YQS-0026

UPDATE ON THE NATIONAL CENTER FOR GEAR METROLOGY

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Update on the National Center for Gear Metrology

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Introduction

Traceability to national or international standards is clearly required by commercial sector standards including ISO 9001:1994 (Ref. 1), ISO/IEC Guide 25 (Ref. 2), and the U. S. equivalent of ISO/ IEC Guide 25 - ANSI/NCSL Z540-2-1997 (Ref. 3). In the draft replacement to ISO/IEC Guide 25 - ISO 17025; measurements, not just equipment, must be traceable to SI units or reference to a natural constant. The implications of traceability to the U. S. gear industry are significant. In order to meet the standards, either gear manufacturers must have calibrated artifacts or must establish their own traceability to SI units.

History

The National Institute of Standards and Technology (NIST) hosted and co-sponsored two industrial workshops that addressed metrology issues in U. S. manufacturing. In August, 1992, NIST hosted "Metrological Issues in Precision Tolerance Manufacturing," in Gaithersburg, Maryland. This workshop revealed a concern among a wide cross-section of American industry that the quality control practices in the production of gears are not sufficiently traceable to NIST standards (Ref. 4). In response to this finding, NIST teamed with the Department of Energy Oak RidgeY-12 Plant in Oak Ridge, Tennessee, to conduct an "Advanced Gear Metrology Workshop" at the DOE Y-12 Plant in April, 1993 . Significant planning assistance for the workshop was also provided by the Defense Logistics Agency, which is responsible for the procurement of gears for U. S. military weapon systems. The most important findings from the workshops were that the gear industry most often uses involute or tooth alignment artifacts, which were often not traceable to NIST; and that there was no national accepted standard artifacts or standard measurement systems to use in measurement comparisons.

As a result of the workshops, a partnership was formed between the American Gear Manufacturers Association (AGMA), the American Society of Mechanical Engineers (ASME), NIST, Pennsylvania State University, and the DOE Y-12 Plant. ASME formed an industrial advisory committee known as the Committee on Gear Metrology (COGM). This committee was established to give industry's priorities on re-establishment of gear measurement traceability to NIST and the DOE Y-12 Plant.

In October 1994, a $3-million stipend was awarded through the Department of Defense's Technology Reinvestment Program. The first item on the agenda was the re-establishment of involute profile artifact calibration with a stated uncertainty and direct traceability to the SI unit of length through NIST. Next, a facility known as the National Center for Gear Metrology (NCGM) was constructed at the DOE Y-12 Plant and equipped with state-of-the-art Coordinate Measuring Machines (CMM) for the calibration of all types of gear artifacts. A computer controlled generative gear checking instrument was loaned to the NCGM for several years by M&M Precision Systems Corporation to help correlate data from the CMMs to the gear checking instrument.

Bruce L. Cox

Is an engineering specialist at the Oak Ridge Metrology Center located at the Department of Energy Oak RidgeY-12 Plant which is managed by Lockheed Martin Energy Systems, Inc. He serves on the AGMA Inspection Handbook Committee and is the vice chairman of the AGMA Calibration Committee.

National Gear Metrology Center

The NCGM is a laboratory controlled to a temperature of ± 0.1° C. It has two Leitz 866 PMM Coordinate Measuring Machines (CMM), a Federal Formscan 3200 circular geometry instrument, and a Moore M-32 CMM being upgraded (see Fig. 1,2,3).

Figure 1. First Leitz 866 PMM CMM in NCGM Laboratory

Figure 2 Second Leitz 866 PMM CMM in NCGM Laboratory

Figure 3 Moore M32 CMM in NCGM Laboratory

Gear Artifact Measurement Uncertainty

The measurement uncertainty method used at NIST and the NCGM is known as measurement decomposition. In this method, which was developed by Dr. Howard Harary at NIST, the complex measurement task is broken down into a series of simple subtasks which can be represented with reference artifacts such as gage blocks, angle blocks, or spheres. The uncertainties of the reference artifacts and repeatability of the measurements are combined to reach a final uncertainty for the gear artifact.

The measurement decomposition for involute profile artifacts consists of measuring the centers of two circles on spheres and calculating a line between the circle centers, translating a distance from the line using a gage block, and measuring a series of points in a direction normal to an involute curve on a sphere (see Fig. 4). A multiplier (k=2) is used to allow the uncertainty to represent approximately a 95% confidence level of uncertainty for involute profile artifacts of ±0.9 micrometers. As a check on the uncertainty, an inter-comparison was done between NIST, NCGM, and M&M Precision Systems Corporation. The results are shown in Fig. 5.

