Supplement to ANSI/AGMA 2003-B97.**

ISBN: 1-55589-869-6 Pages: 18

AGMA 933-B03 ***Basic Gear Geometry***

This information sheet illustrates important geometrical relationships which provide a sound basis for a thoroughly logical and comprehensive system of gear geometry. **Replaces AGMA 115.01.**

ISBN: 1-55589-814-9 Pages: 18

AGMA 935-A05 ***Recommendations Relative to the Evaluation of Radial Composite Gear Double Flank Testers***

The condition and alignment of gear measuring instruments can greatly influence the measurement of product gears. This information sheet provides qualification procedures for double flank testers that are used for the evaluation of radial composite deviations of gears. It discusses guidelines for alignment of double flank tester elements such as centers, ways, probe systems, etc. It also covers the application of artifacts to determine instrument accuracy. This information sheet is a **supplement to standard ANSI/AGMA 2116-A05.**

ISBN: 1-55589-872-6 Pages: 11

AGMA 938-A05 ***Shot Peening of Gears***

This information sheet provides a tool for gear designers interested in the residual compressive stress properties produced by shot peening and its relationship to gearing. It also discusses shot media materials, delivery methods and process controls.

ISBN: 1-55589-847-5 Pages: 14

AGMA 939-A07, *Austempered Ductile Iron for Gears*

This information sheet gives the background and basic guidelines to consider the feasibility of austempered ductile iron (ADI) for gear applications. It contains experimental, experiential and anecdotal information to assist in the specification, purchase and manufacture of ADI components. The metallurgy of ADI, relevant factors in its production, allowable stress numbers, and stress cycle curves are reviewed. It also has references, relevant standards, and evaluation methods used in the manufacture of ADI components.

ISBN: 978-1-55589-901-1 Pages: 10

ANSI/AGMA 1003-H07 *Tooth Proportions for Fine-Pitch Spur and Helical Gears*

Tooth proportions for fine-pitch gearing are similar to those of coarse pitch gearing except in the matter of clearance. This standard is applicable to external spur and helical gears with diametral pitch of 20 through 120 and a profile angle of 20 degrees. It provides a system of enlarged pinions which use the involute form above 5 degrees of roll. Data on 14-1/2 and 25 degree profile angle systems, and a discussion of enlargement and tooth thicknesses are provided in annexes. In addition, it addresses, in a new annex, an analysis of comparative systems of selecting tooth thicknesses of pinions. **Revision of ANSI/AGMA 1003-G93.**

ISBN: 978-1-55589-902-8 Pages: 25

ANSI/AGMA 1006-A97 *Tooth Proportions for Plastic Gears*

Presents a new basic rack, AGMA PT, which, with its full round fillet, may be preferred in many applications of gears made from plastic materials. It contains a description, with equations and sample calculations, of how the proportions of a spur or helical gear may be derived from the design tooth thickness and the basic rack data. In several annexes, there are discussions of possible variations from the basic rack and also a procedure for defining tooth proportions without using the basic rack concept.

ISBN: 1-55589-684-7 Pages: 47

ANSI/AGMA 1010-E95 *Appearance of Gear Teeth - Terminology of Wear and Failure*

This standard provides nomenclature for general modes of gear tooth wear and failure. It classifies, identifies and describes the most common types of failure and provides information which will, in many cases, enable the user to identify failure modes and evaluate the degree or progression of wear. **Replaces AGMA 110.04.**

ISBN: 1-55589-665-0 Pages: 40

ANSI/AGMA 1012-G05 *Gear Nomenclature, Definitions of Terms with Symbols*

This standard establishes the definitions of terms, symbols and abbreviations which may be used to communicate the technology and specifications of external and internal gear teeth. it provides definitive meanings by the use of words and illustrations, for commonly used gearing terms. **Revision of ANSI/AGMA 1012-F90.**

ISBN: 1-55589-846-7 Pages: 72

ANSI/AGMA 1102-A03, *Tolerance Specification for Gear Hobs*

Provides specifications for nomenclature, dimensions, equation based tolerances, and inspection practices for gear hobs. Defines a classification system for accuracy grades D through AAA, in order of increasing precision. The standard describes hob identification practices, manufacturing and purchasing considerations, and hob design parameters. An informative annex is included which provides the reader with a basic understanding of how the different elements of a hob can affect the accuracy of the gear being machined. **Replaces AGMA 120.01.**

ISBN: 1-55589-816-5 Pages: 49

ANSI/AGMA 1103-H07 *Tooth Proportions for Fine-Pitch Spur and Helical Gears (Metric Edition)*

Tooth proportions for fine-pitch gearing are similar to those of coarse pitch gearing except in the matter of clearance. This standard is applicable to external spur and helical gears with diametral pitch of 1.25 through 0.2 and a profile angle of 20 degrees. It provides a system of enlarged pinions which use the involute form above 5 degrees of roll. Data on 14-1/2 and 25 degree profile angle systems, and a discussion of enlargement and tooth thicknesses are provided in annexes. In addition, it addresses, in a new annex, an analysis of comparative systems of selecting tooth thicknesses of pinions. **Metric version of ANSI/AGMA 1003-H07.**

ISBN: 978-1-55589-903-5 Pages: 25

ANSI/AGMA 1106-A97 *Tooth Proportions for Plastic Gears*

Presents a new basic rack, AGMA PT, which, with its full round fillet, may be preferred in many applications of gears made from plastic materials. It contains a description, with equations and sample calculations, of how the proportions of a spur or helical gear may be derived from the design tooth thickness and the basic rack data. In several annexes, there are discussions of possible variations from the basic rack and also a procedure for defining tooth proportions without using the basic rack concept. **Metric edition of ANSI/AGMA 1006-A97.**

ISBN: 1-55589-685-5 Pages: 47

ANSI/AGMA 2001-D04 ***Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth***

Presents a comprehensive method for rating the pitting resistance and bending strength of spur and helical involute gear pairs. Contains detailed discussions of factors influencing gear survival and calculation methods. Revisions reflected in this version include incorporating the latest AGMA accuracy standard (ANSI/AGMA -A01) into the determination of dynamic factor, and change to the relationship between service factor and stress cycle factor. **Revision of ANSI/AGMA 2001-C95.**

ISBN: 1-55589-839-4 Pages: 56

ANSI/AGMA 2002-B88 ***Tooth Thickness Specification and Measurement***

Presents procedures for determining tooth thickness measurements of external and internal cylindrical involute gearing. Includes equations and calculation procedures for commonly used measuring methods.

ISBN: 1-55589-503-4 Pages: 47

ANSI/AGMA 2003-B97 ***Rating the Pitting Resistance and Bending Strength of Generated Straight Bevel, Zerol Bevel, and Spiral Bevel Gear Teeth***

Presents a method for rating the pitting resistance and bending strength of generated straight bevel, zerol bevel, and spiral bevel gear teeth. Includes a detailed discussion of factors influencing gear survival and a calculation method. **Revision of ANSI/AGMA 2003-A86.**

ISBN: 1-55589-692-8 Pages: 75

ANSI/AGMA 2004-C08 ***Gear Materials, Heat Treatment and Processing Manual***

This standard provides information pertaining to ferrous and nonferrous materials used in gearing. Factors in material selection, including material forms, properties, and associated processing and heat treatments are discussed. Manufacturing procedures to prepare materials for machining and final heat treatment are included. Heat treating procedures used for gearing are covered in detail, including process description, product specifications, process controls, and characteristics of heat treated gearing. Post-heat treatment processes to meet gearing requirements are discussed. Product inspection methods and documentation are covered. Term definitions, test methods, distortion and residual stress, sources for additional information and bibliography are included. **Revision of ANSI/AGMA 2004-B89.**

ISBN: 978-1-55589-904-2 Pages: 68

ANSI/AGMA 2005-D03 ***Design Manual for Bevel Gears***

Provides the standards for designing straight bevel, zerol bevel, spiral bevel and hypoid gears along with information on fabrication, inspection and mounting. Covers preliminary gear design parameters, blank design including standard taper, uniform depth, duplex taper and tilted root. Also includes drawing format, inspection, materials, lubrication, mountings and assembly. An Annex contains examples for ease of understanding. **Revision of ANSI/AGMA 2005-C96.**

ISBN: 1-55589-667-7 Pages: 94

ANSI/AGMA 2007-C00 ***Surface Temper Etch Inspection After Grinding [Same as New ISO 14104]***

Explains the materials and procedures to determine and evaluate localized overheating on ground surfaces. Includes a system to describe and classify the indications produced during this inspection. However, does not provide specific acceptance or rejection criteria. **Revision of ANSI/AGMA 2007-B92.**

ISBN: 1-55589-761-4 Pages: 6

ANSI/AGMA 2008-C01 ***Assembling Bevel Gears***

Prepared expressly for the assembly man in the factory and the service man in the field. Each definition, explanation, and instruction is directed toward the physical appearance of the gears as they are inspected and assembled by these personnel. **Revision of ANSI/AGMA 2008-B90.**

ISBN: 1-55589-795-9 Pages: 30

ANSI/AGMA 2009-B01 ***Bevel Gear Classification, Tolerances, and Measuring Methods***

Establishes a classification system which may be used to communicate geometrical accuracy specifications of unassembled bevel gearing. It also provides information on measuring methods and practices to promote uniform measurement procedures. Eight accuracy grades are defined, numbered B3 through B10, in order of DECREASING precision. Equations for the tolerances are provided in metric terms. **Revision of ANSI/AGMA 2009-A98.**

ISBN: 1-55589-794-0 Pages: 68

ANSI/AGMA 2011-A98 ***Cylindrical Wormgearing Tolerance and Inspection Methods***

Establishes a classification system for the geometrical accuracy specification of wormgearing. It also provides uniform measurement procedures including discussions on single and double flank composite testing and tooth thickness measurements. The standard establishes ten accuracy grades, W3 through W12, based on the relative effect of geometrical errors on conjugate action for wormgear sets.

ISBN: 1-55589-716-9 Pages: 43

To search this document, CTRL "F"

ANSI/AGMA 2015-1-A01 ***Accuracy Classification System - Tangential Measurements for Cylindrical Gears***

This standard, for spur and helical gearing, correlates gear accuracy grades with gear tooth tolerances and geometry. It provides information on minimum requirements for accuracy by elemental measurement methods. Annex material provides guidance on measurement filtering influences and information on comparison of gear inspection methods. Users of this standard should have a copy of the companion information sheet, AGMA 915-1-A02. **Replaces elemental tolerance section of AGMA 2000-A88.**

ISBN: 1-55589-797-5 Pages: 37

ANSI/AGMA 2015-2-A06 ***Accuracy Classification System - Radial Measurements for Cylindrical Gears***

This standard establishes a classification system relevant to radial (double flank) composite deviations of individual cylindrical involute gears. It serves as a concise means of specifying gear accuracy without the need of supplying individual element tolerances. It simplifies discussions of gear accuracy between gear manufacturer and purchaser. It specifies the appropriate definitions of gear tooth accuracy terms, the structure of the gear accuracy system, and the tolerances (allowable values of deviations). Annex A provides information on the accuracy of master gears. Annex B provides information on runout tolerance values. **Replaces double flank composite tolerance section of AGMA 2000-A88.**

ISBN: 1-55589-874-2 Pages: 13

Supplemental Tables for AGMA 2015/915-1-A02 ***Accuracy Classification System - Tangential Measurement Tolerance Tables for Cylindrical Gears***

Only provides tolerance tables as a supplement to AGMA 2015-1-A01, *Accuracy Classification System - Tangential Measurements for Cylindrical Gears.*

ISBN: 1-55589-813-0 Pages: 101

ANSI/AGMA 2101-D04 ***Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*** **(Metric Edition)**

Presents a comprehensive method for rating the pitting resistance and bending strength of spur and helical involute gear pairs. Contains detailed discussions of factors influencing gear survival and calculation methods. Revisions reflected in this version include incorporating the latest AGMA accuracy standard (ANSI/AGMA 2015-1-A01) into the determination of dynamic factor, and change to the relationship between service factor and stress cycle factor. **Revision of ANSI/AGMA 2101-C95.**

ISBN: 1-55589-840-8 Pages: 56

ANSI/AGMA 2111-A98 ***Cylindrical Wormgearing Tolerance and Inspection Methods***

Establishes a classification system for the geometrical accuracy specification of wormgearing. It also provides uniform measurement procedures including discussions on single and double flank composite testing and tooth thickness measurements. The standard establishes ten accuracy grades, W3 through W12, based on the relative effect of geometrical errors on conjugate action for wormgear sets. **Metric edition of ANSI/AGMA 2011-A98.**

ISBN: 1-55589-717-7 Pages: 43

ANSI/AGMA 2116-A05 ***Evaluation of Double Flank Testers for Radial Composite Measurement of Gears***

This standard provides the evaluation criteria for double flank testers. Recommended artifact sizes and geometry are provided along with measurement system conditions. Annexes contain methods for estimating calibration uncertainty and specifying artifact.

ISBN: 1-55589-871-8 Pages: 9

ANSI/AGMA 6000-B96 ***Specification for Measurement of Linear Vibration on Gear Units***

Presents a method for measuring linear vibration on a gear unit. Recommends instrumentation, measuring methods, test procedures and discrete frequency vibration limits for acceptance testing. Annexes list system effects on gear unit vibration and system responsibility. The ISO vibration rating curves from ISO 8579-2, Acceptance code for gears - Part 2: Determination of mechanical vibrations of gear units during acceptance testing are introduced.

ISBN: 1-55589-666-9 Pages: 21

!! NEW !!

ANSI/AGMA 6001-E08, ***Design and Selection of Components for Enclosed Gear Drives***

This standard outlines the basic practices for the design and selection of components, other than gearing, for use in commercial and industrial enclosed gear drives. Fundamental equations provide for the proper sizing of shafts, keys, and fasteners based on stated allowable stresses. Other components are discussed in a manner to provide an awareness of their function or specific requirements. This standard applies to the following types of commercial and industrial enclosed gear drives, individually or in combination: spur, helical, herringbone, bevel and worm. **Revision of ANSI/AGMA 6001-D97.**

ISBN: 978-1-55589-951-6 Pages: 44

ANSI/AGMA 6002-B93 ***Design Guide for Vehicle Spur and Helical Gears***

A guide to the design, fabrication, and inspection of spur and helical gears for vehicles and for power transmission on vehicles.

ISBN: 1-55589-616-2 Pages: 38

ANSI/AGMA/AWEA 6006-A03 ***Standard for Design and Specification of Gearboxes for Wind Turbines***

This standard is intended to apply to wind turbine gearboxes. It provides information for specifying, selecting, designing, manufacturing, procuring operating and manufacturing reliable speed increasing gearboxes for wind turbine generator system service.

Annex information is supplied on: wind turbine architecture, wind turbine load description, quality assurance, operation and maintenance, minimum purchaser gearbox manufacturing ordering data, lubrication selection and monitoring, determination of an application factor from a load spectrum using equivalent torque, and bearing stress calculations. Replaces AGMA 921-A97.

ISBN: 1-55589-817-3 Pages: 94

ANSI/AGMA 6008-A98 ***Specifications for Powder Metallurgy Gears***

Defines the minimum detailed information to be included in the powder metallurgy gear specifications submitted by the gear purchaser to the gear producer. Specifications on gear tooth geometry are described in detail for external spur and helical gears and for straight bevel gears. In addition, there are discussions on specifications for gear drawings and gear material data. The standard applies to gears made by the conventional P/M process consisting of compaction followed by sintering and, in some cases, by post sintering treatments.

ISBN: 1-55589-713-4 Pages: 17

ANSI/AGMA 6011-I03 ***Specification for High Speed Helical Gear Units***

This standard includes information on design, lubrication, bearings, testing and rating for single and double helical external tooth, parallel shaft speed reducers and increasers. Units covered include those operating with at least one stage having a pitch line velocity equal to or greater than 35 meters per second or rotational speeds greater than 4500 rpm and other stages having pitch line velocities equal to or greater than 8 meters per second. Annex material includes discussions on service factors, rotor dynamics, efficiency and newly configured purchaser's data sheets. **Revision of ANSI/AGMA 6011-H98.**

ISBN: 1-55589-819-X Pages: 51

ANSI/AGMA 6013-A06 ***Standard for Industrial Enclosed Gear Drives***

This standard includes design, rating, lubrication, testing and selection information for enclosed gear drives, including foot mounted, shaft mounted, screw conveyor drives and gearmotors. These drives include spur, helical, herringbone, double helical, or bevel gearing in single or multistage arrangements, and wormgearing in multistage drives, as either parallel, concentric or right angle configurations. This standard combines and **replaces the information previously found in ANSI/AGMA 6009-A00 and ANSI/AGMA 6010-F97.**

ISBN: 1-55589-822-X Pages: 60

ANSI/AGMA 6014-A06 ***Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment***

This standard specifies methods for rating the pitting resistance and bending strength of open or semi-enclosed spur, single helical, double helical, and herringbone gears made from steel and spheroidal graphitic iron for use on cylindrical shell and trunnion supported equipment, such as cylindrical grinding mills, kilns, coolers and dryers. This standard provides a design comparison method for different open or semi-enclosed gears, where the gear reaction forces are transmitted through a structure which provides independent bearing support for the gear and pinion. Annexes cover installation, alignment, maintenance, lubrication, and a rating method for gears made from ausferritic ductile iron. **Supersedes ANSI/AGMA 6004-F88.**

ISBN: 1-55589-876-9 Pages: 71

ANSI/AGMA 6022-C93 ***Design Manual for Cylindrical Wormgearing***

Covers the design of general industrial coarse--pitch cylindrical worms and throated gears mounted with axes at a 90 degree angle and having axial pitches of 3/16 inch and larger..

ISBN: 1-55589-041-5 Pages: 10

ANSI/AGMA 6025-D98 ***Sound for Enclosed Helical, Herringbone and Spiral Bevel Gear Drives***

Describes a recommended method of acceptance testing and reporting of the sound pressure levels generated by a gear speed reducer or increaser when tested at the manufacturer's facility. The results obtained through the use of this standard should represent only the sound of the gear unit, as other system influences, such as prime mover or driven equipment are minimized. Annexes to the standard present sound power measurement methods for use when required by specific contract provisions between the manufacturer and purchaser. **Revision of ANSI/AGMA 6025-C90.**

ISBN: 1-55589-718-5 Pages: 21

ANSI/AGMA 6032-A94 ***Standard for Marine Gear Units: Rating***

Considers rating practices for marine main propulsion, power take-off and auxiliary propulsion service. Allowable contact stress numbers and allowable bending stress numbers for materials are included. Also addresses bearings, clutches, lubricating oil systems, shafts and certain aspects of vibration.

ISBN: 1-55589-633-2 Pages: 57

!! NEW !!

ANSI/AGMA 6033-C08 ***Materials for Marine Propulsion Gearing***

This standard identifies commonly used alloy steels, heat treatments and inspection requirements for through hardened and surface hardened gearing for main propulsion marine service over 1500 hp. Forged and hot rolled alloy steel bar stock are specified to two metallurgical quality grades (1 and 2) according to cleanliness and test requirements. Cast steel gearing is specified to a single metallurgical quality level. Mechanical, metallurgical and nondestructive test requirements are provided for various heat treatment processes and metallurgical quality grades of gearing. **Revision of ANSI/AGMA 6033-B98.**

ISBN: 978-1-55589-929-5 Pages: 34

ANSI/AGMA 6034-B92 ***Practice for Enclosed Cylindrical Wormgear Speed Reducers and Gearmotors***

Covers the design and rating of cylindrical- wormgear speed reducers, having either solid or hollow output shafts of the following specific types: single reduction; double reduction incorporating cylindrical wormgearing for each reduction; and double reduction incorporating cylindrical wormgearing as final and helical gearing as initial reduction.

ISBN: 1-55589-494-1 Pages: 37

ANSI/AGMA 6035-A02 ***Design, Rating and Application of Industrial Globoidal Wormgearing***

This standard provides guidelines for the design, rating and application of globoidal wormgearing mounted at a 90 degree angle. Specific definitions for globoidal wormgearing terms are presented, along with formulas for determining the geometric sizes of the major features for the worm and gear. Design considerations, design procedures, gear blanks and self-locking conditions are also discussed. Procedures for rating the load capacity of globoidal wormgearing are included. **Replaces ANSI/AGMA 6017-E86 and ANSI/AGMA 6030-C87.**

ISBN: 1-55589-792-4 Pages: 45

!! NEW !!

ANSI/AGMA 6101-E08, ***Design and Selection of Components for Enclosed Gear Drives (Metric Edition)***

This standard outlines the basic practices for the design and selection of components, other than gearing, for use in commercial and industrial enclosed gear drives. Fundamental equations provide for the proper sizing of shafts, keys, and fasteners based on stated allowable stresses. Other components are discussed in a manner to provide an awareness of their function or specific requirements. This standard applies to the following types of commercial and industrial enclosed gear drives, individually or in combination: spur, helical, herringbone, bevel and worm. **Metric Edition of ANSI/AGMA 6001-E08.**

ISBN: 978-1-55589-952-3 Pages: 42

ANSI/AGMA 6113-A06 ***Standard for Industrial Enclosed Gear Drives (Metric Edition)***

This standard includes design, rating, lubrication, testing and selection information for enclosed gear drives, including foot mounted, shaft mounted, screw conveyor drives and gearmotors. These drives include spur, helical, herringbone, double helical or bevel gearing in single or multistage arrangements, and wormgearing in multistage drives, as either parallel, concentric or right angle configurations. This standard combines and replaces the information previously found in ANSI/AGMA 6109-A00 and ANSI/AGMA 6110-F97. **Metric version of ANSI/AGMA 6013-A06.**

ISBN: 1-55589-823-8 Pages: 60

ANSI/AGMA 6114-A06 ***Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment (Metric Edition)***

This standard specifies methods for rating the pitting resistance and bending strength of open or semi-enclosed spur, single helical, double helical, and herringbone gears made from steel and spheroidal graphitic iron for use on cylindrical shell and trunnion supported equipment, such as cylindrical grinding mills, kilns, coolers and dryers. This standard provides a design comparison method for different open or semi-enclosed gears, where the gear reaction forces are transmitted through a structure which provides independent bearing support for the gear and pinion. Annexes cover installation, alignment, maintenance, lubrication, and a rating method for gears made from ausferritic ductile iron. **Supersedes ANSI/AGMA 6004-F88 and is the metric edition of ANSI/AGMA 6014-A06.**

ISBN: 1-55589-877-7 Pages: 71

ANSI/AGMA 6123-B06 ***Design Manual for Enclosed Epicyclic Gear Drives***

This standard provides the user of enclosed epicyclic gear drives with advanced methods of specifying and comparing proposed designs to help predict the relative performance of different drive systems. It provides guidelines for epicyclic gear meshing and assembly requirements, tooth geometry, load sharing between planets, circulating power, component design, thermal rating and lubrication. Annexes provide complete example calculations, and discussions on special design considerations for epicyclic drives. **Replaces ANSI/AGMA 6023-A88 and ANSI/AGMA 6123-A88.**

ISBN: 1-55589-875-0 Pages: 97

!! NEW !!

ANSI/AGMA 6133-C08 ***Materials for Marine Propulsion Gearing***

This standard identifies commonly used alloy steels, heat treatments and inspection requirements for through hardened and surface hardened gearing for main propulsion marine service over 1500 hp. Forged and hot rolled alloy steel bar stock are specified to two metallurgical quality grades (1 and 2) according to cleanliness and test requirements. Cast steel gearing is specified to a single metallurgical quality level. Mechanical, metallurgical and nondestructive test requirements are provided for various heat treatment processes and metallurgical quality grades of gearing. **Metric version of ANSI/AGMA 6033-C08.**

ISBN: 978-1-55589-930-1 Pages: 34

ANSI/AGMA 6135-A02 ***Design, Rating and Application of Industrial Globoidal Wormgearing (Metric Version)***

This standard provides guidelines for the design, rating and application of globoidal wormgearing mounted at a 90 degree angle. Specific definitions for globoidal wormgearing terms are presented, along with formulas for determining the geometric sizes of the major features for the worm and gear. Design considerations, design procedures, gear blanks and self-locking conditions are also discussed. Procedures for rating the load capacity of globoidal wormgearing are included. Replaces ANSI/AGMA 6017-E86 and ANSI/AGMA 6030-C87. **Metric edition of ANSI/AGMA 6035-A02.**

ISBN: 1-55589-793-2 Pages: 45

!! NEW !!

ANSI/AGMA ISO 6336-A08 ***Calculation of Load Capacity of Spur and Helical Gears - Part 6: Calculation of Service Life Under Variable Load***

This standard specifies the information and standardized conditions necessary for the calculation of the service life (or safety factors for a required life) of gears subject to variable loading. While the method is presented in the context of ISO 6336 and the calculation of load capacity for spur and helical gears, it is equally applicable to other types of stress. **Identical adoption of ISO 6336-6:2006.**

ISBN: 978-1-55589-928-8 Pages: 20

ANSI/AGMA 9000-C90 ***Flexible Couplings - Potential Unbalance Classification***

Offers standard criteria for the unbalance classification of flexible couplings. Considers the effects of hardware and eccentricity to give a more accurate value. Presents revised examples in the appendices that illustrate the calculation methods. **Replaces AGMA 515.02.**

ISBN: 1-55589-549-2 Pages: 41

ANSI/AGMA 9001-B97 ***Flexible Couplings - Lubrication***

Examines proper lubrication and why it is an essential element for satisfactory performance and long life. Looks at the requisites for proper lubrication, including: selection of proper lubricant, a well-designed lubrication system, and an adequate maintenance program, are discussed in this standard. **Revision of ANSI/AGMA 9001-A86.**

ISBN: 1-55589-686-3 Pages: 6

ANSI/AGMA 9002-B04 ***Bores and Keyways for Flexible Couplings (Inch Series)***

This standard describes sizes and tolerances for straight and tapered bores and the associated keys and keyways, as furnished in flexible couplings. The data in the standard considers commercially standard coupling bores and keyways, not special coupling bores and keyways that may require special tolerances. Annexes provide material on inspection methods and design practices for tapered shafts. **Revision of ANSI/AGMA 9002-A86.**

ISBN: 1-55589-841-6 Pages: 22

!! NEW !!

ANSI/AGMA 9003-B08 ***Flexible Couplings - Keyless Fits***

This standard presents information on design, dimensions, tolerances, inspection, mounting, removal, and equipment that is in common use with

To search this document, CTRL "F"

keyless tapered and keyless straight (cylindrical) bore hubs for flexible couplings. Example calculations of important design issues are provided in an annex. **Revision of ANSI/AGMA 9003-A91.**
ISBN: 1-55589-572-7 Pages: 21

!! NEW !!

ANSI/AGMA 9004-B08 ***Flexible Couplings - Mass Elastic Properties and Other Characteristics***
This standard provides calculation methods related to mass elastic properties of flexible couplings. Properties discussed include coupling mass, polar mass moment of inertia (WR2), center of gravity, axial stiffness, axial natural frequency, lateral stiffness, lateral natural frequency, and torsional stiffness. Calculation examples are provided in informative annexes. **Revision of ANSI/AGMA 9004-A99.**
ISBN: 978-1-55589-973-8 Pages: 33

ANSI/AGMA 9005-E02 ***Industrial Gear Lubrication***
This standard provides the end user, original equipment builder, gear manufacturer and lubricant supplier with guidelines for minimum performance characteristics for lubricants suitable for use with enclosed and open gearing which is installed in general industrial power transmission applications. It provides recommendations for selecting lubricants based on current theory and practice in the industry, and attempts to align with current ISO standards. It is not intended to supplant specific instructions from the gear manufacturer. Replaces ANSI/AGMA 9005-D94.
ISBN: 1-55589-800-9 Pages: 31

ANSI/AGMA 9008-B00 ***Flexible Couplings – Gear Type – Flange Dimensions, Inch Series***
Defines the North American industry practice for the interface dimensions of the sleeve and rigid hubs of both shrouded and exposed bole, inch series, gear type couplings.
ISBN: 1-55589-736-3 Pages: 3

ANSI/AGMA 9009-D02 ***Flexible Couplings - Nomenclature for Flexible Couplings***
Presents the nomenclature common to flexible couplings as used in mechanical power transmission drives. It was prepared to reduce the language barriers that arise between designers, manufacturers and users when attempting to designate various types of flexible couplings and their elements. It does not address nomenclature for flexible shafts, quill shafts, universal joints or devices which exhibit slip such as clutches, fluid couplings, magnetic couplings or torque converters.
ISBN: 1-55589-796-7 Pages: 17

!! NEW !!

ANSI/AGMA 9103-B08 ***Flexible Couplings - Keyless Fits (Metric Edition)***
This standard presents information on design, dimensions, tolerances, inspection, mounting, removal, and equipment that is in common use with keyless tapered and keyless straight (cylindrical) bore hubs for flexible couplings. Example calculations of important design issues are provided in an annex. **Metric version of ANSI/AGMA 9003-B08.**
ISBN: 978-1-55589-925-7 Pages: 22

ANSI/AGMA 9104-A06 ***Flexible Couplings - Mass Elastic Properties and Other Characteristics (Metric Edition)***
This standard provides calculation methods related to mass elastic properties of flexible couplings. Properties discussed include coupling mass, polar mass moment of inertia, center of gravity, axial stiffness, axial natural frequency, lateral stiffness, lateral natural frequency, and torsional stiffness. Calculation examples are provided in informative annexes. **Metric edition of ANSI/AGMA 9004-A99.**
ISBN: 1-55589-900-4 Pages: 32

ANSI/AGMA 9112-A04 ***Bores and Keyways for Flexible Couplings (Metric Series)***
This standard describes sizes and tolerances for straight and tapered bores and the associated keys and keyways, as furnished in flexible couplings. The data in the standard considers commercially standard coupling bores and keyways, not special coupling bores and keyways that may require special tolerances. Annexes provide material on inspection methods and design practices for tapered shafts. **Metric edition of ANSI/AGMA 9002-B04.**
ISBN: 1-55589-842-4 Pages: 35

AGMA ISO 10064-5-A06, ***Code of Inspection Practice - Part 5: Recommendations Relative to Evaluation of Gear Measuring Instruments***
This information sheet provides methods and examples to support the implementation of ANSI/AGMA ISO 18653-A06. It includes evaluation and calibration procedures for involute, helix, runout, and tooth thickness measurement processes. Methods are given for the evaluation of condition and alignment of instrument elements such as centers, guideways, probe systems, etc. Recommendations include statistical data evaluation procedures. Guidance is given on the application of measurement processes to the inspection of product gears, including fitness for use and the recommended limits of U95 uncertainty based on the accuracy tolerances of product gears to be inspected. Many of its recommendations could be applied to the measurement of worms, worm wheels, bevel gears and gear cutting tools. **Replaces AGMA 931-A02.**
ISBN: 1-55589-881-5 Pages: 62

AGMA ISO 14179-1, *Gear Reducers - Thermal Capacity Based on ISO/TR 14179-1*

This information sheet utilizes an analytical heat balance model to provide a means of calculating the thermal transmittable power for a single- or multi-stage gear drive lubricated with mineral oil. The calculation is based on standard conditions of 25C maximum ambient temperature and 95C maximum oil sump temperature in a large indoor space, but provides modifiers for other conditions. Differences from ISO/TR 14179-1 are: a) errors were identified and corrected, b) text was added to clarify the calculation methods, and c) an illustrative example was added to assist the reader. **Modified adoption of ISO/TR 14179-1.**

ISBN: 1-55589-821-1 Pages: 26

!! NEW !!

ANSI/AGMA *ISO 17485-A08 Bevel Gears - ISO System of Accuracy*

This standard establishes a classification system that can be used to communicate geometrical accuracy specifications of unassembled bevel gears, hypoid gears, and gear pairs. It defines tooth accuracy terms, specifies the structure of the gear accuracy grade system, and provides allowable values. The standard provides the gear manufacturer and the gear buyer with a mutually advantageous reference for uniform tolerances. Ten grades are defined, numbered 2 to 11 in order of decreasing precision. Equations for tolerances and their ranges of validity are provided for bevel and hypoid gearing. Identical adoption of ISO 17485:2006.

ISBN: 978-1-55589-926-4 Pages: 23

!! NEW !!

Supplemental Tables for ANSI/AGMA ISO 17485-A08, *Bevel Gears - ISO System of Accuracy - Tolerance Tables*

This information sheet contains tolerance tables dealing with the measurements of bevel gear tooth flanks. While the tables may be used to estimate the tolerance, the actual tolerances are provided in ANSI/AGMA ISO 17485-A08.

ISBN: 978-1-55589-950-9 Pages: 39

ANSI/AGMA ISO 18653-A06 *Gears - Evaluation of Instruments for the Measurement of Individual Gears*

This International Standard specifies methods for the evaluation of measuring instruments used to measure cylindrical gear involute, helix, pitch and runout. It includes instruments that measure runout directly, or compute it from index measurements. Of necessity, it includes the estimation of measurement uncertainty with the use of calibrated gear artifacts. It also gives recommendations for the evaluation of tooth thickness measuring instruments. The estimation of product gear measurement uncertainty is beyond its scope (see AGMA ISO 10064-5-A06 for recommendations). This standard is an identical adoption of ISO 18653:2006. **Replaces ANSI/AGMA 2010-A94, ANSI/AGMA 2110-A94, ANSI/AGMA 2113-A97 and ANSI/AGMA 2114-A98.**

ISBN: 1-55589-882-3 Pages: 14

!! NEW !!

ANSI/AGMA ISO 23509-A08 *Bevel and Hypoid Gear Geometry*

This standard specifies the geometry of bevel gears. The term bevel gears is used to mean straight, spiral, zerol bevel and hypoid gear designs. The standard integrates straight bevel gears and the three major design generation methods for spiral bevel gears into one complete set of formulas. The formulas of the three methods are developed for the general case of hypoid gears and calculate the specific cases of spiral bevel gears by entering zero for the hypoid offset. Identical adoption of ISO 23509:2006.

ISBN: 978-1-55589-927-1 Pages: 138

ISO Standards by Technical Committee 60

Technical Committee 60 is responsible for the development of all international gear-related standards.

Many standards require additional documents for their proper use. A list of these standards are normally supplied after the scope, in the normative references section of a document. Be sure to inquire whether the standard you need requires other documents listed herein.

53:1998 Cylindrical gears for general and heavy engineering – Standard basic rack tooth profile

54:1996 Cylindrical gears for general engineering and for heavy engineering - Modules

677:1976 Straight bevel gears for general engineering and heavy engineering - Basic rack

678:1976 (1996) Straight bevel gears for general engineering and heavy engineering - Modules and diametral pitches

701:1998 International gear notation - Symbols for geometric data

1122-1:1998 Glossary of gear terms - Part 1: Definitions related to geometry

1122-2:1999 Vocabulary of gear terms - Part 2: Definitions related to worm gear geometry

1328-1:1995 Cylindrical gears - ISO system of accuracy - Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth **(See ANSI/AGMA ISO 1328-1)**

1328-2:1997 Cylindrical gears - ISO system of accuracy - Part 2: Definitions and allowable values of deviations relevant to radial composite deviations and runout information **(See ANSI/AGMA ISO 1328-2)**

1340:1976 Cylindrical gears - Information to be given to the manufacturer by the purchaser in order to obtain the gears required

1341:1976 Straight bevel gears - Information to be given to the manufacturer by the purchaser in order to obtain the gears required

2490:1996 Single-start solid (monoblock) gear hobs with tenon drive or axial keyway, 1 to 40 module - Nominal dimensions

4468:2009 Gear hobs - Accuracy requirements

6336-1:2006 Calculation of load capacity of spur and helical gears - Part 1: Basic principles, introduction and general influence factors

6336-2:2006 Calculation of load capacity of spur and helical gears - Part 2: Calculation of surface durability (pitting)

6336-3:2006 Calculation of load capacity of spur and helical gears - Part 3: Calculation of tooth bending strength

6336-5:2003 Calculation of load capacity of spur and helical gears - Part 5: Strength and quality of materials

6336-6:2006 Calculation of load capacity of spur and helical gears - Part 6: Calcultion of service life under variable load

8579-1:2002 Acceptance code for gears - Part 1: Determination of airborne sound power levels emitted by gear units

8579-2:1993 Acceptance code for gears - Part 2: Determination of mechanical vibration of gear units during acceptance testing

9083:2001 Calculation of load capacity of spur and helical gears - Application to marine gears

9085:2002 Calculation of load capacity of spur and helical gears - Application for industrial gears

TR10064-1:1992 Cylindrical gears - Code of inspection practice - Part 1: Inspection of corresponding flanks of gear teeth **(See AGMA ISO 10064-1)**

TR10064-2:1996 Cylindrical gears - Code of inspection practice - Part 2: Inspection related to radial composite deviations, runout, tooth thickness and backlash **(See AGMA ISO 10064-2)**

TR10064-3:1996 Cylindrical gears - Code of inspection practice - Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes

TR10064-4:1998 Cylindrical gears - Code of inspection practice - Part 4: Recommendations relative to surface texture and tooth contact pattern checking

TR10064-5:2005/Cor 1:2006 Code of inspection practice -- Part 5: Recommendations relative to evaluation of gear measuring instruments -- Technical Corrigendum 1

TR10064-6:2009 Code of inspection practice - Part 6: Bevel gear measurement methods

10300-1:2001 Calculation of load capacity of bevel gears - Part 1: Introduction and general influence factors

10300-2:2001 Calculation of load capacity of bevel gears - Part 2: Calculation of surface durability (pitting)

10300-3:2001 Calculation of load capacity of bevel gears - Part 3: Calculation of tooth root strength

TR10495:1997 Cylindrical gears- Calculation of service life under variable loads - Conditions for cylindrical gears according to ISO 6336

10825:1995 Gears - Wear and damage to gear teeth - Terminology

TR10828:1997 Wormgears - Geometry of worm profiles

TR13593:1999 Enclosed gear drives for industrial applications

13691:2001 Petroleum and natural gas industries - High speed special-purpose gear units

TR13989-1:2000 Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears – Part 1: Flash temperature method

TR13989-2:2000 Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears – Part 2: Integral temperature method

14104:1995 Gears - Surface temper etch inspection after grinding

TR14179-1:2001 Gears - Thermal capacity - Part 1: Rating gear drives with thermal equilibrium at 95°C sump temperature

TR14179-2:2001 Gears - Thermal capacity - Part 2: Thermal load-carrying capacity

14635-1:2000 Gears – FZG test procedures – Part 1: FZG method A/8, 3/90 for relative scuffing load carrying capacity of oils

14635-3:2005 Gears - FZG test procedures - Part 3: FZG test method A/2,8/50 for relative scuffing load-carrying capacity and wear characteristics of semifluid gear greases

17485:2006 Bevel gears - ISO system of accuracy

18653:2003 Gears -- Evaluation of instruments for the measurement of individual gears

TR18792:2009 Lubrication of industrial gear drives

21771:2007 Gears - Cylindrical involute gears and gear pairs - concepts and geometry

23509:2006 Bevel and hypoid gear geometry

Gear Software
(for ANSI/AGMA 2001 and ISO 6336)

AGMA's Gear Rating Suite

Beginning with AGMA's ISO6336 Software , which was developed and tested over several years by a group of AGMA men and women working closely with the developers of the international standard, the software addresses ISO 6336 method B, the most comprehensive, analytical calculation method. It has gained international acceptance since its release in 1998 and enables you to:

- determine gear capacity in accordance with the ISO 6336 standard quickly and accurately;
- compare your own design and practices with ISO 6336 results;
- understand your competitor's ratings.

The manual alone is worth the price! In addition to explaining the software, this handy document is a great tool for learning how to use ISO 6336, guiding you through the complexities and teaching you the correct inputs, especially in the exacting areas of tooth geometry and tooling.

Two of the most recognized standards in the world today for determining the rating of spur and helical gears are ANSI/AGMA 2001-C95 and ISO 6336. Now for the first time, software to calculate ratings in accordance with each standard is available in one package from AGMA. Entitled the ***Gear Rating Suite***, the software allows the user to input data once for each gearset, and obtain ratings to both standards. Among the many features of the software package are:

- An in-depth User's Manual, and all required AGMA and ISO standards.
- User friendly I/O that provides an intuitive user interface, with drop-down boxes, look-up tables, and graphical guides used to assist in data entry.
- Dual input units which allow the user to switch between SI and inch units.
- Error and warning messages are provided within both the input and rating routines to help identify problems.
- A help program is incorporated within the software.
- Long and short form outputs are provided.

In addition to the gear rating routines and aids, the package also provides:

- A Geometry Checker for checking input data to ensure they are within allowable ranges. The Geometry Checker will help identify data entry errors and unusual gear designs.
- Tolerance worksheets which allow the user to calculate tooth tolerances from quality numbers, convert quality numbers between AGMA and ISO, and to display tolerances for adjacent grades.

The potential of the ***Gear Rating Suite*** to improve your efficiency and save you time in performing these rigorous calculations makes this a "must have" tool for all gear engineers.

Fall Technical Meeting Papers: 2000 - 2009

2009 PAPERS

09FTM01. *Influence of the Residual Stresses Induced by Hard Finishing Processes on the Running Behavior of Gears*
Authors: **V. Vasiliou, C. Gorgels and F. Klocke**

Low noise and high load carrying capacity are two important characteristics of competitive power transmissions. The challenge in the development, design and manufacturing of these power transmissions is to meet these requirements economically. One of the ways to meet both of these requirements is through a process known as hard finishing. There are various types of hard finishing and it is important to know which process produces which requirement.

The aim of this research project is to induce residual stresses in the edge of the work pieces by different hard finishing processes and to analyze their influence on the durability of the gears. The tested gears are manufactured by profile grinding, gear honing and generating grinding. The gear deviations and the finish quality have to be comparable. Through this the influence of the residual stresses on the durability can be analyzed independent from the geometrical conditions. The presentation will show the results of the load carrying capacity tests depending on the values of the residual stresses.