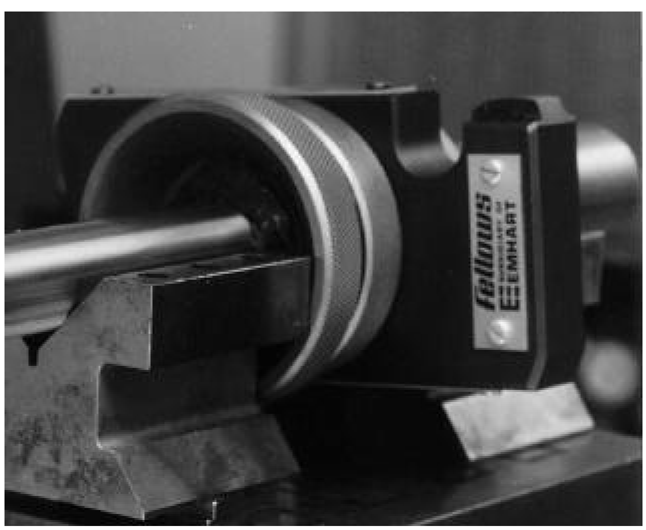

Figure 4 Involute Profile Artifact

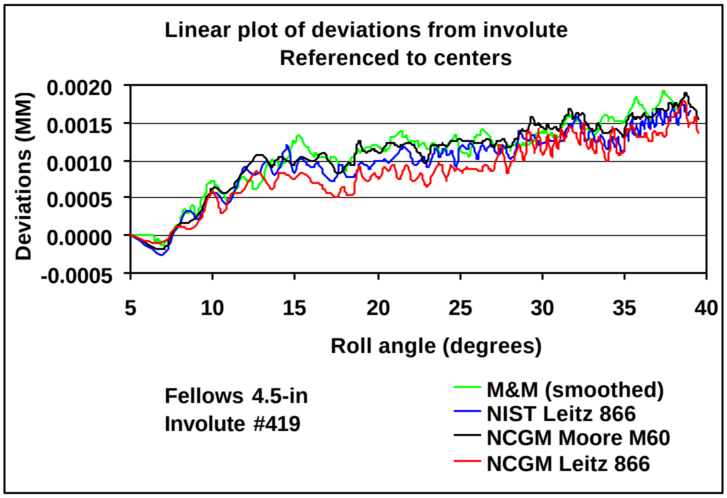

Figure 5 Inter-Comparison of Involute Profile Artifact

The measurement decomposition for pin artifacts consists of measuring the centers of two circles on spheres and calculating a line between the circle centers, translating a distance from the line using a gage block, and measuring the diameter of a sphere (see Fig. 6). The stated uncertainty at approximately 95% confidence level for pin artifacts is ±0.7 micrometers for offset, ±0.5 micrometers for diameter, and ±0.3 micrometers for roundness.

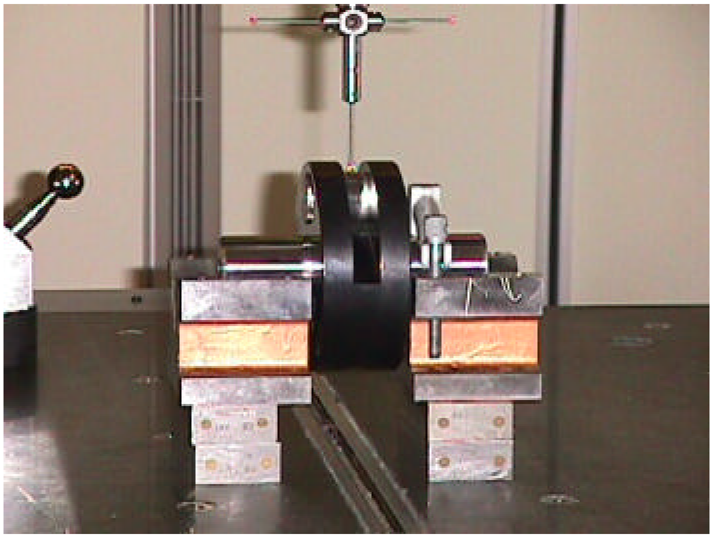

Figure 6 Pin Artifact

The measurement decomposition for tooth alignment artifacts consists of measuring the centers of two circles on spheres and calculating a line between the circle centers, translating a distance from the line using a gage block, and measuring a series of points at an angle to the line using an angle block (see Fig. 7). The stated uncertainty at approximately 95% confidence level for tooth alignment artifacts is ±0.8 micrometers for infinite leads, ±0.9 micrometers for 100 inch leads, ±1.1 micrometers for 32 inch leads, ±1.2 micrometers for 16 inch leads, and ±1.3 micrometers for 11 inch leads. Inter-comparison data between NIST and NCGM for tooth alignment artifacts is shown in Fig. 8.