ISBN: 978-1-55589-954-7 Pages: 11

09FTM02. *Implementing ISO 18653, Evaluation of Instruments for the Measurement of Gears*
Authors: **R.C. Frazer and S.J. Wilson**

A trial test of the calibration procedures outlined in ISO 18653, *Gears- Evaluation of instruments for the measurement of individual gears*, showed that the results are reasonable, but a minor change to the uncertainty formula is recommended.

Gear measuring machine calibration methods are reviewed. The benefits from using work-piece like artifacts are discussed and a procedure for implementing the standard in the work place is presented.

Problems with applying the standard to large gear measuring machines are considered and some recommendations are offered.

ISBN: 978-1-55589-955-2 Pages: 15

09FTM03. *Producing Profile and Lead Modifications in Threaded Wheel and Profile Grinding*
Author: **A. Türich**

Modern gear boxes are characterized by high torque load demands, low running noise, and compact design. In order to fulfill these demands, profile and lead modifications are being applied more and more. The main reason for the application of profile and or lead modification is to compensate for the deformation of the teeth due to load, thus ensuring proper meshing of the teeth which will result in optimized tooth contact pattern.

This paper will focus on how to produce profile and lead modifications by using the two most common grinding processes, threaded wheel and profile grinding. In addition, more difficult modifications, such as defined flank twist or topological flank corrections, will also be described in this paper.

ISBN: 978-1-55589-956-1 Pages: 16

09FTM04. *New Developments in Gear Hobbing*
Author: **O. Winkel**

Several innovations have been introduced to the gear manufacturing industry in the past few years. In the case of gear hobbing, dry cutting technology and the ability to do it with powder-metallurgical HSS-materials might be two of the most impressive ones. But the technology is still moving forward. The aim of this paper is to present recent developments in the field of gear hobbing, focusing on innovations regarding tool materials, process technology and process integration.

ISBN: 978-1-55589-957-8 Pages: 18

09FTM05. *HYPOLOID ™ Gears with Small Shaft Angles and Zero to Large Offsets*
Author: **H. Stadtfeld**

Beveloid gears are used to accommodate a small shaft angle. The manufacturing technology used for beveloid gearing is a special set up of cylindrical gear cutting and grinding machines.

A new development, called Hypoloid gearing, addresses the desire of gear manufacturers for more freedom in shaft angles. Hypoloid gear sets can realize shaft angles between zero and 20° and at the same time allow a second shaft angle (or an offset) in space which provides the freedom to connect two points in space.

In all wheel driven vehicles that traditionally use a transfer case with a pinion/idler/gear arrangement or a chain, the exit of the transfer case needs to be connected with the front axle. This connection necessitates the use of two CV joints, because the front axle input point has a vertical offset and is shifted sideways with respect to the transfer case exit. Compared to a single CV joint, the two CV connections are more costly and less efficient.

However, the newly developed Hypoloids can remedy the situation by offering more freedom in shaft angle and additional offset which eliminates the need for an additional CV joint. Moreover, the Hypoloid technology offers enhanced performance compared to beveloids with straight teeth. In addition to the automotive drive trains, Hypoloid technology can be applied to aircraft as well as general gearbox manufacturing.

ISBN: 978-1-55589-958-5 Pages: 15

09FTM06. *Dependency of the Peak-to-Peak Transmission Error on the Type of Profile Correction and Transverse Contact Ratio of the Gear Pair*
Author: **U. Kissling**

Profile corrections on gears are a commonly used method to reduce transmission error, contact shock, and scoring risk. There are different types of profile corrections. It is a known fact, that the type of profile correction used will have a strong influence on the resulting transmission error. The degree of this influence may be determined by calculating tooth loading during mesh. The current method for this calculation is very complicated and time consuming; however, a new approach has been developed which could reduce the calculation time.

This approach uses an algorithm which includes the conventional method for calculating tooth stiffness in regards to bending and shearing deformation, flattening due to Hertzian pressure, and tilting of the tooth in the gear body. The new method was tested by comparing its results with FEM and LVR.

This paper illustrates and discusses the results of this study. Furthermore the maximum local power losses are compared with the scoring safety calculated following the flash temperature criteria of AGMA 925 and DIN 3990.

ISBN: 978-1-55589-959-2 Pages: 19

09FTM07. *Optimizing Gear Geometry for Minimum Transmission Error, Mesh Friction Losses and Scuffing Risk*
Authors: **R.C. Frazer, B.A. Shaw, D. Palmer and M. Fish**

Minimizing gear mesh friction losses is important if plant operating costs and environmental impact are to be minimized. This paper describes how a validated 3D FEA and TCA can be used to optimize cylindrical gears for low friction losses without compromising noise and power density. Some case studies are presented and generic procedures for minimizing losses are proposed. Future development and further validation work is discussed.

ISBN: 978-1-55589-960-8 Pages: 20

09FTM08. *Load Sharing Analysis of High Contact Ratio Spur Gears in Military Tracked Vehicle Application*
Authors: **M. Rameshkumar, P. Sivakumar, K. Gopinath and S. Sundaresh**

Military tracked vehicles demand a very compact transmission to meet mobility requirements. Some of the desirable characteristics of these transmissions include: increased rating, improved power to weight ratio, low operating noise and vibration, and reduced weight. To achieve all or some of these characteristics, it is has been decided to apply a High Contact Ratio (HCR) spur gearing concept which will improve load carrying capacity, lower vibration, and reduce noise. Similar to helical gears, the load in HCR gearing is shared by minimum two pair of teeth. Therefore, load sharing analysis was conducted on Normal Contact Ratio (NCR) gearing used in sun - planet gears of an existing drive.

This paper deals with analysis of load sharing of individual teeth in mesh for different load conditions throughout the profile for both sun and planet gears of NCR/HCR gearing using Finite Element Analysis. Also, the paper reveals the variation of bending stress and deflection along the profile of both gearing designs.

ISBN: 978-1-55589-961-5 Pages: 12

09FTM09. *Designing for Static and Dynamic Loading of a Gear Reducer Housing with FEA*
Authors: **M. Davis, Y. S. Mohammed, A.A. Elmustafa, P.F. Martin and C. Ritinski**

A recent trend has been toward more user friendly products in the mechanical power transmission industry. One of these products is a high horsepower, right angle, shaft mounted drive designed to minimize installation efforts. Commonly referred to as "alignment free" type, this drive assembly offers quick installation with minimum level of expertise required. It is also more cost effective. These characteristics make this type of drive ideal for use in applications such as underground mining where there is little room to maneuver parts.

An alignment free drive is direct coupled to the driven shaft only; it is not firmly attached to a foundation or rigid structure. A connecting link or torque arm connects the drive to a fixed structure, which limits the drive's rotational movement about the driven shaft. The electric motor is supported by the reducer housing through a fabricated steel motor adapter; the coupling connecting the motor shaft and reducer shaft is enclosed by this motor adapter.

FEA was used to test the cast iron housing to determine any potential problem areas before production began. Once analyses were completed, the motor adaptor was redesigned to lower stresses using the information from the FEA and comparing it to the infield test data.

ISBN: 978-1-55589-962-2 Pages: 9

09FTM10. *The Effect of Flexible Components on the Durability, Whine, Rattle and Efficiency of a Transmission Geartrain System*
Author: **A. Korde and B.K. Wilson**

Gear Engineers have long recognized the importance of considering system factors when analyzing a single pair of gears in mesh. These factors include: load sharing in multi-mesh gear trains, bearing clearances, and effects of flexible components such as housings, gear blanks, shafts, and carriers for planetary gears. Quality requirements and expectations in terms of durability, lower operating noise and vibration, and efficiency have increased. With increased complexity and quality requirements, a gear engineer must use advanced system design tools to ensure a robust gear train is delivered on time, meeting all quality, cost, and weight requirements.

As a standard practice, finite element models have traditionally been used for analyzing transmission system deflections, but this modeling environment does not always include provisions for analysis of vibration, efficiency, or any considerations for attribute variation. And that often requires many runs of the test to ensure all variations have been included and tested.

An advanced software tool is available for the analysis of transmission system durability, noise, vibration, and efficiency, all within a single programming environment, including the effects of flexible components such as housings, gear blanks, and shafting, while also allowing manufacturing variation studies to be performed. This paper includes the results of a case study of this program.

ISBN: 978-1-55589-963-9 Pages: 13

09FTM11. *Unique Design Constraints for Molded Plastic Transmissions*

Authors: **R. Kleiss and E. Wiita**

Molded plastic gears and transmissions must work effectively in extremely variable conditions just as their counterparts in steel. Plastics have the added variables of large thermal expansion and contraction, moisture absorption, greater tolerance variation, lower strength, and form deviations due to the molding process. The design of a molded transmission must consider these effects and characteristics. This paper will offer an example of the development of a molded plastic gear pump intended for the very steady delivery of 50 psi water pressure for a medical application. It will present our approach in design, tolerancing, material selection, molding procedure, and testing to achieve and verify an effective as-molded transmission.

ISBN: 978-1-55589-964-6 Pages: 7

09FTM12. *The Anatomy of a Micropitting Induced Tooth Fracture Failure - Causation, Initiation, Progression and Prevention*

Authors: **R.J. Drago, R.J. Cunningham, and S. Cymbala**

Micropitting has become a major concern in certain classes of industrial gear applications, especially wind power and other relatively highly loaded somewhat slow speed applications, where carburized gears are used to facilitate maximum load capacity in a compact package. While by itself the appearance of micropitting does not generally cause much perturbation in the overall operation of a gear system, the ultimate consequences of a micropitting failure can, and frequently are, much more catastrophic.

Micropitting is most often associated with parallel axis gears (spur and helical) however, the authors have also found this type of distress when evaluating damage to carburized, hardened and hard finished spiral bevel gears.

This paper presents a discussion of the initiation, propagation and ultimate tooth fracture failure mechanism associated with a micropitting failure. The subject is presented by way of the discussion of detailed destructive metallurgical evaluations of several example micropitting failures that the authors have analyzed on both parallel axis and bevel gears.

ISBN: 978-1-55589-965-3 Pages: 12

09FTM13. *Bending Fatigue, Impact Strength and Pitting Resistance of Ausformed Powder Metal Gears*

Authors: **N. Sonti, S. Rao and G. Anderson**

Powder metal (P/M) process is making inroads in automotive transmission applications because of substantially lower cost of P/M steel components for high volume production as compared to wrought or forged steel parts. Although P/M gears are increasingly used in powered hand tools, gear pumps, and as accessory components in automotive transmissions, P/M steel gears are currently in limited use in vehicle transmission applications.

The primary objective of this project was to develop high strength P/M steel gears with bending fatigue, impact, and pitting fatigue performance equivalent to current wrought steel gears. Ausform finishing tools and process were developed and applied to powder forged (P/F) steel gears in order to enhance the strength and durability characteristics of P/M gears, while maintaining the substantive cost advantage for vehicle transmission applications.

This paper presents the processing techniques used to produce Ausform finished P/F steel gears, and comparative bending fatigue, impact and surface durability performance characteristics of Ausform finished P/F steel gears, as well as conventional wrought steel gears.

ISBN: 978-1-55589-966-0 Pages: 14

09FTM14. *Design Development and Application of New High-Performance Gear Steels*

Authors: **J.A. Wright, J.T. Sebastian, C.P. Kern, and R.J. Kooy,**

A new class of high strength, secondary hardening gear steels that are optimized for high-temperature, low-pressure (i.e., vacuum) carburization is being developed. These alloys were computationally designed as secondary-hardening steels at three different levels of case hardness. The exceptional case hardness, in combination with high core-strength and toughness properties, offer the potential to reduce drive train weight or increase power density relative to incumbent alloys such as AISI 9310 or Pyrowear® X53.

This new class of alloys utilizes an efficient nano-scale M2C carbide strengthening dispersion, and their key benefits include: high fatigue resistance (contact, bending, scoring); high hardenability achieved via low-pressure carburization (thus reducing quench distortion and associated manufacturing steps); a tempering temperature of >900°F to provide up to a 500°F increase in thermal stability relative to incumbent alloys; and core tensile strengths in excess of 200 ksi. Ferrium C69™, is one alloy in this family that can achieve a carburized surface hardness of HRC 67 (with a microstructure substantially free of primary carbides), has exceptionally high contact fatigue resistance which

make it an excellent candidate for applications such as camshafts and bearings as well as gear sets.
ISBN: 978-1-55589-967-7 Pages: 14

09FTM15. *High Performance Industrial Gear Lubricants for Optimal Reliability*
Authors: **K.G. McKenna, J. Carey, N.Y. Leon, and A.S. Galiano-Roth**

In recent years gearbox technology has advanced and Original Equipment Manufacturers have required gear oils to meet the lubrication requirements of these new designs. Modern gearboxes operate under severe conditions and maintain their reliability to ensure end-user productivity. The latest generation of industrial gear lubricants can provide enhanced performance even under extreme operating conditions for optimal reliability and reduced cost of operation.

This paper describes how gear lubricants function in gearboxes and discusses the facts vs. myths of industrial gear lubricants. The paper will show how advanced gear lubricant technology can optimize the life of the gears, bearings and seals, resulting in reduced cost of operation. Opportunities to use advanced synthetic gear lubricants to achieve operational benefits in the areas of improved energy efficiency, wider operating temperature ranges, extended oil drain intervals and equipment life will be discussed.
ISBN: 978-1-55589-968-4 Pages: 16

09FTM16. *Allowable Contact Stresses of Jacking Gear Units Used in the Offshore Industry*
Author: **A. Montestruc**

An offshore jack-up drilling rig is a barge upon which a drilling platform is placed. The barge has legs which can be lowered to the sea floor to support the rig. Then the barge can be "jacked-up" out of the water providing a stable work platform from which to drill for oil and gas. The rack and pinion systems used to raise and lower the rig are enormous in terms of gear pitch or module by gear industry standards. Quarter pitch (101.6 module) pinions are common. Lifetime number of cycles for these units are -- again, by gear industry standards – small, as rack teeth typically have 25 year lifetime cycles measured in the low hundreds. That is off the charts for AGMA (and ISO or DIN) design rules which draw a straight line to zero cycles for contact stress cycles less than 10,000. Use of any standards was abandoned from the start in the offshore industry for jacking applications. The author presents methods, and experience of that industry and suggested allowable contact stresses in such applications.
ISBN: 978-1-55589-969-1 Pages: 8

09FTM17. *Variation Analysis of Tooth Engagement and Load-Sharing in Involute Splines*
Authors: **K. Chase, C. Sorenson and B. DeCaires**

Involute spline couplings are used to transmit torque from a shaft to a gear hub or other rotating component. External gear teeth on the shaft engage an equal number of internal teeth in the hub. Because multiple teeth engage simultaneously, they can transmit much larger torques than a simple key and keyway assembly. However, due to manufacturing variations, the clearance between each pair of mating teeth varies, resulting in only partial engagement.

A new model for tooth engagement, based on statistics, predicts that the teeth engage in a sequence, determined by the individual clearances. As the shaft load is applied, the tooth pair with the smallest clearance engages first, then deflects as the load increases, until the second pair engage. Thus, only a subset of teeth carry the load. In addition, the load is non-uniformly distributed, with the first tooth carrying the biggest share. As a consequence, the load capacity of spline couplings is greatly reduced, though still greater than a single keyway.

This paper discusses the results of a statistical model which predicts the average number of teeth which will engage for a specified load, plus or minus the expected variation. The model quantitatively predicts the load and stress in each engaged pair. Critical factors in the model are the stiffness and deflection of a single tooth pair and the characterization of the clearance. Detailed finite element analyses were conducted to verify the tooth deflections and engagement sequence. The closed form statistical results were verified with intensive Monte Carlo simulations.
ISBN: 978-1-55589-970-7 Pages: 14

09FTM18. *Does the Type of Gear Action Affect the Appearance of Micro-Pitting and Gear Life?*
Authors: **A. Williston**

Early results from testing conducted have raised questions concerning the role of gear action with the appearance of micropitting as well as surface fatigue (macropitting). Comparisons between similar gear sets with the same loads, speeds, and lubrication but operated either as speed increasers or as speed reducers have yielded strikingly different propensities for wear. Further, these observations are not limited to lubrication based failures such as micropitting, but, so far, have applied to traditional surface fatigue failures (macropitting) as well.

Findings point to an increase in the presence of micropitting on gearing operated as speed reducers. All components are operating at the same speed and load, yet wear is greatly reduced for the driven components.

Perhaps more intriguing is that to date all macropitting failures have occurred to the driving pinions of gear sets operated as speed reducers. While the number of samples is decidedly small, the length of life for these components is much less than would be anticipated under smooth load circumstances. The other gear sets (operated as speed increasers) do not show any fatigue wear.

In addition to how gear action affects micropitting in gearing is the question of how the gear action affects fatigue life. Current gear rating standards are based upon statistical analysis of real-world experience and mathematical stress-versus-cycle calculations. If gear action affects how gearing fails in fatigue, there may be significant ramifications in the industry.

However, before any such conclusion may be made, additional testing is necessary.
ISBN: 978-1-55589-971-4 Pages: 30

09FTM19. *The Effect of Gearbox Architecture on Wind Turbine Enclosure Size*
Author: **C.D. Schultz**

Gearbox architecture - the type of gearing used, the overall gear ratio, the number of increaser stages, the number of meshes, the ratio combinations, and the gear proportions- can have a profound effect on the "package" size of a wind turbine. In this paper the author applies a common set of requirements to a variety of potential gearbox designs for a 2.0 MW wind turbine and compares the resulting "geared component" weights, gearbox envelope sizes, generator sizes, and generator weights. Each design option is also evaluated for manufacturing difficulty via a relative cost estimate.
ISBN: 978-1-55589-972-1 Pages: 19

2008 PAPERS

08FTM01. *Parametric Study of the Failure of Plastic Gears*
Authors: **M. Cassata and Dr. M. Morris**

This paper presents the results of collaboration to develop tools for the prediction of plastic gear tooth failure for any given set of operating conditions and to classify failure modes of these gears. The goal of the project is to characterize and predict the failure of plastic gears over a range of given parameters.

A test plan was developed to explore the effect of rotational speed, root stress, and flank temperature on the life of plastic gears. The dependent variable for the experiments was the number of cycles (or rotations) until failure.
ISBN: 978-1-55589-931-8 Pages: 7

08FTM02. *A Methodology for Identifying Defective Cycloidal Reduction Components Using Vibration Analysis and Techniques*
Authors: **V. Cochran and T. Bobak**

For several years predictive maintenance has been gaining popularity as method for preventing costly and time consuming machine breakdowns. Vibration analysis is the cornerstone of predictive maintenance programs, and the equations for calculating expected vibration frequencies for bearings and toothed gear sets are widely available. Cycloidal reducers present a special case due to the nature of their reduction mechanism. This paper will describe a method for utilizing vibration analysis in order to identify a defective Cycloidal ring gear housing, disc, and eccentric bearing.
ISBN: 978-1-55589-932-5 Pages: 25

08FTM03. *Effects of Gear Surface Parameters on Flank Wear*
Authors: **J.C. Wang, J. Chakraborty, and H. Xu**

Non-uniform gear wear changes gear topology and affects the noise performance of a hypoid gear set. This paper presents the effects of gear surface parameters on gear wear and the measurement/testing methods used to quantify the flank wear in laboratory tests. Gear tooth profile, transmission error, gear tooth surface finish determined by cutting, and gear tooth surface finish determined by other processes are the factors considered in this paper. The measurements include transmission error, pattern rating, and surface roughness before and after test. The effects and interaction between controlled factors provided the information for product improvement. The action resulted from this study is anticipated to significantly improve product reliability and customer satisfaction.
ISBN: 978-1-55589-933-2 Pages: 15

08FTM04. *The Effect of Manufacturing Microgeometry Variations on the Load Distribution Factor and on Gear Contact and Root Stresses*
Authors: **D. Houser**

Traditionally, gear rating procedures directly consider manufacturing accuracy in the application of the dynamic factor, but only indirectly through the load distribution consider such errors in the calculation of stresses used in the durability and gear strength equations. This paper discusses how accuracy affects the calculation of stresses and then uses both statistical design of experiments and Monte Carlo simulation techniques to quantify the effects of different manufacturing and assembly errors on root and contact stresses. Manufacturing deviations to be considered include profile and lead slopes and curvatures, as well as misalignment. The effects of spacing errors, runout and center distance variation will also be discussed.
ISBN: 978-1-55589-934-9 Pages: 15

08FTM05. *Gear Failure Analysis Involving Grinding Burn*
Authors: **G.Blake, M. Margetts, and W. Silverthorne**

Aerospace gears require post case-hardening grinding of the gear teeth to achieve their necessary accuracy. Tempering of the case hardened surface, commonly known as grinding burn, occurs in the manufacturing process when control of the heat generation at the surface is lost.

A gearbox with minimal service time was removed in service from an aircraft, disassembled, and visual inspection performed. Linear cracks along the dedendum of the working gear tooth face were found in three adjacent teeth. A detailed inspection of the gearbox found no other components with distress.

AGMA 2007-C00 provides details of the temper etch process and exclusively uses a Nitric acid etch process, which is typically used in production quality inspections. The incident gear was processed for grinding burn using an Ammonium Persulfate etch solution. Quality records documented variation in chemical concentration levels during the time the failed gear was manufactured. A design of experiments was conducted to understand the effects of the factors and interactions that impact the capability of the Ammonium Persulfate process used in production to detect griding burn.

Presented are the metallurgical findings, load distribution analysis of actual geometry, crack propagation analysis, and design of experiment results of the Ammonium Persulfate etch process.

ISBN: 978-1-55589-935-6 Pages: 10

08FTM06. *Tooth Fillet Profile Optimization for Gears with Symmetric and Asymmetric Teeth*

Authors: **A. Kapelevich and Y. Shekhtman**

Involute flanks are nominally well described and classified by different standard accuracy grades, depending on gear application and defining their tolerance limits for such parameters as runout, profile, lead, pitch variation, and others.

The gear tooth fillet is an area of maximum bending stress concentration. However, its profile is typically marginally described as a cutting tool tip trajectory. Its accuracy is defined by a usually generous root diameter tolerance. The most common way to reduce bending stress concentration is application of the basic (or generating) rack with full radius.

This paper presents a fillet profile optimization technique based on the FEA and random search method, which allows for a substantial bending stress reduction, by 15 to 30% compared to traditionally designed gears. This reduction results in higher load capacity, longer lifetime, and lower cost. It includes numerical examples confirming the benefits of fillet optimization.

ISBN: 978-1-55589-936-3 Pages: 11

08FTM07. *Planetary Gearset Lubrication Requirement Estimation Based on Heat Generation*

Authors: **H. Kim, D. Zini, J. Chen and N. Anderson**

A planetary gearset is composed of sun gear, planet gears, ring gear, carrier and bearings. As the gearset is in motion under torque, heat is generated at all sliding and rolling contacts for gear meshes and bearing surfaces as lubricant is supplied. Without lubrication the gearset cannot operate properly because all contact surfaces are influended by heat and subsequent damages. On the other hand, excessive lubrication could cause a significant heat generation as churning or dragging losses increase. It is very important to predict a right amount of lubrication required for each component and to supply a necessary amount of lubricant in an effective way.

Empirical data of temperature increase inside a planetary gearset at different inlet lubrication temperature, torque and speed are presented with physical explanation. It has been attempted to utilize heat generation data as an indicator for required lubrication measure and also for gearset efficiency measure. Heat generation sources are classified to examine largest and smallest contributors and then project a better way to effective lubrication for the planetary gearset. Some published gear efficiency equations are examined with power loss calculations based on gearset heat generations which are empirically measured in the present study.

ISBN: 978-1-55589-937-0 Pages: 17

08FTM08. *PM Materials for Gear Applications*

Authors: **S. Dizdar, A. Flodin, U. Engström, I. Howe and D. Milligan**

The latest material and process developments in powder metal (PM) gears have increased their load capacity. These new developments allow PM to fully compete with hardened machined wrought gears in a variety of power transmission applications. New grades of PM materials that can be case hardened using the same conditions as wrought materials improve their load capacity. Increased load capacity is also achieved by surface densifying gear teeth deeper than case hardened depth requirements. Since tooth Hertzian and bending stress gradients are within the fully dense layer, PM gears are virtually equivalent to wrought gears. The performance is demonstrated by gear tooth bending and RCF data on prototype gears.

ISBN: 978-1-55589-938-7 Pages: 9

08FTM09. *Concept for a Multi Megawatt Wind Turbine Gear and Field Experience*

Authors: **T. Weiss and B. Pinnekamp**

The increasing call for the use of renewable energy in all industrial countries demands for the extension of wind power generation capacity. In central Europe, as in parts of the Americas and Asia, such further expansion is only possible by re-powering - replacement of existing turbines by higher rated ones - or by developing locations in the open sea - offshore. To this end, the gear industry worldwide is challenged to develop and supply the required number of reliable 5 MW class wind turbine gears.

This paper summarizes the concept evaluation and design of the 5 MW MultibridE wind turbine transmission arrangement, test bed measurements with the prototype, as well as field experience over a test period of 3 years.

ISBN: 978-1-55589-939-4 Pages 11

08FTM10. *The Effect of Superfinishing on FZG Gear Micropitting – Part II*

Authors: **L. Winkelmann and M. Bell**

The most common failure mechanism of highly stressed case carburized gears is micropitting (grey staining). The standard FZG gear test (FVA Work Sheet 54) is generally used to determine the micropitting load capacity of gear lubricants. In recent years, FZG gear testing has also demonstrated its usefulness for evaluating the effect of superfinishing on increasing the micropitting load capacity of gears. Results from the Technical University of Munich were previously presented in Part 1 of this paper. Part II will present the results of Ruhr University Bochum. Both research groups concluded that superfinishing is one of the most powerful technologies for significantly increasing the load carrying capacity of gear flanks.

ISBN: 978-1-55589-940-0 Pages: 10

08FTM11. *Bending Fatigue Tests of Helicopter Case Carburized Gears: Influence of Material, Design and Manufacturing Parameters*
Authors: **G. Gasparini, U. Mariani, C. Gorla, M. Filippini, and F. Rosa**

For helicopter gears many aspects of design and manufacturing must be analyzed, such as material cleanliness, case depth and hardness, tooth root shape and roughness, and compressive residual stresses. Moreover, these gears are designed to withstand loads in the gigacycle field, but are also subjected to short duration overloads. Therefore a precise knowledge of the shape of the S-N curve is of great importance for assessing their in-service life.

A single tooth bending (STB) test procedure has been developed to optimally map gear design parameters and a test program on case carburized, aerospace standard gears has been conceived and performed in order to appreciate the influence of various technological parameters on fatigue resistance, and to draw the curve shape up to the gigacycles region.

The program has been completed by failure analysis on specimens and by static tests. Some accessory investigations, like roughness and micro-hardness measurements, have also been performed. Gigacycle tests confirm the estimations done on the basis of the shorter tests, both in term of fatigue limit and of curve shapes.

ISBN: 978-1-55589-941-7 Pages: 12

08FTM12. *In-situ Measurement of Stresses in Carburized Gears via Neutron Diffraction*
Authors: **R. LeMaster, B. Boggs, J. Bunn, J. Kolwyck, C. Hubbard, and W. Bailey**

The total stresses in a mating gear pair arise from two sources: 1) externally induced stresses associated with the transmission of power, and 2) residual stresses associated with the heat treatment and machining of the tooth profiles. The stresses due to power transmission are the result of complex normal and shearing forces that develop during the meshing sequence. The total stress from these two sources contributes to the life of a gear.

This paper, funded by the AGMA Foundation, presents the results of research directed at measuring the total stress in a pair of statically loaded and carburized spur gears. Measurements were made using neutron diffraction methods to examine the change in total stress as a function of externally applied load and depth below the surface. The paper includes a summary of the various test methods that were used and a discussion of their applicability to carburized gears.

ISBN: 978-1-55589-942-4 Pages: 10

08FTM13. *Hydrogen & Internal Residual Stress Gear Failures - Some Failure Analyses and Case Studies*
Author: **R. Drago**

Hydrogen and internal stress failures are relatively rare; however, when they occur they are often very costly and sometimes quite catastrophic. While hydrogen and internal stress issues are generally recognized as significant in the design and manufacture of larger gears, they are also important for smaller gears as well.

This paper presents, via illustrated actual case studies, the mechanisms by which these failure occur, the manner in which they progress, and methods for testing finished gears for the possibility of internal problems. In addition, precautionary steps that can be taken during design, manufacture, heat treatment and quality control to minimize the possibility of these problems occurring in a finished part along with similar steps required to prevent any flawed gears from entering service are also presented and discussed.

ISBN: 978-1-55589-943-1 Pages: 11

08FTM14. *Effects of Axle Deflection and Tooth Flank Modification on Hypoid Gear Stress Distribution and Contact Fatigue Life*
Authors: **H. Xu, J. Chakraborty, and J.C. Wang**

Flank modifications are often made to overcome the influences of errors coming from manufacturing and assembly processes, as well as deflections of the system. This paper presents a semi-analytical approach on estimating the axle system deflections by combining computer simulations and actual loaded contact patterns obtained from lab tests. By using an example hypoid gear design, influences of axle deflections and typical flank modifications (lengthwise crowning, profile crowning and twist) on stress distribution of the hypoid gear drive are simulated. Finally, several experimental gear samples are made and tested. Tooth surface topography is examined by using a Coordinate Measuring Machine. Test results are reported to illustrate the effect of tooth flank modifications on contact fatigue life cycles.

ISBN: 978-1-55589-944-8 Pages: 11

08FTM15. *Extending the Benefits of Elemental Gear Inspection*
Author: **I. Laskin**

It may not be widely recognized that most of the inspection data supplied by inspection equipment following the practices of AGMA Standard 2015 and similar standards are not of elemental accuracy, deviations but of some form of composite deviations. This paper demonstrates the validity of this "composite" label by first defining the nature of a true elemental deviation, and then, by referring to earlier literature, demonstrating how the common inspection practices for involute, lead (on helical gears), pitch, and in some cases, total accumulated pitch, constitute composite measurements. The paper further explains how such measurements often obscure the true nature of the individual deviations. It also contains suggestions as to some likely source of the deviation in various gear manufacturing processes, and how that deviation may affect gear performance. It further raises the question of the likely inconsistencies of some of these inspection results and of inappropriate judgments of gear quality, even to the point of the rejection of otherwise satisfactory gears. Finally, there are proposals for modifications to inspection software,

possibly to some inspection routines, all to extending the benefits of the basic elemental inspection process.
ISBN: 978-1-55589-945-5 Pages: 12

08FTM16. *Hob Tool Life Technology Update*
Author: **T. Maiuri**

The method of cutting teeth on a cylindrical gear by the hobbing process has been in existence since the late 1800's. Advances have been made over the years in both the machines and the cutting tools used. This paper will examine hob tool life and the many variables that affect it. It will cover the state of the art cutting tool materials and coatings, hob tool design characteristics, process speeds and feeds, hob shifting strategies, wear characteristics, etc. The paper will also discuss the use of a common denominator method for evaluating hob tool life in terms of meters [or inches] per hob tooth as an alternative to tool life expressed in parts per sharpening.
ISBN: 978-1-55589-946-2 Pages: 15

08FTM17. *Innovative Concepts for Grinding Wind Power Energy Gears*
Author: **C. Kobialka**

Over the past years wind power energy has gained greater importance to reduce CO2 emissions and thus antagonize global warming. The development of wind power is driven by increased performance, which requires larger wind turbines and gear boxes. The quality demands of those gears are increasing while the production cost must decrease. This requires new production methods to grind the gears. Profile grinding is known as a process to achieve highest possible quality, even for complex flank modifications, while threaded wheel grinding is known for high productivity. New machine concepts make it now possible to use both advantages at the same time.

This paper will show the newest developments for cycle time reduction and increased workpiece quality using tool change systems to be able to use different grinding wheels for rough and finishing operation, workpiece clamping systems, and concepts of process integration for one workpiece flow.
ISBN: 978-1-55589-947-9 Pages: 12

08FTM18. *Gear Corrosion During the Manufacturing Process*
Authors: **G. Blake and G. Sroka**

No matter how well gears are designed and manufactured, gear corrosion can occur that may easily result in catastrophic failure. Since corrosion is often difficult to observe in the root fillet region or in fine pitched gears with normal visual inspection, it may well go undetected. This paper presents the results of an incident that occurred in a gear manufacturing facility several years ago that resulted in pitting corrosion and intergranular attack (IGA). It shows that superfinishing can mitigate the damaging effects of IGA and pitting corrosion, and suggests that the superfinishing process is a superior repair method for corrosion pitting versus the current practice of glass beading.
ISBN: 978-1-55589-948-6 Pages: 13

08FTM19. *How Are You Dealing With The Bias Error In Your Helical Gears?*
Author: **J. Lange**

Using illustrations this paper explains that bias error ("the twisted tooth phoneme") is a by-product of applying conventional radial crowning methods to produced crowned leads on helical gears. The methods considered are gears that are finished, shaped, shaved, form and generated ground. The paper explains why bias error occurs in these methods, and then addresses what techniques are used to limit/eliminate bias error. Profile and lead inspection charts will be used to detail bias error and the ability to eliminate it.

The paper details the simultaneous interpolation of multiple axes in the gear manufacturing machine to achieve the elimination of bias error. It also explains that CNC machine software can be used to predict bias error, and equally important that it could be used to create an "engineered bias correction" to increase the load carrying capacity of an existing gear set.
ISBN: 978-1-55589-949-3 Pages: 14

2007 PAPERS

07FTM01. *Estimation of Lifetime of Plastic Gears*
Author: **S. Beermann**

This paper gives an overview on the state of art in plastic gear resistance calculation. The main problem with plastics is the dependency of the stress cycle curve (Woehler line) with temperature. Today, more plastic gears (as in automobile headlights) are used in a high temperature range. Furthermore, flank resistance depends strongly on lubrication (lifetime may vary by a factor of ten and more, if oil, grease lubricated or dry running).

As no secure data for plastic gears is available, how can nevertheless plastic gear design and life time prediction be improved? The best strategy is to use the feedback of existing reducers. Plastic gearboxes, before starting production in big series, are normally submitted to endurance tests. If these tests are used to check also the real lifetime limits — or by increasing test length, or by increasing applied torque — these results can be used to define the required safety factors for future gear design. This procedure has been very successful, and will be described with some examples.
ISBN: 978-1-55589-905-9 Pages: 14

07FTM02. *Study of the Correlation Between Theoretical and Actual Gear Fatigue Test Data on a Polyamide*
Author: **S. Wasson**

Fatigue tests have been run on actual molded gears in order to provide design data, using fully lubricated, plastic on plastic spur gears in a temperature controlled experiment. The purpose of the testing is to see if there is a good correlation between fatigue data, generated in a lab 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. 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 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.

ISBN: 978-1-55589-906-6 Pages: 6

07FTM03. *Material Integrity in Molded Plastic Gears and Its Dependence on Molding Practices*

Author: **T. Vale**

The quality of molded plastic gears is typically judged by dimensional feature measurements only. This practice overlooks potential deficiencies in the plastic injection molding process and its effect on the integrity of the plastic material. These deeper issues are often not given proper consideration until a related gear failure demands its study and evaluation. This paper identifies some of these oversights in the molding process, the resultant effect on the plastic material, and discusses their likely effect on short and long term gear performance.

ISBN: 978-1-55589-907-3 Pages: 11

07FTM04. *Applying Elemental Gear Measurement to Processing of Molded Plastic Gears*

Author: **G. Ellis**

Although elemental gear inspection is rarely specified for molded plastic gears, the measurement equipment and practices can be valuable in advancing the molding processes and improving quality. After a brief description of plastic gear tooling and molding, this paper gives examples of specific elemental measurements and relates them to process changes and quality improvements. Such examples for spur and helical gears include: profile measurements, leading to gear mesh noise reduction; lead measurement, leading to increased face width load distribution and, continuing from that, even to the molding of crowned gears; and index measurement, leading to improved roundness of gears molded from fiber reinforced plastic materials.

ISBN: 978-1-55589-908-0 Pages: 10

07FTM05. *Vacuum Carburizing Technology for Powder Metal Gears and Parts*

Authors: **J. Kowalewski and K. Kucharski,**

Carburizing is one of the leading surface hardening processes applied to the sintered, low-alloyed steel gears in the automotive industry. While diffusion of carbon in wrought steel is well documented, this is not the case for PM steel subject to carburizing in vacuum furnaces. This paper presents results that show that the density of the powder metal is the main factor for the final carbon content and distribution. Also important is the state of the surface of the part; either sintered with open porosity or machined with closed porosity. The way the carburizing gas moves through the furnace might be of some influence as well.

ISBN: 978-1-55589-909-7 Pages: 5

07FTM06. *Using Barkhausen Noise Analysis for Process and Quality Control in the Production of Gears*

Authors: **S. Kendrish, T. Rickert and R. Fix**

The use of magnetic Barkhausen Noise Analysis (BNA) has been proven to be an effective tool for the non-destructive detection of microstructural anomalies in ferrous materials. Used as an in-process tool for the detection of grinding burn, heat treat defects and stresses, BNA is a quick comparative and quantitative alternative to traditional destructive methods.

This paper presents examples that demonstrate how BNA is used to evaluate changes in microstructual properties. Quantitative results correlate BNA test values to X-Ray diffraction values for the detection of changes in residual stress. Qualitative results correlate BNA test values to acid etch patterns/colors for the detection of grinding burn defects.

ISBN: 978-1-55589-910-3 Pages: 5

07FTM07. *Grinding Induced Changes in Residual Stresses of Carburized Gears*

Authors: **R. LeMaster, B. Boggs, J. Bunn, C. Hubbard, and T. Watkins**

This paper presents the results of a study performed to measure the change in residual stress that results from the finish grinding of carburized gears. Residual stresses were measured in five gears using the x-ray diffraction equipment in the Large Specimen Residual Stress Facility at Oak Ridge National Laboratory. Two of the gears were hobbed, carburized, quenched and tempered, but not finished. The remaining three gears were processed similarly, but were finish ground. The residual stresses were measured at 64 different locations on a tooth from each gear. Residual stresses were also measured at fewer points on other teeth to determine the tooth-to-tooth variation. Tooth profile measurements were made of the finished and unfinished gear samples.

The results show a fairly uniform and constant compressive residual field in the nonfinished gears. There was a significant reduction in the average residual stress measured in the finished gears. Additionally, there was a significant increase in the variability of the residual stress that was introduced by the grinding process. Analysis of the data suggests a linear relationship between the change in average residual stress and the amount of material removed by the grinding process.

ISBN: 978-1-55589-911-0 Pages: 14

07FTM08. *Manufacturing Net Shaped Cold Formed Gears*
Author: **D. Engelmann**

An innovative metal forming process has been developed for manufacturing quality, durable and cost efficient gears for high volume production. In this paper, the development of net shaped Cold Formed Gears (CFG) is presented along with their suitable applications. The manufacturing technique and equipment is introduced, as well as the advantages and limitations. Applicable materials and heat treatment practices are also discussed. Gear tooth inspection charts are presented and compared to conventional manufacturing methodologies.

ISBN: 978-1-55589-912-7 Pages: 7

07FTM09. *The Ikona Clutch and Differential*
Authors: **J. Colbourne, V. Scekic, and S. Tesic**

This paper describes two devices, a clutch and a differential, which are based on the Ikona CVT. This CVT is essentially an internal gear pair, in which the pinion is mounted on an eccentric that can drive or be driven by an electric motor/generator, thus providing a variable ratio. Since this arrangement allows for "branching" of energy flow(s), it can be classified as summation-type CVT.

When the CVT is used as a clutch, it would replace the friction-plate clutch in vehicles with standard transmissions, and the fluid torque converter in automatic transmissions. The new clutch will be referred to as the electric torque converter. Any excess energy is converted into electrical energy, and either stored in the battery, or reintroduced into the system through the motor/generator. Modulation of the clutch can be very smooth which is particularly advantageous when the vehicle starts from rest on uphill slopes. Since no friction element is involved, and only a fraction of torque is being manipulated, the modulation can be repeatable regardless of conditions. Finally, in a hybrid-vehicle arrangement, the clutch can be used to maintain the engine at its optimum speed (within limits), regardless of the road speed and the gearbox ratio.

Similar principals apply to the Ikona differential. Unlike today's limited slip differentials, the Ikona differential allows full torque to be transmitted through one drive wheel, even though the other drive wheel may have completely lost traction. Unlike traditional differentials that allow wheels to rotate at different speeds, the Ikona differential forces the wheels to do so. Accordingly when the vehicle is changing direction, the differential can be used to control the speed of each drive wheel, thus providing active torque steering.

ISBN: 978-1-55589-913-4 Pages: 6

07FTM10. *The Gear Dynamic Factor, Historical and Modern Perspective*
Authors: **D. Houser and D. Talbot**

The dynamic factor has been included in gear design and rating formulas since the 1930's. Its original formulation was based on an assessment of entering tooth impacts, but in modern gear design procedures, where tip relief and lead modifications are common, these impacts may be virtually eliminated. With this elimination, one finds that gear dynamics are mainly excited by steady state phenomena such as transmission error, friction and axial shuttling of the mesh force. This paper will first provide a historical progression of the dynamic factor equations that are based on impact theory and will define when this methodology is appropriate. The paper will then discuss the various steady state modeling approaches and will use one of these approaches to demonstrate the effects of manufacturing deviations on predicted dynamic loads.

ISBN: 978-1-55589-914-1 Pages: 11

07FTM11. *Helicopter Accessory Gear Failure Analysis Involving Wear and Bending Fatigue*
Authors: **G. Blake and D. Schwerin**

Gear tooth wear is a very difficult phenomenon to predict analytically. The failure mode of wear is closely correlated to the lambda ratio, and can manifest into more severe failure modes, such as bending. Presented is a failure analysis in which this occurred. A legacy aerospace gear mesh experienced nine failures within a two year time period. The failures occurred after more than eight years in service and within tight range of cycles to one another. Each failure resulted in the loss of all gear teeth with origins consistent with classic bending fatigue.

Non-failed gears, with slightly lower time than the failed gears, were removed from service and inspected. Gear metrology measurements quantified a significant amount of wear. The flank form of these worn gears was measured and the measured data used to analytically predict the new dynamic load distribution and bending stress. To predict if the failure mode of wear was expected for this gear mesh, an empirical relationship of wear to lambda ratio was created using field data from multiple gear meshes in multiple applications. Presented are the metallurgical failure analysis findings, dynamic gear mesh analysis, the empirical wear rate curve developed, and design changes.

ISBN: 978-1-55589-915-8 Pages: 12

07FTM12. *The Effect of Start-Up Load Conditions on Gearbox Performance and Life — Failure Analysis and Case Study*
Author: **R.J. Drago**

When gearboxes are used in applications in which the connected load has high inertia, the starting torque transmitted by the gearbox can be much higher than the rated load of the prime mover. Power plants often require several evaporative cooling towers or large banks of air cooled condensers (ACC) to discharge waste heat. Because of the very large size of the fans used in these applications, they fall into this category of high inertia starting load devices. When started from zero speed, a very high torque is required to accelerate the fan to normal operating speed. If the fan is started infrequently and run continuously for long periods of time, this high starting torque is of minimal significance. However, when the fan is started and stopped frequently, the number of cycles at the high starting torque can accumulate to a point where they can cause extensive fatigue damage, even if the gear system is adequately rated.

Where the gear unit is marginally rated, very early, catastrophic gear failure is often the result. As part of the overall investigation of several failures in such gearboxes, we measured starting torque on a typical installation, examined many failed gears, and calculated the load capacity ratings for the gearboxes under actual operating conditions. This paper describes the failures observed, the testing conducted, the data analyses and the effect of the high measured starting torque on the life and performance of the gear systems. The test results revealed surprising results, especially during starts where the fan was already wind-milling due to natural air flow in the ACC bank.

ISBN: 978-1-55589-916-5 Pages: 12

07FTM13. *Influence of Grinding Burn on the Load Carrying Capacity of Parts under Rolling Stress*

Authors: **F. Klocke, T. Schröder and C. Gorgels**

The demand for continuous improvement concerning economic efficiency of products and processes leads to an increasing cost pressure in manufacturing and design of power transmissions. Also, the power density of gears has been increased which leads to a demand for higher gear quality. In more and more cases this can only be achieved using hard finishing processes.

The demand for higher gear qualities leads to an increased use of gear grinding, which incurs the risk of thermal damage, such as grinding burn on the gear flank. The influence of thermal damage on the set in operation is nevertheless hard to judge so that damaged gears are often scrapped. This leads to increasing failure costs.

The lack of knowledge of the effect of grinding burn on the load carrying capacity of gears leads to the point that the same degree of damage is judged differently by different companies. Therefore it is necessary to do trials with thermally damaged parts in order to know how much a certain degree of thermal damage influences the load carrying capacity.

The investigations described in this report are aimed at determining the load carrying capacity of parts under rolling stress. Thermally damaged rollers are employed on a roller test rig, since with this analogy process the part geometry is easier to describe and easier to damage reproducibly.

ISBN: 978-1-55589-917-2 Pages: 10

07FTM14. *Roughness and Lubricant Chemistry Effects in Micropitting*

Authors: **A. Olver, D. Dini, E. Lainé, D. Hua, and T. Beveridge**

Micropitting has been studied using a disc machine in which a central carburized steel test roller contacts three, harder, counter-rollers with closely controlled surface roughness. Roughness was varied using different finishing techniques, and the effects of different oil base-stocks and additives were investigated.

Damage on the test rollers included dense micropitting and "micropitting erosion" in which tens of microns of the test surface were completely removed. This phenomenon is particularly damaging in gear teeth where it has the potential to destroy profile accuracy. It was found that anti-wear additives led to a high rate of micropitting erosion, and the effect correlated more or less inversely with simple sliding wear results. There were also appreciable effects from base-stock chemistry.

The key parameter affecting the severity of damage seemed to be the near-surface shear stress amplitude arising from the evolved roughness; different chemistries led to the evolution of different roughness during initial running and to different contact stresses and levels of damage.

ISBN: 978-1-55589-918-9 Pages: 8

07FTM15. *Experience with a Disc Rig Micropitting Test*

Authors: **M. Talks and W. Bennett**

The experimental work carried out was aimed at developing a test method that was able to consistently produce micropitting damage and could discriminate between a good oil (i.e., one that rarely produces micropitting in service) and a poor oil (i.e., one that does produce micropitting in service).

The disc rig control system allows test parameters such as entrainment velocity, contact stress and slide/roll ratio at the disc/roller contacts to be accurately and independently controlled. This enables the effect of key parameters to be studied in isolation, which is something that cannot be easily achieved using conventional gear test rigs.

A test procedure has been developed which provides a good level of repeatability and discrimination between oils. In addition, a study of the effect of slide/roll ratio (SRR) has shown that the severity of micropitting damage increases as SRR increased, whereas at 0% SRR no micropitting occurred, and, at negative SRRs, microcracking occurred, but not micropitting. This is the way that SRR seems to affect micropitting in gears.

ISBN: 978-1-55589-919-6 Pages: 9

07FTM16. *Straight Bevel Gear Cutting and Grinding on CNC Free Form Machines*

Author: **H. Stadtfeld**

Manufacturing of straight bevel gears was in the past only possible on specially dedicated machines. One type of straight bevel gears are those cut with a circular cutter with a circumferential blade arrangement. The machines and the gears they manufacture have the Gleason trade name Coniflex®. The cutters are arranged in the machine under an angle in an interlocking arrangement which allows a completing cutting process. The two interlocking cutters have to be adjusted independently during setup, which is complicated and time consuming.

The outdated mechanical machines have never been replaced by full CNC machines, but there is still a

considerable demand in a high variety of low quantities of straight bevel ears. Just recently it was discovered that it is possible to connect one of the interlocking straight bevel gear cutter disks to a free form bevel gear generator and cut straight bevel gears of identical geometry compared to the dedicated mechanical straight bevel gear generator. A conversion based on a vector approach delivers basic settings as they are used in modern free form machines. The advantages are quick setup, high accuracy, easy corrections and high repeatability.
ISBN: 978-1-55589-920-2 Pages: 10

07FTM17. *Simulation Model for the Emulation of the Dynamic Behavior of Bevel Gears*
Authors: **C. Brecher, T. Schröder and A. Gacka**
The impact of bevel gear deviations on the noise excitation behavior can only be examined under varying working conditions such as different rotational speed and torque. The vibration excitation of bevel gears resulting from the tooth contact is primarily determined by the contact conditions and the stiffness properties of the gears. By the use of a detailed tooth contact analysis, the geometry based gear properties can be developed and provided for a dynamical analysis of the tooth mesh.

A model has been developed for the simulation of the dynamic behavior of bevel gears. With the aid of a load-free tooth contact analysis, the geometry-based part of the path excitation is determined. With a tooth contact analysis under load, the path excitation caused by deflections can be calculated. The geometry based part of the path excitation and a characteristic surface of the excitation values is created and provided for dynamic simulation.

This dynamic model is able to consider every deviation of the micro- and macrogeometry from the ideal flank topography, i.e., waves and/or grooves in the surface structure, in combination with two and three dimensional flank deviations like profile deviations, helix deviations and twists. It is also possible to consider the influence of friction and the contact impact caused by load and/or manufacturing errors with a test rig to verify the calculations.
ISBN: 978-1-55589-921-9 Pages: 8

07FTM18. *Bevel Gear Model*
Author: **Ted Krenzer**
The paper presents a method for developing an accurate generic bevel gear model including both the face milling and face hobbing processes. Starting with gear blank geometry, gear and pinion basic generator machine settings are calculated. The contact pattern and rolling quality are specified and held to the second order in terms of pattern length, contact bias and motion error. Based on the setup, a grid of tooth points are found including the tooth flank, fillet and, if it exists, the undercut area. It is proposed as the model for the next generation of bevel gear strength calculations in that the procedure produces true bevel gear geometry, uses blank design parameters as input and is vendor independent except for cutter diameter.
ISBN: 978-1-55589-922-6 Pages: 10

07FTM19. *How to Determine the MTBF of Gearboxes*
Author: **G. Antony**
Mean Time Between Failures (MTBF) became a frequently used value describing reliability of components, assemblies, and systems. While MTBF was originally introduced and used mainly in conjunction with electronic components and systems, the definition and application for mechanical components, such as gearboxes, is not broadly available, used, or recognized. In the field of gears it is difficult to obtain an MTBF from the manufacturer due to the lack of applicable, generally recognized definitions and standards. The paper will evaluate, compare and suggest ways in determining a gearbox MTBF based on the already established, proven, design calculation standards and test methods used in the gear design.
ISBN: 978-1-55589-923-3 Pages: 9

2006 PAPERS

06FTM01. *The Effects of Super Finishing on Bending Fatigue*
Author: **G. Blake**
A super finishing study was designed and conducted for bending fatigue. AMS6265 parts were created: with and without super finishing. Bending fatigue was tested using Single Tooth Fatigue (STF) and RR Moore rotating beam methods. The STF parts were designed with tooth geometry replicating a spiral bevel gear section. Two lots of material were processed. Thus, a minimum of two carburized and hardened lots, two shot peen batches and two super finishing cycles (if applicable) were processed per sample group. A detailed metallurgical evaluation was performed to characterize the material and compare to actual spiral bevel gears. Analysis of the test data concluded no statistical difference in bending fatigue strength.
ISBN: 1-55589-883-1 Pages: 14

06FTM02. *Isotropic Superfinishing of S-76C+ Main Transmission Gears*
Authors: **B. Hansen, M. Salerno and L. Winkelmann**
Isotropic superfinishing 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. A description of the tests, performance data and a general description of the process is presented.
ISBN: 1-55589-884-X Pages: 12

06FTM03. *Detailed Procedure for the Optimum Design of an Epicyclic Transmission Using Plastic Gears*
Authors: **I. Regalado and A. Hernández**

Shows the steps to get an optimum (volume based) design for an epicyclic transmission using plastic materials, the tooth proportions of ANSI/AGMA 1006-A97, the recommendations given in ANSI/AGMA 6023-A88, and ANSI/AGMA 2101-C95. It gives 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 gear performance in a proposed (not optimized) transmission, going step by step to an optimum design for the given load conditions and expected minimum life.

ISBN: 1-55589-885-8 Pages: 11

06FTM04. *Precision Planetary Servo Gearheads*
Authors: **G.G. Antony and A. Pantelides**

Automated machines use servomotors to perform complex motions. Planetary gearheads are frequently used in conjunction with servomotors to match the inertias, lower the speed, boost the torque, and at the same time provide a mechanical interface for pulleys, cams, drums and other mechanical components. This paper covers topics such as: reasons why planetary gear systems are chosen for "servo applications"; what influences the planetary servo gear positioning accuracy and repeatability; rating practices to establish a "comparability" of different torques; and, an introduction of a simple method to determine the required gearbox torque rating for a servo-application based on motor torque data.

ISBN: 1-55589-886-6 Pages: 11

06FTM05. *Development of a Gear Rating Standard - A Case Study of AGMA 6014-A06*
Author: **F.C. Uherek**

The AGMA Mill Gearing Committee completed AGMA 6014 for grinding mill and kiln service gear rating. The approach the committee took in the development of this standard to determine the content is reviewed. Through a review of previous standards, the performance history of applications for long life (over 20 years), and considering the large gear size, the committee achieved consensus on a 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.

ISBN: 1-55589-887-4 Pages: 8

06FTM06. *An Analytical Approach to the Prediction of Micropitting on Case Carburised Gears*
Authors: **D. Barnett, J.P. Elderkin and W. Bennett**

Micropitting is an area of gear failure that influences gear noise and transmission error. This paper outlines an approach to analysing micropitting by looking at the critical factors for a given gear design. A practical 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 are also discussed.

ISBN: 1-55589-888-2 Pages: 15

06FTM07. *Improvement of Standardized Test Methods for Evaluating the Lubricant Influence on Micropitting and Pitting Resistance of Case Carburized Gears*
Authors: **B.-R. Höhn, P. Oster, T. Radev, G. Steinberger and T. Tobie**

Micropitting and pitting are fatigue failures that occur on case carburized gears. The performance of lubricants in regard to micropitting and pitting can be evaluated by test methods. The FVA-FZG-micropitting test consists of two parts: a load stage test followed by an endurance test. The tests require relatively high costs and are time consuming. Therefore an analogous short test method was developed to classify candidate lubricants, and supplement the existing test. The results of the short test method are given. The FVA-FZG-pitting test is for limited-life using 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 test results reproducibility. In the test gears were superfinished to prevent micropitting, and given flank modifications for improved test relevance. The paper describes test procedures and shows basic examples of test results.

ISBN: 1-55589-889-0 Pages: 11

06FTM08. *An Evaluation of FZG Micropitting Test Procedures and Results for the Crowned AGMA Test Gears*
Authors: **D.R. Houser, S. Shon and J. Harianto**

This paper reports on surface fatigue testing. The goal was to develop models for predicting wear. As part of this goal, the study reports on developing an understanding of the stresses and wear predictors using FZG 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 higher contact stress levels that are predicted for the heavily crowned and tip relieved AGMA test gears that were manufactured as a part of the AGMA tribology test program. This paper provides extensive analysis that includes detailed topography measurements of the tooth profiles, predictions of contact stresses and contact patterns. It discusses factors that affect contact stresses, flash temperatures, and test film thickness.

ISBN: 1-55589-890-4 Pages: 12

06FTM09. *Opportunities to Replace Wrought Gears with High Performance PM Gears in Automotive Applications*
Authors: **U. Engström, D. Milligan, P. Johansson and S. Dizdar**

Powder metallurgy (PM) enables production of components with complex geometries such as gears. The cost effective use of PM components in automotive applications has showed a continuous growth. This growth is due to the the net shape capability, while maintaining performance. 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 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 production. Helical and spur gears were used where the densification, as well as the resulting gear quality and durability, were tested.
ISBN: 1-55589-891-2 Pages: 7

06FTM10. *Fabrication, Assembly and Test of a High Ratio, Ultra Safe, High Contact Ratio, Double Helical Planetary Transmission for Helicopter Applications*
Authors: **F.W. Brown, M.J. Robuck, M. Kozachyn, J.R. Lawrence and T.E. Beck**

An ultra-safe, high ratio planetary transmission, for application as a helicopter main rotor final drive, has been designed, fabricated and tested. The transmission improvements are reduced weight, reduced noise and improved fail-safety and efficiency. This paper discusses the fabrication, assembly and testing of the planetary transmission. An existing planetary transmission utilized a two-stage conventional spur gear design with fixed internal ring gears. The new double helical planetary (DHP) system design uses a compound planetary arrangement with staggered planets and high contact ratio gearing in a unique configuration. Double helical gears in the planet to ring meshes balance axial tooth forces without axial planet bearing reactions. The spur gear sun to planet meshes are staggered to achieve a compact arrangement. The sun gear is fully floating.
ISBN: 1-55589-892-0 Pages: 12

06FTM11. *On Tooth Failure Analysis in Small -Teeth-Number Gearing: An Analytical Approach*
Author: **S.P. Radzévich**

This paper is an analytical study of tooth failure in gearing having small numbers of teeth. For the analysis, tooth contact stresses and combined shear stresses are investigated. The study is based on 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 by simultaneous: (a) contact stresses together with (b) stresses caused by the pinion and gear sliding. While developed for use in gearing with low numbers of teeth, the method can be used for computation of stresses in gearing having more teeth. The results of the research could be used with AGMA 908-B89 for gears having less than 12 teeth.
ISBN: 1-55589-893-9 Pages: 22

06FTM12. *A Crane Gear Failure Analysis - Case Study, Observations, Lessons Learned, Recommendations*
Author: **R.J. Drago**

The gearboxes used in cranes have proven themselves to be reliable. However, some gear failures have caused a reevaluation of the design, configuration, and manufacture of gearboxes in large cranes. Since crane gearboxes do not operate continuously, gear system fatigue characteristics have not been in the forefront of system operation. Studies have indicated that in many cases usage rates, loading, and in many cases both, have increased. In some applications, crane usage has increased by factors of two, or three, or even more, and gear loading has similarly increased. This higher usage makes the cumulative effects of fatigue much more important. 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.
ISBN: 1-55589-894-7 Pages: 10

06FTM13. *Economic Aspects of Vacuum Carburizing*
Author: **J. Kowalewski**

This paper presents the aspects of vacuum carburizing technology that have an impact on process costs and quality improvements in the final product. There is an interest in furnaces for vacuum carburizing due to the demand for products with overall metallurgical quality and low unit cost. Vacuum carburizing technology produces work with minimum distortion, and desired surface metallurgy. Systems can provide "cold to cold" (cold work going in, cold work coming out) and fully automatic operation that reduces operator involvement, thus minimizing labor. Considering upstream and downstream requirements, vacuum carburizing can provide a total reduction of costs. This technology differs considerably from traditional gas carburizing both in the equipment used and in the process economy.
ISBN: 1-55589-895-5 Pages: 6

06FTM14. *The Optimal High Speed Cutting of Bevel Gears - New Tools and New Cutting Parameters*
Author: **H.J. Stadtfeld**

High speed carbide dry cutting improvements have a dependency of many important parameters upon the particular job situation, which makes it difficult for a manufacturing engineer to establish an optimal cutting scenario. An analysis of the different parameters and their influence on 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. Also, how to choose the blade system, thus giving the manufacturing engineer information to support optimizing cutter performance, tool life and part quality.
ISBN: 1-55589-896-3 Pages: 13

06FTM15. *Optimal Tooth Modifications in Spiral Bevel Gears Introduced by Machine Tool Setting Variation*
Author: **V. Simon**

A method for the determination of optimal tooth modifications in spiral bevel gears based on load distribution, minimized tooth root stresses, and reduced transmission errors is presented. Modifications are introduced into the pinion tooth surface considering 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 of mating members. By applying a set of machine tool setting parameters, the maximum tooth contact pressure can be reduced by 5.4%, the tooth fillet stresses in the pinion by 8% and the angular position error of the driven gear by 48%, based on a spiral bevel gear pair manufactured by machine tool settings determined by a commonly used method.
ISBN: 1-55589-897-1 Pages: 12

06FTM16. *Certificate for Involute Gear Evaluation Software*
Author: F. Härtig

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. Beside 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.
ISBN: 1-55589-898-X Pages: 5

2005 PAPERS

05FTM01. *Fine Pitch, Plastic Face Gears: Design and Manufacture*
Authors: **I. Laskin and E. Reiter**

Face gear technology has attracted attention. Products benefiting include those which use molded plastic gears. More applications could benefit, justifying the need for more information on the special features of face gears, their design and manufacture, in comparison to other non-parallel-shaft gears. A description of manufacturing methods, particularly in plastic molding is given with inter-related design and gear performance issues. New methods of graphic modeling are included with descriptions of face gear configurations and applications.
ISBN: 1-55589-849-1 Pages: 11

05FTM02. *The Effects of Pre Rough Machine Processing on Dimensional Distortion During Carburizing*
Author: **G. Blake**

A study to isolate the influence of pre-rough machine processing on final dimensional distortion. Methods are discussed to aid process development and minimize dimensional change during carburizing. The study examined the distortion during carburizing between five possible raw material starting conditions. Coupons were used and manufactured from each population of material processing. Dimensions were made before and after carburizing using a scanning coordinate measurement machine. The results show that dimensional distortion during carburizing increases with mechanical and thermal processing.
ISBN: 1-55589-850-5 Pages: 18

05FTM03. *Modelling Gear Distortion*
Author: **P.C. Clarke**

Dealing with carburize case hardened gear distortion and growth is a challenge for the global gear industry. Attempts started in 1978 with computer programs to calculate distortion and growth, plus residual stress distributions for a gear and evolved by gathering distortion data for a wide range of sizes, shapes, grinding allowances with trends for different geometries. A spread sheet program with gear dimensional input, calculates the distortions and growths, and then calculates the modified dimensions for required protuberance and the minimum carburized case depth. Case histories illustrate the consequences of various geometries and future developments are discussed.
ISBN: 1-55589-851-3 Pages: 12

05FTM04. *Tooth Meshing Stiffness Optimisation Based on Gear Tooth Form Determination for a Production Process Using Different Tools*
Authors: **U. Kissling, M. Raabe, M. Fish**

The variation of the tooth meshing stiffness is a source of noise and the exact calculation of tooth form is important for the stiffness determination. For this purpose, software was written with the concept of an unlimited number of tools such as hobs, grinding disk, and honing defining a manufacturing sequence. Stiffness variation can be improved by optimization of final gear geometry with a calculation of the contact path under load. The meshing stiffness is derived making it possible to study the effect of a proposed profile correction of a gear under different loads. Calculations with AGMA2001 or ISO6336 check the point with the highest root stress. Effect of a grinding notch is also included.
ISBN: 1-55589-852-1 Pages: 11

05FTM05. *Computerized Design of Face Hobbed Hypoid Gears: Tooth Surface Generation, Contact Analysis and Stress Calculation*
Authors: **M. Vimercati and A. Piazza**

Face milled hypoid gears have been widely studied. Aim of this paper is just to propose an accurate tool for computerized design of face hobbed hypoid gears. A mathematical model able to compute detailed gear tooth surface is presented. Then, the obtained surfaces will be employed as input for an advanced contact solver that, using a hybrid method combining finite element technique with semianalytical solutions, is able to efficiently carry out contact analysis under light and heavy loads and stress calculation of these gears.

ISBN: 1-55589-853-X Pages: 13

05FTM06. A Model to Predict Friction Losses of Hypoid Gears
Authors: **H. Xu, A. Kahraman and D.R. Houser**

A model to predict friction-related mechanical efficiency losses of hypoid gear pairs is proposed, which combines a commercial available finite element based gear contact analysis model and a friction coefficient model with a mechanical efficiency formulation. The contact analysis model is used to provide contact pressures and other contact parameters required by the friction coefficientmodel. The instantaneous friction coefficient is computed by using a validated formula that is developed based on a thermal elastohydrodynamic lubrication (EHL) model. Computed friction coefficient distributions are then used to calculate the friction forces and the resultant instantaneous mechanical efficiency losses of the hypoid gear pair at a given mesh angle. The model is applied to study the influence of speed, load, surface roughness, and lubricant temperature as well as assembly errors on the mechanical efficiency of an example face-hobbed hypoid gear pair.

ISBN: 1-55589-854-8 Pages: 15

05FTM07. *Spiral Bevel and Hypoid Gear Cutting Technology Update*
Author: **T.J. Maiuri**

Spiral bevel and hypoid gear cutting technology has changed significantly over the years. The machines, tools, materials, coatings and processes have steadily advanced to the current state of the art. This paper will cover the progression from mechanical machines with complex drive trains using the five cut method of cutting gears with coolant, to machines with direct drive CNC technology dry cutting gears by the completing method with carbide and high speed steel tools. The latest cutting tool materials and tool coatings will be discussed. Production examples from the automotive and truck industries will be provided, as well as examples from the gear jobbing industry.

ISBN: 1-55589-855-6 Pages: 20

05FTM08. *New Developments in Tooth Contact Analysis (TCA) and Loaded TCA for Spiral Bevel and Hypoid Gear Drives*
Authors: **Q. Fan and L. Wilcox**

Tooth Contact Analysis (TCA) and Loaded Tooth Contact Analysis (LTCA) are two powerful tools for the design and analysis of spiral bevel and hypoid gear drives. TCA and LTCA respectively simulate gear meshing contact characteristics under light load and under significant load. Application of CNC hypoid gear generators has brought new concepts in design of spiral bevel and hypoid gears with sophisticated modifications. This paper presents new developments in TCA and LTCA of spiral bevel and hypoid gears. The first part of the paper describes a new universal tooth surface generation model with consideration of capabilities of CNC bevel gear generators. The universal model is based on the kinematical modeling of the basic machine settings and motions of a virtual bevel gear generator which simulates the hypoid gear generator and integrates both face milling and face hobbing processes. Mathematical descriptions of gear tooth surfaces are represented by a series of coordinate transformations in terms of surface point position vector, unit normal, and unit tangent. Accordingly, a generalized TCA algorithm and program are developed. In the second part of this paper the development of a finite element analysis (FEA) based LTCA is presented. The LTCA contact model is formulated using TCA generated tooth surface and fillet geometries. The FEA models accommodate multiple pairs of meshing teeth to consider a realistic load distribution among the adjacent teeth. An improved flexibility matrix algorithm is formulated by introducing specialized gap elements with considerations of deflection and deformation due to tooth bending, shearing, local Hertzian contact, and axle stiffness. Two numerical examples, a face-hobbing design and a face milling design, are illustrated to verify the developed mathematical models and programs.

ISBN: 1-55589-856-4 Pages: 12

05FTM09. *Hypoid Gear Lapping Wear Coefficient and Simulation*
Authors: **C. Gosselin, Q. Jiang, K. Jenski and J. Masseth**

Hypoid gears are usually hard finished after heat treatment using lapping. Because of the rolling and sliding motion inherent to hypoid gears, the lapping compound abrades and refines the tooth surface to achieve smoothness in rolling action and produce high quality gear sets. The pinions and gears are lapped in pairs and must therefore remain as coordinated pairs for the rest of their lives. However, heat treatment distortion can vary significantly. Thus, developing a lapping sequence for manufacturing requires both time and experienced technicians who can establish lapping operating positions and sequence times to produce quality gear sets both in terms of performance and cost. This development is generally trial and error. In this paper, the lapping process is simulated using advanced modelling tools such as gear vectorial simulation for the tooth surfaces and path of contact and reverse engineering to analyze the tooth contact pattern of existing gear sets under load (static LTCA). Test gear sets are measured using a CMM prior to a special lapping cycle where the position of the gear sets on the lapper does not change, and then re-measured after lapping in order to establish how much, and where, material was removed. A wear constant named "wear coefficient" specific to the lapping compound composition is then calculated. Based on the obtained wear coefficient value, an algorithm for simulating the lapping process is presented. Gear sets lapped on the production line are used for simulation case studies. Results show that it is possible to predict how much and where material will be removed, thereby opening the door to better understanding of the lapping process.

ISBN: 1-55589-857-2 Pages: 16

05FTM10. *Finite Element Study of the Ikona Gear Tooth Profile*

Authors: **J.R. Colbourne and S. Liu**

The Ikona gear tooth profile is a patented non-involute tooth profile for internal gear pairs. Gears with this profile have the following properties: the teeth are conjugate; the contact ratio is very high; there is no tip interference, even when only a one-tooth difference between the pinion and internal gear; there is minimal backlash; and the gears can be cut on conventional gear-cutting machines. Large reduction ratios can be achieved by a single gear pair and a high contact ratio results in lower tooth stresses than for a similar involute gear. Plus, minimal backlash makes the Ikona profile ideal for many applications, such as servo-drives, medical prostheses, and robots. Stress analysis of these gears assumes that the contact force is equal at each contacting tooth pair. Finite element results demonstrate how the number of tooth pairs in contact may increase under load. Finally, an estimate will be presented, showing the variation of tooth force between the contacting teeth.

ISBN: 1-55589-858-0 Pages: 9

05FTM11. *Low Loss Gears*

Authors: **B.-R. Höhn, K. Michaelis and A. Wimmer**

In most transmission systems one power loss sources is the loaded gear mesh. High losses lead to high energy consumption, high temperatures, early oil ageing, increased failure risk and high cooling requirements. In many cases high efficiency is not the main focus and design criteria as load capacity or vibration excitation predominate the gear shape design. Those design criteria can counteract high efficiency. The influences of gear geometry parameters on gear efficiency, load capacity, and excitation are shown. Design preference guidelines can be followed to a varying extent which leads to more or less unconventional, but more efficient gear design. Low loss gears can save substantial energy in comparison to conventional gears. The power loss reduction is dependent on the operating conditions and can add up to 70% of the power loss of conventional gears. Such low loss gears have significant advantages in terms of energy consumption, heat development, and cooling requirements.

ISBN: 1-55589-859-9 Pages: 11

05FTM12. *Modal Failure Analysis of a Gear and Drive Ring Assembly*

Author: **D.D. Behlke**

After years of successful reliable applications, a component failure on a new application cannot be explained with static stress analyses,modal failure analyses may be required. Finite element modal analyses was used to identify the mode and its frequency that cause a high range gear and drive ring assembly to fail prematurely. A Campbell Diagram was used to identify modes in the operating range of a six-speed transmission that could cause the drive ring to fail. Redesigning the assembly to move the critical modes out of the operating range is described.

ISBN: 1-55589-860-2 Pages: 8

05FTM13. *Evaluation of the Scuffing Resistance of Isotropic Superfinished Precision Gears*

Authors: **P.W. Niskanen, B. Hansen and L. Winkelmann**

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. Isotropic superfinishing improved Rolling/Sliding Contact Fatigue up to nine times that of baseline test specimens. Tests demonstrated the ability to successfully carry 30 percent higher loads for at least three times the life of the baseline samples. A study was conducted on actual gears having an isotropic superfinish. This study showed 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. The paper discusses an additional study which is underway to determine the scuffing resistance of isotropic superfinished aerospace gears to that of baseline ground gears. 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.

ISBN: 1-55589-861-0 Pages: 10

05FTM14. *Determining the Shaper Cut Helical Gear Fillet Profile*

Author: **G. Lian**

This paper describes a root fillet form calculating method for a helical gear generated with a shaper cutter. The shaper cutter considered has an involute main profile and elliptical cutter edge in the transverse plane. Since the fillet profile cannot be determined with closed form equations, a Newton's approximation method was used in the calculation procedure. The

paper will also explore the feasibility of using a shaper tool algorithm for approximating a hobbed fillet form. Finally, the paper will also discuss some of the applications of fillet form calculation procedures such as form diameter (start of involute) calculation and finishing stock analysis.
ISBN: 1-55589-862-9 Pages: 16

05FTM15. *Repair of Helicopter Gears*
Authors: **S. Rao, D. McPherson and G. Sroka,**

In order to reduce costs by extending the operational life of the sun and input pinion gears of a helicopter transmission, scraped gears were subject to a superfinishing process. This process was found to remove minor foreign object damage by uniformly removing a minimal amount of material on the gear teeth, while meeting original manufacturing specifications for geometry. The process also resulted in enhanced surface quality and did not exhibit detrimental metallurgical effects on the surface or sub-surface of the teeth. The process was also found to eliminate gray staining, an early precursor to pitting. This paper describes the results of the helicopter gear repair project and includes the geometry and metallurgical evaluations on the repaired gear. Further effort to characterize the durability and strength characteristics of the repaired gear is ongoing.
ISBN: 1-55589-863-7 Pages: 9

05FTM16. *CH47D Engine Transmission Input Pinion Seeded Fault Test*
Authors: **J.P. Petrella, J.S. Kachelries and S.M. Holder, and T.E. Neupert**

This paper summarizes an Engine Transmission Input Pinion Seeded Fault Test that was accomplished as a portion of the validation process for the Transmission Vibration Diagnostic System (TVDS) Analyzer. The test specimen was a high speed engine transmission input pinion with a known defect (i.e., seeded fault) machined into a high stress area of a gear tooth root. During the testing, the TVDS analyzer monitored the test pinion real time to provide a sufficient warning time of the impending failure. The TVDS data was evaluated along with a post-test evaluation of the fatigue crack. During the post-test fractographic evaluation, arrest lines and fatigue striations were analyzed to develop crack propagation data as a function of the number of applied load cycles. This data was then correlated to better understand the potential warning signals the TVDS system could provide that would allow the pilot enough time to unload the suspect engine transmission.
ISBN: 1-55589-864-5 Pages: 11

05FTM17. Influences of Bearing Life Considerations on Gear Drive Design
Author: **F.C. Uherek**

Historically, catalog gear drives have been designed with 5000 hours of L10 bearing life at service factor 1.0 power. Advances in bearing analysis methods have brought new considerations to the design and selection process. The impact of new modeling techniques, additional considerations, and various extensions to the traditional bearing fatigue calculations are explored. The modeling of these various additions to a traditional catalog L10 calculation is illustrated by bearing selections for cases of single, double, and triple reduction gear drives. A roadmap is presented listing critical considerations when applying various bearing manufacturer recommendations.
ISBN: 1-55589-865-3 Pages: 13

05FTM18. *Planet Pac: Increasing Epicyclic Power Density and Performance through Integration*
Author: **D.R. Lucas**

Epicyclical gear systems are typically equipped with straddle-mounted planetary idlers and are supported by pins on the input and output sides of a carrier. These carriers can be either one-piece or two-piece carrier designs. Traditionally many of the higher power rated epicyclic gear systems use cylindrical roller bearings to support the planetary gears. This paper will demonstrate that using a preloaded taper roller bearing in an integrated package should be the preferred choice for this application to increase the bearing capacity, power density, and fatigue life performance. Based on DIN281-4 calculations, this patented [1], fully integrated solution allows for calculated bearing fatigue lives to be 5 times greater than a non-integrated solution and more than 1.5 times greater than a semi-integrated solution, without changing the planet gear envelope.
ISBN: 1-55589-866-1 Pages: 7

05FTM19. *The Application of Very Large, Weld Fabricated, Carburized, Hardened & Hard Finished Advanced Technology Gears in Steel Mill Gear Drives*
Authors: **R.J. Drago, R. Cunningham and S. Cymbala**

In the 1980's, Advanced Technology Gear (ATG) steel rolling mill gear drives consisting of carburized pinions in mesh with very large, weld fabricated, high through hardened gears were introduced to improve capacity. Recently, even the improvements obtained from these ATG gear sets were not sufficient to meet higher production rates and rolling loads. For greater load capacity ATG sets have been developed consisting of carburized, hardened pinions in mesh with very large, weld fabricated, carburized and hard finished gears. Single and double helical gears of this type, ranging in size from 80 to 136 inches pitch diameter have been implemented in several steel rolling applications. This paper describes the conditions that require the use of these gears and the technology required to design, manufacture, and, especially, heat treat, these very special, very large gear sets.
ISBN: 1-55589-867-X Pages: 16

05FTM20. *Dual Drive Conveyor Speed Reducer Failure Analysis*
Author: **M. Konruff**

With increasing requirements, many conveyor systems utilize dual drive arrangements to increase output. Dual drives can provide an economical solution by utilizing smaller, more efficient, systemdesigns.

However, multiple drive conveyors must proportion the load between drives and load sharing without some type of control is difficult to achieve. This paper presents a case study on a failure analysis of a coal mine dual drive conveyor system that experienced gear reducer failures between 2 to 18months. Physical and metallurgical inspection of failed gearing did not indicate material or workmanship defects, but indicated overload. In order to determine the cause of the failures, strain gage load testing was performed. The testing of the conveyor drives revealed load sharing problems which that will be reviewed.

ISBN: 1-55589-868-8 Pages: 9

2004 PAPERS

04FTM1. *Gear Noise - Challenge and Success Based on Optimized Gear Geometries*

Authors: **F. Hoppe and B. Pinnekamp**

Airborne and structure borne noise behaviour becomes more and more an important feature for industrial applications. Noise excitation requirements may differ with applications. Industrial conveyor belts or cement mills are less sensitive with respect to noise emission than military applications, such as navy ship propulsion. This paper describes requirements and solutions with regard to noise behaviour focussing on examples taken from wind turbine gear transmissions and navy applications. The individual approaches have to be a suitable compromise to meet the challenge of noise requirement and cost optimization without restrictions on gear load carrying capacity. Therefore, the paper shows requirements and measurements examples from shop and field tests in comparison to gear micro geometry and calculation results.

ISBN: 1-55589-824-6 Pages: 15

04FTM2. *Noise Optimized Modifications: Renaissance of the Generating Grinders?*

Author: **H. Geiser**

While load and stress optimized tooth modifications may be normal in production, noise and vibration optimized tooth modifications need higher production accuracies and more complex modifications than with crowning and root or tip relief. Topological modifications show advantages for low noise and vibration behavior due to the higher variability in direction of contact pattern. Unfortunately, a load optimized tooth flank modification is not always a noise optimized modification - a compromise between optimized load distribution and low noise has to be found. In a practical example the calculation possibilities will be demonstrated on how an optimized tooth modification can be found. To satisfy the new requirements the gear grinder manufacturers needed to improve their machines. This improvement was possible with the substitution for the mechanical transmissions in the grinder with the modern CNC controls. By introducing a torque motor as the main table drive of a grinder, together with the direct mounted encoder, an advantage is offered in comparison to the mechanical drive. Problems like worm gear wear, backlash and deviations are eliminated. This, and the possibility of topological modifications, could now lead to a renascence of the generating grinders.

ISBN: 1-55589-825-4 Pages: 9

04FTM3. *A Method to Define Profile Modification of Spur Gear and Minimize the Transmission Error*

Authors: **M. Beghini, F. Presicce, C. Santus**

The object of this presentation is to propose a simple method to reduce the transmission error for a given spur gear set, at a nominal torque, by means of profile modification parameters. Iterative simulations with advanced software are needed. A hybrid method has been used, combining the finite element technique with semi analytical solutions. A two dimensional analysis is thought to be adequate for this kind of work; in fact, the resulting software does not require much time for model definition and simulations, with very high precision in the results. The starting configuration is presented. At each subsequent step, little alteration of one parameter is introduced, and the best improvement in terms of static transmission error is followed, until a minimum peak-to-peak value is achieved. At the end a check is needed to verify that the tip relief is enough to avoid the non-conjugate contact on the tip corner for a smooth transfer load.

ISBN: 1-55589-826-2 Pages: 11

04FTM4. *Influence of Surface Roughness on Gear Pitting Behavior*

Authors: **T.C. Jao, M.T. Devlin, J.L. Milner, R.N. Iyer, and M.R. Hoeprich**

In earlier studies, surface roughness had been shown to have a significant influence on gear pitting life. Within a relatively small range of surface roughness (Ra = 0.1 - 0.3 micron), gear pitting life as measured by the FZG pitting test decreases as the gear surface roughness increases. This inverse relationship between gear surface roughness and pitting life is well understood in the field. To determine whether this inverse relationship is applicable to a wider range of surface roughness values, a pitting study was conducted using gears whose surface roughness ranges from 0.1 - 0.6 micron. The results were not completely expected. The study showed that the micropitting area is radically expanded when the gear surface roughness is close to the upper limit of the range studied. At the same time, the formation of macropitting is also greatly delayed. Not only is the pitting life significantly longer, but the initiation of macropitting can occur near or slightly beyond the pitch line. The paper discusses how high surface roughness introduces a wear mechanism that delays the formation of macropits.

ISBN: 1-55589-827-0 Pages: 12

04FTM5. *Investigations on the Micropitting Load Capacity of Case Carburized Gears*
Authors: **B.-R. Höhn, P. Oster, U. Schrade and T. Tobie**

Micropitting is fatigue damage that is frequently observed on case carburized gears. It is controlled by conditions of the tribological system of tooth flank surface and lubricant. The oil film thickness has been found to be a dominant parameter. Based on the results of investigations a calculation method to evaluate the risk of micropitting respectively to determine a safety factor for micropitting on case carburized gears was developed. The calculation method is based on the result of the micropitting test as a lubricant tribological parameter, but enables the gear designer to take major influences such as operating conditions, gear geometry and gear size of the actual application into consideration. The paper summarizes important results of the continuous experimental investigations and introduces the proposed calculation method for rating the micropitting load capacity of case carburized gears.

ISBN: 1-55589-828-9 Pages: 15

04FTM6. *The Effect of a A ZnDTP Anti-wear Additive on Micropitting Resistance of Carburised Steel Rollers*
Authors: **Chi-Na Benyajati and Andrew V. Olver**

Zinc di-alkyl dithio-phosphate (ZnDTP) compounds are widely used in engine and transmission oils both as anti-oxidants and as anti-wear additives. However, recent work has shown that many anti-wear additives appear to have a detrimental effect on the resistance of gears and other contacting components to various types of rolling contact fatigue, including micropitting. The paper examines the effect of a secondary C6 ZnDTP presence in low viscosity synthetic base oil on the resistance to micropitting and wear of carburized steel rollers, using a triple-contact disk tester. It was found that the additive caused severe micropitting and associated wear, whereas the pure base oil did not give rise to any micropitting. It was further found that the additive was not detrimental unless it was present during the first 100 000 cycles of the test when it was found to exert a strong effect on the development of roughness on the counter-rollers. It is concluded that the additive is detrimental to micropitting resistance because it retards wear-in of the contact surfaces, favoring the development of damaging fatigue cracks. This contrasts with some earlier speculation that suggested a direct chemical effect could be responsible.

ISBN: 1-55589-829-7 Pages: 10

04FTM7. *A Short Procedure to Evaluate Micropitting Using the New AGMA Designed Gears*
Authors: **Kevin J. Buzdygon and Angeline B. Cardis**

At the 1998 AGMA Fall Technical Meeting, encouraging results of a prototype micropitting test using specially designed gears on the standard FZG test rig were reported. Additional gear sets became available from AGMA in 2000. Subsequently, several sets of these experimental AGMA test gears were used in an attempt to develop a relatively short test procedure to evaluate micropitting. The detailed results of these tests are discussed in the paper. The procedure involved running the test gears on the standard FZG test rig with oil circulation for 168 hours. At the end of test, the gears are rated for micropitting, weight loss, pitting, and scuffing. Five commercially available ISO VG 320 gear oils, with performance in the FVA Procedure 54 micropitting test ranging from FLS 9-low to FLS >10-high, were evaluated using this procedure. The degree of micropitting coverage ranged from 34% to 7% in the new test procedure. Micropitting generally originated in the middle of the gear tooth, instead of the root or tip. Overall, there was excellent correlation of the degree of micropitting damage between the new test procedure and FVA Procedure 54.

ISBN: 1-55589-830-0 Pages: 8

04FTM8. *Generalized Excitation of Traveling Wave Vibration in Gears*
Author: **Paul B. Talbert**

Rotation of gears under load creates dynamic loading between the gears at tooth mesh frequency and its harmonics. The dynamic loading can excite traveling wave vibration in the gears. The strain associated with the traveling wave vibration can be excessive and result in high cycle fatigue of the gears. Prior investigations have examined traveling wave excitation for specific configurations, such as a sequential star system with a fixed planetary carrier. Gear mesh excitation of traveling wave vibration can be generalized to include the following: (1) any number of gears surrounding the center gear, (2) non-symmetric spacing of the surrounding gears, (3) non-equal power transfer of the surrounding gears, and (4) the effect of periodic features in the center gear. A closed form expression is developed to quantify the relative excitation of traveling wave vibration for each nodal diameter. This expression for the relative excitation is verified using analytical finite element examples.

ISBN: 1-55589-831-9 Pages: 13

04FTM9. *Design of a High Ratio, Ultra Safe, High Contact Ratio, Double Helical Compound Planetary Transmission for Helicopter Applications*
Authors: **Frederick W. Brown, Mark J. Robuck, G. Keith Roddis and Timothy E. Beck**

An ultra-safe, high ratio planetary transmission, for application as a helicopter main rotor drive, has been designed under the sponsorship of NRTC-RITA. It is anticipated that this new planetary transmission offers improvements relative to the current state-of-the-art including, reduced weight, reduced transmitted noise and improved fail-safety. This paper discusses the analysis and design results for the subject planetary transmission. Fabrication and testing of the transmission will be conducted in subsequent phases of the project. Typically, the final stage in helicopter main rotor transmission is the most critical and usually the heaviest assembly in the drive system for any rotary wing aircraft. The new ultra-safe, high ratio planetary transmission design utilizes a

compound planetary configuration with a 17.5:1 reduction ratio which would replace a conventional two stage simple planetary transmission. The new design uses split-torque paths and high combined contact ratio gearing.
ISBN: 1-55589-832-7 Pages: 12

04FTM10. *The Failure Investigation and Replacement of a Large Marine Gear*
Authors: **Peter Hopkins, Brian Shaw, J. Varo, and A. Kennedy**

The paper presents details of a recent gearbox problem encountered on a Naval ship and the final solution bringing the ship back to full ability. The problem occurred on the main wheel of a large, high power Naval gearbox. The investigation showed that pitting damage had developed as a result of loose side plate bolts, which led on to bending fatigue cracking. Additional investigations and monitoring established that the damage had been assisted by increased usage at high power levels, as well as a small number of significant overloads. Assessment of the gearbox design was that it had been running very close to original design limits. Repairs were then carried out to remove and arrest any damage present, and monitoring procedures were put in place to ensure no further damage developed. Risk assessments were performed to allow the ship to continue to meet its demands. Full repair options were then considered and replacement gear elements designed and produced to increase future abilities and safety factors. The paper covers the discovery of the problem, failure investigation, the in-situ repair, risk assessment of continued running, prevention of further damage, damage monitoring, the permanent repair assessment, design, manufacture and installation of replacement gears, and trials.
ISBN: 1-55589-833-5 Pages: 11

04FTM11. *Gear Lubrication as a Reliability Partner*
Author: **Michael Holloway**

Performance lubrication is quickly becoming a component of preventive, predictive, proactive and reliability based maintenance programs. Using the best gear lubricant, coupled with system condition, monitoring and analysis, actually reduces overall operating expenses dramatically. Various techniques such as system conditioning, oil and equipment analysis, along with product selection and management are valuable tools which convert many maintenance departments into reliability centers. These concepts and others are discussed in this informative, hands on discussion which will review best maintenance practices from various companies and review how to implement similar programs.
ISBN: 1-55589-834-3 Pages: 8

04FTM12. *Improved Tooth Load Distribution in an Involute Spline Joint Using Lead Modifications Based on Finite Element Analysis*
Authors: **Frederick W. Brown, Jeffrey D. Hayes and G. Keith Roddis**

Involute splines are prone to non-uniform contact loading along their length, especially in lightweight, flexible applications such as a helicopter main rotor shaft-to-rotor hub joint. A significantly improved tooth load distribution is achieved by applying, to the internally splined member, complex lead corrections which vary continuously along the length of the spline. Rotor hub splines with analytically determined lead corrections were manufactured and tested under design load conditions. A standard rotor shaft-to-hub joint, which uses a step lead correction between splines, was also tested as a baseline. Test data indicated that the complex lead corrections resulted in a nearly uniform contact load distribution along the length of the spline at the design torque load. The data also showed that the load distribution for the splines with the complex lead corrections was significantly improved relative to the baseline splines.
ISBN: 1-55589-835-1 Pages: 16

04FTM13. *Superfinishing Motor Vehicle Ring and Pinion Gears*
Authors: **Lane Winkelmann, Jerry Holland and Russell Nanning**

Today, the automotive market is focusing on "lubed for life" differentials requiring no service for the life of the vehicle. Premature differential failure can be caused by bearing failures as well as ring and pinion failure. By super finishing the lapped ring and pinion gear sets to a surface roughness less than 10 micro inch, lubricant, bearing and gear lives can be significantly increased because of the concomitant elimination of wear and the temperature spike associated with break-in. It was assumed that super finishing technology could not preserve the contact pattern of the lapped and matched gear set. This paper discusses a mass finishing operation which overcomes these obstacles and meets the needs of a manufacturing facility. Gear metrology, contact patterns, transmission error and actual performance data for super finished gear sets will be presented along with the super finishing process.
ISBN: 1-55589-836-X Pages: 16

04FTMS1. *Stress Analysis of Gear Drives Based on Boundary Element Method*
Author: Daniele Vecchiato

The stress analysis is performed as a part of TCA (Tooth Contact Analysis) for a gear drive. Unlike the existing approaches, the proposed one does not require application of commercial codes (like ANSYS or ABAQUS) for derivation of contact model and determination of contact and bending stresses. The

contacting model is derived directly by using the equations of tooth surfaces determined analytically. The boundary element approach allows to reduce substantially the number of nodes of the model. Determination of stresses caused by applied load is obtained directly for the applied contacting model for any position of meshing. The developed approach is illustrated by stress analysis of helical gears with modified geometry.
ISBN: 1-55589-837-8 Pages: 16

2002 PAPERS

02FTM1. *The Effect of Chemically Accelerated Vibratory Finishing on Gear Metrology*
Authors: **Lane Winklemann, Mark Michaud, Gary Sroka, Joseph Arvin and Ali Manesh**

Chemically accelerated vibratory finishing is a commercially proven process that is capable of isotropically superfinishing metals to an Ra < 1.0 in. Gears have less friction, run significantly cooler and have lower noise and vibration when this technology is applied. Scuffing, contact fatigue (pitting), and bending fatigue are also reduced or eliminated both in laboratory testing and field trials. This paper presents studies done on aerospace Q13 spiral bevel gears showing that the amount of metal removed to superfinish the surface is both negligible and controllable. Media selection and metal removal monitoring procedures are described ensuring uniform surface finishing, controllability and preservation of gear metrology.
ISBN: 1-55589-801-7 Pages: 18

02FTM2. *Development and Application of Computer-Aided Design and Tooth Contact Analysis of Spiral-Type Gears with Cylindrical Worm*
Authors: **V.I. Goldfarb and E.S. Trubachov**

This paper presents the method of step-by-step computer-aided design of spiroid-type gears, which involves gear scheme design, geometric calculation of gearing, drive design, calculation of machine settings and tooth-contact analysis. Models of operating and generating gearing have been developed, including models of manufacture and assembly errors, force and temperature deformations acting in real gearing, and drive element wear. Possibilities of CAD-technique application are shown to solve design and manufacture tasks for gearboxes and gear-motors with spiroid-type gears.
ISBN: 1-55589-802-5 Pages: 15

02FTM3. *The Application of Statistical Stability and Capability for Gear Cutting Machine Acceptance Criteria*
Author: **T.J. (Buzz) Maiuri**

Over the years the criteria for gear cutting machine acceptance has changed. In the past, cutting a standard test gear or cutting a customer gear to their specification was all that was expected for machine acceptance. Today, statistical process control (SPC) is required for virtually every machine runoff. This paper will cover the basic theory of stability and capability and its application to bevel and cylindrical gear cutting machine acceptance criteria. Actual case studies will be presented to demonstrate the utilization of these SPC techniques.
ISBN: 1-55589-803-3 Pages: 26

02FTM4. *Multibody-System-Simulation of Drive Trains of Wind Turbines*
Author: **Berthold Schlecht**

During the last years a multitude of wind turbines have been put into operation with continuously increased power output. Wind turbines with 6 MW output are in the stage of development, a simple extrapolation to larger dimensions of wind turbines on the basis of existing plants and operational experiences is questionable. This paper deals with the simulation of the dynamic behavior of the complete drive train of a wind turbine by using a detailed Multi-System-Model with special respect of the gear box internals. Starting with the model creation and the analysis of the natural frequencies, various load cases in the time domain will be discussed.
ISBN: 1-55589-804-1 Pages: 13

02FTM5. *Crack Length and Depth Determination in an Integrated Carburized Gear/Bearing*
Authors: **Raymond Drago and James Kachelries**

In an effort to determine if processing cracks posed a safety of flight concern, several gears that contained cracks were designated to undergo a rigorous bench test. Prior to the start of the test, it was necessary to document, nondestructively, all of the crack dimensions. This paper will present a specially modified magnetic rubber inspection technique to determine crack lengths as short as 0.006 inch, and a unique, highly sensitive, laboratory eddy current inspection technique to estimate crack depths up to +/- 0.003 inch.
ISBN: 1-55589-805-X Pages: 9

02FTM6. *Contemporary Gear Hobbing - Tools and Process Strategies*
Author: **Claus Kobialka**

Gear manufacturing without coolant lubrication is getting more and more important. Modern hobbing machines are designed to cope with dry hobbing. In the last years, carbide hobs were prevailing in high-speed hobbing due to their excellent thermal stability. Today, this high performance rate is confronted with rather high tool costs and critical tool handling. Powder metallurgical HSS combined with extremely wear resistant coating on the base of (Ti, Al)N offer interesting alternatives for dry hobbing. It is evident that existing conventional hob geometries can be optimized respecting limiting factors like maximum chip thickness and maximum depth of scallops.
ISBN: 1-55589-806-8 Pages: 11

02FTM7. *Selecting the Best Carburizing Method for the Heat Treatment of Gears*
Authors: **Daniel Herring, Gerald Lindell, David Breuer and Beth Madlock**

Vacuum carburizing has proven itself a robust heat treatment process and a viable alternative to atmosphere carburizing. This paper will present scientific data in support of this choice. A comparison of atmosphere carburized gears requiring press quenching to achieve dimensional tolerances in a "one piece at a time" heat treating operation, with a vacuum carburized processing a full load of gears that have been high gas pressure quenched within required tolerances.

ISBN: 1-55589-807-6 Pages: 13

02FTM8. *Compliant Spindle in Lapping and Testing Machines*
Author: **Bill McGlasson**

This paper presents theory, analysis and results of a novel spindle design with application to bevel gear lapping and testing machines. The spindle design includes a rotationally compliant element which can substantially reduce the dynamic forces induced between the gear members while rolling under load. The theory of this spindle concept is presented using simplified models, providing the explanation for the process benefits it brings. Analysis and simulations give additional insight into the dynamics of the system. Finally, actual lapping and testing machine results are presented.

ISBN: 1-55589-808-4 Pages: 11

02FTM9. *Gear RollScan for High Speed Gear Measurement*
Author: **Andreas Pommer**

This presentation features a revolutionary new method for the complete topographical measurement of gears. The Gear RollScan system is similar to one-flank gear rolling inspection. However, the master gear has measuring tracks on selected flanks. With two master gears in roll contact, both the left and right flanks of the specimen can be inspected simultaneously. After a specified number of rotations, every measuring track on the master gears will contact every flank of the specimen this measuring device will always find the worst tooth.

ISBN: 1-55589-809-2 Pages: 10

02FTM10. *Comparing the Gear Ratings from ISO and AGMA*
Author: **Octave LaBath**

In the early 1980's several technical papers were given comparing gear ratings from ISO and AGMA showing some interesting and diverse differences in the trends when the gear geometry was changed slightly. These changes included addendum modification coefficients and helix angle. Differences also existed when the hardness and hardening methods were changed. This paper will use rating programs developed by an AGMA committee to compare AGMA and ISO ratings while having the same gear geometry for both ratings. This will allow consistent trend analysis by only changing one gear geometry parameter while holding other geometry items constant.

ISBN: 1-55589-810-6 Pages: 17

02FTM11. *Gear Design Optimization Procedure that Identifies Robust, Minimum Stress and Minimum Noise Gear Pair Designs*
Author: **Donald Houser**

Typical gear design procedures are based on an iterative process that uses rather basic formulas to predict stresses. Modifications such as tip relief and lead crowning are based on experience and these modifications are usually selected after the design has been considered. In this process, noise is usually an after thought left to be chosen by the designer after the geometric design has been established. This paper starts with micro-topographies in the form of profile and lead modifications. Then, evaluations are made on the load distribution, bending and contact stresses, transmission error, film thickness, flash temperature, etc. for a large number of designs. The key to this analysis is the rapid evaluation of the load distribution.

ISBN: 1-55589-811-4 Pages: 15

02FTMS1 *Design and Stress Analysis of New Version of Novikov-Wildhaber Helical Gears*
Author: **Ignacio Gonzalez-Perez**

This paper covers design, generation, tooth contact analysis and stress analysis of a new type of Novikov-Wildhaber helical gear drive. Great advantages of the developed gear drive in comparison with the previous ones will be discussed, including: reduction of noise and vibration caused by errors of alignment, the possibility of grinding, and application of hardened materials and reduction of stresses. These achievements are obtained by application of: new geometry based on application of parabolic rack-cutters, double-crowning of pinion and parabolic type of transmission errors.

ISBN: 1-55589-812-2 Pages: 25

2001 PAPERS

01FTM1. *Carbide Hobbing Case Study*
Author: **Yefim Kotlyar**

Carbide hobbing improves productivity and cost, however many questions remain regarding the best application, carbide material, hob sharpening, coating and re-coating, hob handling, consistency and optimum hob wear, best cutting conditions, and concerns for the initial cutting tool investment. This paper is a case study of a successful implementation of carbide hobbing for an annual output of 250,000 gears, average lot size of about 200-300 gears, producing gears of about 150 different sizes and pitches, with 4 setups per day on average.

ISBN: 1-55589-780-0 Pages: 16

01FTM2. *The Ultimate Motion Graph for "Noiseless" Gears*
Authors: **Hermann J. Stadtfeld and Uwe Gaiser**

Gear noise is a common problem in all bevel and hypoid gear drives. A variety of expensive gear geometry optimizations are applied daily in all hypoid gear manufacturing plants, to reduce gear noise. In many cases those efforts have little success. This paper will present "The Ultimate Motion Graph", a concept for modulating the tooth surfaces that uses modifications to cancel operating dynamic disturbances that are typically generated by any gear types.

ISBN: 1-55589-781-9 Pages: 16

01FTM3. *Automated Spiral Bevel Gear Pattern Inspection*
Authors: **S.T. Nguyen, A. Manesh, K. Duckworth and S. Wiener**

Manufacturing processes for precision spiral bevel gears are operator intensive, making them particularly costly in today's small lot production environment. This problem is compounded by production requirements for replacement parts that have not been produced for many years. The paper will introduce a new closed loop system capable of reducing development costs by 90% and bevel gear grinder setup time by 80%. In addition, a capability to produce non-standard designs without part data summaries is reviewed. Advancements will also be presented for accepting precision gears using an electronic digital master in lieu of a physical master.

ISBN: 1-55589-782-7 Pages: 15

01FTM4. *How to Inspect Large Cylindrical Gears with an Outside Diameter of More Than 40 Inches*
Author: **Güenter Mikoleizig**

This paper discusses the design and function of the relevant machines used for individual error measurements such as lead and profile form as well as gear pitch and runout. The author will cover different types of inspection machines such as: stationary, CNC-controlled gear measuring centers, and transportable equipment for checking individual parameters directly on the gear cutting or gear grinding machine.

ISBN: 1-55589-783-5 Pages: 20

01FTM5. *Traceability of Gears - New Ideas, Recent Developments*
Authors: **Frank Härtig and Franz Wäldele**

Some national standard tolerances for cylindrical gears lie in, and even below, the range of instrument measurement uncertainties. This paper presents a concept based on three fundamental goals: reduction of measurement uncertainty, construction of workpiece-like standards, and shortening of the traceability chain. One of the focal points is the development of a standard measuring device as an additional metrological frame integrated into a coordinate measuring machine.

ISBN: 1-55589-784-3 Pages: 6

01FTM6. *Performance-Based Gear-Error Inspection, Specification, and Manufacturing-Source Diagnostics*
Authors: **William D. Mark and Cameron P. Reagor**

This paper will show that a frequency-domain approach for the specification of gear tooth tolerance limits is related to gear performance and transmission errors. In addition, it is shown that one can compute, from detailed tooth measurements, the specific tooth error contributions that cause any particularly troublesome rotational harmonic contributions to transmission error, thereby permitting manufacturing source identification of troublesome operation.

ISBN: 1-55589-785-1 Pages: 15

01FTM7. *Chemically Accelerated Vibratory Finishing for the Elimination of Wear and Pitting of Alloy Steel Gears*
Authors: **Mark Michaud, Gary Sroka and Lane Winkelmann**

Chemically accelerated vibratory finishing eliminates wear and contact fatigue, resulting in gears surviving higher power densities for a longer life compared to traditional finishes. Studies have confirmed this process is metallurgically safe for both through hardened and case carburized alloy steels. The superfinish can achieve an Ra < 1.5 μinch, while maintaining tolerance levels. Metrology, topography, scanning electron microscopy, hydrogen embrittlement, contact fatigue and lubrication results are presented.

ISBN: 1-55589-786-X Pages: 16

01FTM8. *The Effect of Spacing Errors and Runout on Transverse Load Sharing and the Dynamic Factor of Spur and Helical Gears*
Authors: **Husny Wijaya, Donald R. Houser and Jonny Harianto**

This paper addresses the effect of two common manufacturing errors on the performance of spur and helical gears; spacing error and gear runout. In spacing error analysis, load sharing for two worst-case scenarios are treated, one where a tooth is out of position and the second where stepped index errors are applied. The analyzed results are then used as inputs to predict gear dynamic loads, dynamic tooth stresses and dynamic factors for gear rating.

ISBN: 1-55589-787-8 Pages: 16

01FTM9. *New Opportunities with Molded Gears*
Authors: **Roderick E. Kleiss, Alexander L. Kapelevich and N. Jack Kleiss Jr.**

Unique tooth geometry that might be difficult or even impossible to achieve with cut gears can be applied to molded gears. This paper will investigate two types of gears that have been designed, molded and tested in plastic. The first is an asymmetric mesh with dissimilar 23 and 35 degree pressure angles. The second is an orbiting transmission with a 65 degree

pressure angle. Both transmissions have higher load potential than traditional design approaches.
ISBN: 1-55589-788-6 Pages: 11

01FTM10. *Design Technologies of High Speed Gear Transmission*
Author: **Jeff Wang**
This paper discusses a few critical factors and their effects on high speed gear transmissions. The first factor is centrifugal force and its effect on tooth root strength, tooth expansion and backlash and the interference fit between gear and shaft. The second is system dynamics, including critical speed, dynamic balancing and the torsional effects of flexible couplings. The third is the windage loss with different combinations of helix and rotation direction, lubricant flow rate, flow distribution and their effects on tooth bulk temperature field and tooth thermal expansion.
ISBN: 1-55589-789-4 Pages: 8

01FTM11. *Kinematic and Force Analysis of a Spur Gear System with Separation of Sliding and Rolling between Meshing Profiles*
Author: **D. E. Tananko**
This paper describes a comprehensive study of the novel gear design with physical separation between sliding and rolling motions of the mesh gear contact point. The sliding motion is accommodated by shear deformation of a thin-layered rubber-metal laminate allowing very high compression loads. Several important advantages will be presented when comparing the composite gear design to the conventional involute profile.
ISBN: 1-55589-790-8 Pages: 50

01FTMS1. *Optical Technique for Gear Contouring*
Author: **Federico Sciammarella**
This paper presents an optical technique (projection moiré) that is compact and can provide a quick full field analysis of high precision gears. Comparisons are made between mechanical and optical profiles obtained of a gear tooth.
ISBN: 1-55589-791-6 Pages: 12

2000 PAPERS

2000FTM1. *Minimization of In-Process Corrosion of Aerospace Gears*
Authors: **S.T. Nguyen, A. Manesh, and J. Reeves**
This paper discusses problems and root causes associated with the corrosion of aerospace gears during the manufacturing process.
Specimens of common base materials used in precision gearing were subjected to process conditions that contribute to corrosion initiation including: different coolant types and concentrations, material heat treat conditions, base material magnetism, surface finish and iron particles in coolant.
ISBN: 1-55589-762-2 Pages: 7

2000FTM2. *The Calculation of Optimum Surface Carbon Content for Carburized Case Hardened Gears*
Author: **P.C. Clarke**
At present, there is not a method to calculate eutectoid carbon from chemical analysis and the eutectoid carbon is not the best element upon which to base surface carbon requirements. This paper will define the conditions and propose a method to calculate an optimum carbon level to minimize the possibilities of retained austenite, cementite and bainite.
ISBN: 1-55589-763-0 Pages: 8

2000FTM3. *Comparison of New Gear Metallurgy Documents, ISO 6336-5 and AGMA 923 with Gear Rating Standards AGMA 2001 and 2003*
Author: **A.A. Swiglo**
This paper will compare and contrast these four documents. What's new, what's different and what's hidden in the footnotes. Knowing the differences will be important to the users of these documents.
ISBN: 1-55589-764-9 Pages: 110

2000FTM4. *Parametric Influences in the ISO Project Concerning Worm Gear Rating*
Author: **M. Octrue**
This paper analyzes the influence of different parameters in CD ISO 14561 Load Capacity Calculation of Worm Gears such as; efficiency, wear load capacity, pitting, deflection and tooth root stress. The influencing parameters are divided into different categories such as external parameters of loading conditions, environmental parameters of lubricant temperature and driving and driven machines.
ISBN: 1-55589-765-7 Pages: 10

2000FTM5. *Systematic Investigations on the Influence of Viscosity Index Improvers on EHL-Film Thickness*
Authors: **B.-R. Hohn, K. Michaelis and F. Kopatsch**
This paper compares film thickness calculations to measurements taken using polymer containing oils in a twin disk machine. Results will show all polymer containing oils form lower film thicknesses than straight mineral oils of the same viscosity after shearing. A polymer correction factor is derived from test results improving the accuracy of film thickness calculation.
ISBN: 1-55589-766-5 Pages: 11

2000FTM6. *Did the Natural Convection Exist in Mechanical Power Transmissions? Theoretical and Experimental Results*
Author: **M. Pasquier**
ISO TR14179 parts 1 and 2, give values of total heat exchange coefficients in the case of natural convection and forced convection. This paper will compare the values of total heat exchange obtained from a theoretical study to the values given in the ISO Technical Reports.
ISBN: 1-55589-767-3 Pages: 10

2000FTM7. *An Analytical - FEM Tool for the Design and Optimization of Aerospace Gleason Spiral Bevel Gears*
Author: **C. Gorla, F. Rosa, and P.G. Schiannini**

To save time and money during the design process a tool based on analytical algorithms and on FEM models is introduced. As a first step, the conjugate surfaces theory is applied to a bevel set. An analytical tooth contact analysis is performed to determine the theoretical contact points on flank surfaces versus the meshing points. Information is then derived by the contact analysis and used to generate Finite Element models of the gear pair on the basis of the theoretical contact pattern. A final simulation by means of FEM models takes into account load sharing between tooth pairs.

ISBN: 1-55589-768-1 Pages: 12

2000FTM8. *Stock Distribution Optimization in Fixed Setting Hypoid Pinions*
Author: **C. Gosselin and J. Masseth**

This paper presents an algorithm used to optimize the stock distribution between the roughing and finishing cuts for fixed setting spiral bevel and hypoid members. The optimization is based on the Surface Match algorithm, where differences between the roughing and finishing spiral angle, pressure angle and tooth taper are minimized in order to obtain rough and finished tooth flanks that are parallel.

ISBN: 1-55589-769-X Pages: 8

2000FTM9. *Cylindrical Gear Inspection and Bevel Gear Inspection - A Simple Task by Means of Dedicated CNC-Controlled Gear Inspection Machines*
Author: **G. Mikoleizig**

This paper will discuss the design, function, software management and probe systems of the inspection machines. Analytical tooth contact analysis of a cylindrical gear set by means of the combined effects of gear and pinion is shown on the basis of individual profile and alignment measurements. A fully automatic correction system will be introduced for checking the flank form on spiral bevel gears.

ISBN: 1-55589-770-3 Pages: 25

2000FTM10. *Bending Fatigue Investigation under Variable Load Conditions on Case Carburized Gears*
Authors: **B.-R. Hohn, P. Oster, K. Michaelis, Th. Suchandt and K. Stahl**

Variable load spectrum tests are carried out at different load levels in a step program and at random loading. The results of step programmed tests show a substantial influence of the period of the programmed subsequence of fatigue life. Fatigue life decreases when the subsequence period is shortened. With substantially shortened subsequences in step programmed test nearly the same fatigue life is reached as in random load tests.

ISBN: 1-55589-771-1 Pages: 14

2000FTM11. *UltraSafe Gear Systems - Single Tooth Bending Fatigue Test Results*
Authors: **R.J. Drago, A. Isaacson and N. Sonti**

This paper will discuss a system from a point of view of "what happens when a failure occurs". Gears were manufactured with seeded faults to simulate unexpected defects in various portions of the highly loaded gear tooth and rim sections. Crack propagation was monitored by measuring effective mesh stiffness and applied loading to provide both warning of an impending failure and a reasonable period operation after initiation of a failure for a safe landing.

ISBN: 1-55589-772-X Pages: 9

2000FTM12. *The Finite Strips Method as an Alternative to the Finite Elements in Gear Tooth Stress and Strain Analysis*
Authors: **C. Gosselin and P. Gagnon**

The Finite Strip Method (FSM), which may be considered a subset of the Finite Element Method (FEM), is presented as an alternative to (FEM) that requires very little meshing effort and can be applied to virtually any tooth geometry while offering precision comparable to that of Finite Elements. This paper will cover the (FSM) model for spur and helical gears, plates of variable thickness such as the teeth of face gear members and for spiral bevel and hypoid gears.

ISBN: 1-55589-773-8 Pages: 11

2000FTMS1. *Effects of Helix Slope and Form Deviation on the Contact and Fillet Stresses of Helical Gears*
Authors: **R. Guilbault**

An investigation is conducted on the effects of helix slope and form deviation tolerances specified for grades 5 and 7 of the ANSI/AGMA ISO 1328-1 for cylindrical gears. The results show and almost linear correspondence between deviation amplitude and tooth load and fillet stress increases: using grade 7 instead of grade 5 can double the tooth flank load increase and associated fillet stress increase. Results also show that effects are even more significant on the maximum contact pressure.

ISBN: 1-55589-774-6 Pages: 21

Price List

Full Set of Current Standards (CD) $4297.00
(Priced separately: $6446.00)
Full Set of Current Standards (Printed copy) $5450.00

NUMBER	TITLE	LIST PRICE
900-H06	Style Manual for the Preparation of Standards	$30.00
901-A92	A Rational Procedure for the Preliminary Design of Minimum Volume Gears	$32.00
904-C96	Metric Usage	$40.00
908-B89	Information Sheet - Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth	$80.00
909-A06	Specifications for Molded Plastic Gears	$45.00
910-C90	Formats for Fine-Pitch Gear Specification Data	$48.00
911-A94	Guidelines for Aerospace Gearing	$91.00
912-A04	Mechanisms of Gear Tooth Failure	$66.00
913-A98	Method for Specifying the Geometry of Spur and Helical Gears	$55.00
914-B04	Gear Sound Manual - Part I: Fundamentals of Sound as Related to Gears; Part II: Sources, Specifications and Levels of Gear Sound; Part III: Gear Noise Control	$72.00
915-1-A02	Inspection Practices - Part 1: Cylindrical Gears - Tangential Measurements	$55.00
915-2-A05	Inspection Practices - Part 2: Cylindrical Gears - Radial Measurements	$44.00
915-3-A99	Inspection Practices - Gear Blanks, Shaft Center Distance and Parallelism	$30.00
917-B97	Design Manual for Parallel Shaft Fine-Pitch Gearing	$80.00
918-A93	A Summary of Numerical Examples Demonstrating the Procedures for Calculating Geometry Factors for Spur and Helical Gears	$64.00
920-A01	Materials for Plastic Gears	$55.00
922-A96	Load Classification and Service Factors for Flexible Couplings	$38.00
923-B05	Metallurgical Specifications for Steel Gearing	$75.00
925-A03	Effect of Lubrication on Gear Surface Distress	$65.00
926-C99	Recommended Practice for Carburized Aerospace Gearing	$45.00
927-A01	Load Distribution Factors - Analytical Methods for Cylindrical Gears	$65.00
929-A06	Calculation of Bevel Gear Top Land and Guidance on Cutter Edge Radius	$75.00
930-A05	Calculated Bending Load Capacity of Powder Metallurgy (P/M) External Spur Gears	$83.00
932-A05	Rating the Pitting Resistance and Bending Strength of Hypoid Gears	$60.00
933-B03	Basic Gear Geometry	$35.00
935-A05	Recommendations Relative to the Evaluation of Radial Composite Gear Double Flank Testers	$40.00
938-A05	Shot Peening of Gears	$45.00
939-A07	Austempered Ductile Iron for Gears	$55.00
1003-H07	Tooth Proportions for Fine-Pitch Spur and Helical Gears	$69.00
1006-A97	Tooth Proportions for Plastic Gears	$64.00
1010-E95	Appearance of Gear Teeth -Terminology of Wear and Failure	$91.00
1012-G05	Gear Nomenclature, Definitions of Terms with Symbols	$78.00
1102-A03	Tolerance Specification for Gear Hobs	$78.00
1103-H07	Tooth Proportions for Fine-Pitch Spur and Helical Gears (Metric Edition)	$64.00
1106-A97	Tooth Proportions for Plastic Gears	$59.00

AGMA Standards (continued)

2000-A88		Gear Classification and Inspection Handbook – Tolerances and Measuring Methods for Unassembled Spur and Helical Gears (Including Metric Equivalents) . . . $133.00
2001-D04		Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth . . . $159.00
2002-B88		Tooth Thickness Specification and Measurement . . . $85.00
2003-B97		Rating the Pitting Resistance and Bending Strength of Generated Straight Bevel, Zerol Bevel, and Spiral Bevel Gear Teeth . . . $138.00
2004-C08		Gear Materials, Heat Treatment and Processing Manual . . . $98.00
2005-D03		Design Manual for Bevel Gears . . . $159.00
2007-C00		Surface Temper Etch Inspection After Grinding . . . $38.00
2008-C01		Assembling Bevel Gears . . . $64.00
2009-B01		Bevel Gear Classification, Tolerances, and Measuring Methods . . . $96.00
2011-A98		Cylindrical Wormgearing Tolerance and Inspection Methods . . . $80.00
2015-1-A01		Accuracy Classification System – Tangential Measurements for Cylindrical Gears . . . $60.00
2015-2-A06		Accuracy Classification System – Radial Measurements for Cylindrical Gears . . . $40.00
Supp to 2015/915		Accuracy Classification System – Tangential Measurement Tolerance Tables for Cylindrical Gears . . . $35.00
2101-D04		Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth . . . $133.00
2111-A98		Cylindrical Wormgearing Tolerance and Inspection Methods . . . $70.00
2116-A05		Evaluation of Double Flank Testers for Radial Composite Measurement of Gears $38.00
6000-B96		Specification for Measurement of Linear Vibration on Gear Units . . . $69.00
6001-E08	NEW	Design and Selection of Components for Enclosed Gear Drives . . . $90.00
6002-B93		Design Guide for Vehicle Spur and Helical Gears . . . $64.00
6006-A03		Standard for Design and Specification of Gearboxes for Wind Turbines . . . $198.00
6008-A98		Specifications for Powder Metallurgy Gears . . . $53.00
6011-I03		Specification for High Speed Helical Gear Units . . . $95.00
6013-A06		Standard for Industrial Enclosed Gear Drives . . . $159.00
6014-A06		Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment . . . $115.00
6022-C93		Design Manual for Cylindrical Wormgearing . . . $69.00
6025-D98		Sound for Enclosed Helical, Herringbone and Spiral Bevel Gear Drives . . . $75.00
6032-A94		Standard for Marine Gear Units: Rating . . . $95.00
6033-C08	NEW	Materials for Marine Propulsion Gearing . . . $85.00
6034-B92		Practice for Enclosed Cylindrical Wormgear Speed Reducers and Gearmotors . . . $53.00
6035-A02		Design, Rating and Application of Industrial Globoidal Wormgearing . . . $75.00
6101-E08	NEW	Design and Selection of Components for Enclosed Gear Drives (Metric) . . . $85.00
6113-A06		Standard for Industrial Enclosed Gear Drives (Metric) . . . $135.00
6114-A06		Gear Power Rating for Cylindrical Shell and Trunnion Supported Equipment (Metric) . . . $100.00
6123-B06		Design Manual for Enclosed Epicyclic Gear Drives . . . $140.00
6133-C08	NEW	Materials for Marine Propulsion Gearing . . . $75.00
6135-A02		Design, Rating and Application of Industrial Globoidal Wormgearing (Metric) . . . $70.00
6336-6-A08	NEW	Calculation of Load Capacity of Spur and Helical Gears – Part 6: Calculation of Service Life Under Variable Load . . . $100.00
9000-C90		Flexible Couplings – Potential Unbalance Classification . . . $59.00
9001-B97		Flexible Couplings – Lubrication . . . $38.00

AGMA Standards (concluded)

9002-B04		Bores and Keyways for Flexible Couplings (Inch Series)	$52.00
9003-B08	NEW	Flexible Couplings - Keyless Fits	$55.00
9004-B08	NEW	Flexible Couplings - Mass Elastic Properties and Other Characteristics	$65.00
9005-E02		Industrial Gear Lubrication	$80.00
9008-B00		Flexible Couplings – Gear Type – Flange Dimensions, Inch Series	$38.00
9009-D02		Flexible Couplings - Nomenclature for Flexible Couplings	$46.00
9103-B08	NEW	Flexible Couplings - Keyless Fits (Metric Edition)	$52.00
9104-A06		Flexible Couplings - Mass Elastic Properties and Other Characteristics (Metric Edition)	$60.00
9112-A04		Bores and Keyways for Flexible Couplings (Metric Series)	$50.00
10064-5-A06		Cylindrical Gears - Code of Inspection Practice - Part 5: Recommendations Relative to Evaluation of Gear Measuring Instruments	$145.00
14179-1		Gear Reducers - Thermal Capacity Based on ISO/TR 14179-1	$65.00
17485-A08	NEW	Bevel Gears - ISO System of Accuracy	$110.00
Supp to 17485-A08	NEW	Bevel Gears - ISO System of Accuracy Tables	$35.00
18653-A06		Gears - Evaluation of Instruments for the Measurement of Individual Gears	$75.00
23509-A08	NEW	Bevel and Hypoid Gear Geometry	$210.00

ISO STANDARDS BY TECHNICAL COMMITTEE 60

53:1998		Cylindrical gears for general and heavy engineering – Standard basic rack tooth profile	$41.00
54:1996		Cylindrical gears for general engineering and for heavy engineering - Modules	$30.00
677:1976		Straight bevel gears for general engineering and heavy engineering - Basic rack	$30.00
678:1976		Straight bevel gears for general engineering and heavy engineering - Modules and diametral pitches	$30.00
701:1998		International gear notation - Symbols for geometric data	$35.00
1122-1:1998		Glossary of gear terms - Part 1: Definitions related to geometry	$139.00
1122-2:1999		Vocabulary of gear terms - Part 2: Definitions related to worm gear geometry	$82.00
1328-1:1995		Cylindrical gears - ISO system of accuracy - Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth (See ANSI/AGMA ISO 1328-1)	- -
1328-2:1997		Cylindrical gears - ISO system of accuracy - Part 2: Definitions and allowable values of deviations relevant to radial composite deviations and runout information (See ANSI/AGMA ISO 1328-2)	- -
1340:1976		Cylindrical gears - Information to be given to the manufacturer by the purchaser in order to obtain the gears required	$30.00
1341:1976		Straight bevel gears - Information to be given to the manufacturer by the purchaser in order to obtain the gears required	$30.00
2490:2007		Single-start solid (monoblock) gear hobs with tenon drive or axial keyway, 1 to 40 module - Nominal dimensions	$54.00
4468:2009	NEW	Gear hobs - Accuracy requirements	$122.00
6336-1:2006		Calculation of load capacity of spur and helical gears - Part 1: Basic principles, introduction and general influence factors	$170.00
6336-2:2006		Calculation of load capacity of spur and helical gears - Part 2: Calculation of surface durability (pitting)	$107.00
6336-3:2006		Calculation of load capacity of spur and helical gears - Part 3: Calculation of tooth bending strength	$117.00
6336-5:2003		Calculation of load capacity of spur and helical gears - Part 5: Strength and quality of materials	$117.00

6336-6:2006	Calculation of load capacity of spur and helical gears - Part 6: Calcultion of service life under variable load $92.00
8579-1:2002	Acceptance code for gears - Part 1: Determination of airborne sound power levels emitted by gear units $131.00
8579-2:1993	Acceptance code for gears - Part 2: Determination of mechanical vibration of gear units during acceptance testing $66.00
9083:2001	Calculation of load capacity of spur and helical gears - Application to marine gears $131.00
9085:2002	Calculation of load capacity of spur and helical gears - Application for industrial gears $131.00
TR10064-1:1992	Cylindrical gears - Code of inspection practice - Part 1: Inspection of corresponding flanks of gear teeth (See AGMA ISO 10064-1) . . . . - -
TR10064-2:1996	Cylindrical gears - Code of inspection practice - Part 2: Inspection related to radial composite deviations, runout, tooth thickness and backlash (See AGMA ISO 10064-2) . . . . - -
TR10064-3:1996	Cylindrical gears - Code of inspection practice - Part 3: Recommendations relative to gear blanks, shaft centre distance and parallelism of axes $41.00
TR10064-4:1998	Cylindrical gears - Code of inspection practice - Part 4: Recommendations relative to surface texture and tooth contact pattern checking $92.00
TR10064-5:2005	Code of inspection practice -- Part 5: Recommendations relative to evaluation of gear measuring instruments -- Technical Corrigendum 1 . . . . $160.00
TR10064-6:2009	Code of inspection practice - Part 6: Bevel gear measurement methods $135.00
10300-1:2001	Calculation of load capacity of bevel gears - Part 1: Introduction and general influence factors $124.00
10300-2:2001	Calculation of load capacity of bevel gears - Part 2: Calculation of surface durability (pitting) $77.00
10300-3:2001	Calculation of load capacity of bevel gears - Part 3: Calculation of tooth root strength $112.00
TR10495:1997	Cylindrical gears- Calculation of service life under variable loads - Conditions for cylindrical gears according to ISO 6336 . . . . $66.00
10825:1995	Gears - Wear and damage to gear teeth - Terminology $139.00
TR10828:1997	Wormgears - Geometry of worm profiles $82.00
TR13593:1999	Enclosed gear drives for industrial applications $150.00
13691:2001	Petroleum and natural gas industries - High speed special-purpose gear units $139.00
TR13989-1:2000	Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears – Part 1: Flash temperature method $112.00
TR13989-2:2000	Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears – Part 2: Integral temperature method $124.00
14104:1995	Gears - Surface temper etch inspection after grinding $41.00
14179-1:2001	Gears - Thermal capacity - Part 1: Rating gear drives with thermal equilibrium at 95°C sump temperature . . . . - -
TR14179-2:2001	Gears - Thermal capacity - Part 2: Thermal load-carrying capacity $102.00
14635-1:2000	Gears – FZG test procedures – Part 1: FZG method A/8, 3/90 for relative scuffing load carrying capacity of oils $77.00
14635-3:2005	Gears - FZG test procedures - Part 3: FZG test method A/2,8/50 for relative scuffing load-carrying capacity and wear characteristics of semifluid gear greases $82.00
17485:2006	Bevel gears -- ISO system of accuracy $98.00
18653:2003	Gears -- Evaluation of instruments for the measurement of individual gears . . . $82.00
TR18792:2009	Lubrication of industrial gear drives $157.00
21771:2007	Gears - Cylindrical involute gears and gear pairs - concepts and geometry . . . $160.00
23509:2006	Bevel and hypoid gear geometry $180.00

TECHNICAL PAPERS

2008 Full Set of Fall Technical Meeting Papers (19 papers on CD)	$550.00
2008 Full Set of Fall Technical Meeting Papers (19 papers on CD)	$425.00
2007 Full Set of Fall Technical Meeting Papers (19 papers on CD)	$375.00
2006 Full Set of Fall Technical Meeting Papers (16 papers on CD)	$275.00
2005 Full Set of Fall Technical Meeting Papers (20 papers on CD)	$175.00
2004 Full Set of Fall Technical Meeting Papers (14 papers on CD)	$125.00
2002 Full Set of Fall Technical Meeting Papers (12 papers on CD)	$125.00
2001 Full Set of Fall Technical Meeting Papers (12 papers on CD)	$125.00
1990-2000 AGMA Fall Technical Meeting Papers - Millennium CD	$200.00

All Individual Technical Papers $35.00

For titles and authors of papers from FTM Meetings prior to 1990, please send for our "TECHNICAL PAPERS CATALOG".

GEAR SOFTWARE

Gear Rating Suite	(AGMA Members)	$1195.00
	(Non Members)	$1495.00