Figure 7 Tooth Alignment Artifact

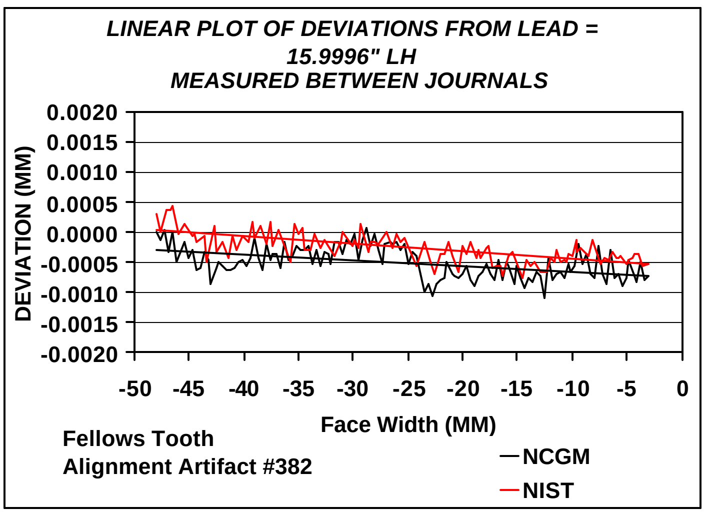

Figure 8 Inter-Comparison of Tooth Alignment Artifact

The measurement decomposition for index artifacts utilizes a rotary table and the principle of circle closure to subtract rotary table errors. In circle closure, all angular measurements must add to 360°; therefore any error can be subtracted from the measurement (Ref. 5). The decomposition consists of measuring the radial and axial runout of the rotary table, the repeatability of measuring an angle between three spheres on the rotary table, and the repeatability of an index artifact on the rotary table (see Fig. 9). The stated uncertainty at approximately 95% confidence level for index artifacts is ±1.6 arcseconds or ±0.6 micrometers for index artifacts up to 6 inches in diameter. Inter-comparison data between NIST, NCGM, and The Gleason Works is shown in Fig. 10.

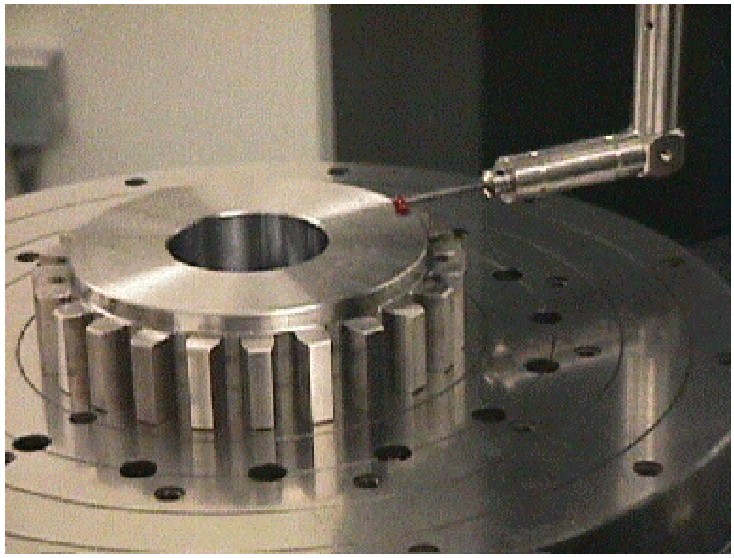

Figure 9 Index Artifact

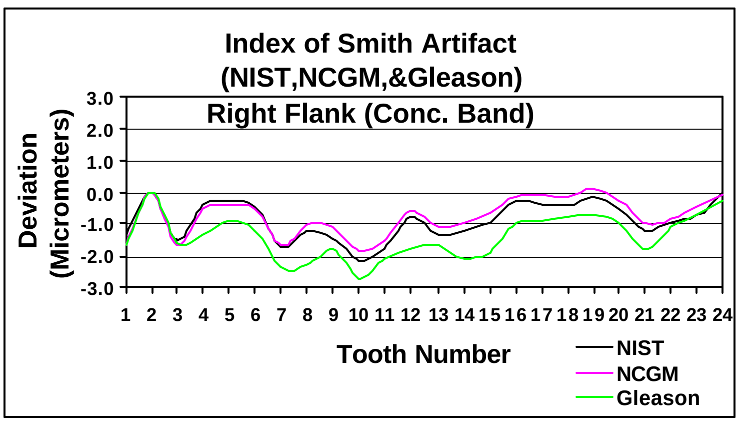

Figure 10 Inter-Comparison of Index Artifact

In addition to the inter-comparison measurements above, the NCGM has been involved in a round robin of involute profile artifacts sponsored by the AGMA Calibration Committee and an international round robin of gear artifacts sponsored by the University of Newcastle, UK. The results of the AGMA round robin were published in the proceedings of the 1998 AGMA Fall Technical Meeting. The results of the international round robin have not been published yet.

National Voluntary Laboratory Accreditation Program

The NGMC was accredited by the NIST National Voluntary Laboratory Accreditation Program (NVLAP) for measurement of involute profile artifacts, pin artifacts, and tooth alignment artifacts on July 8, 1999. This is the first laboratory accredited by NVLAP to calibrate gears (see Fig. 11).

National Institute of Standards and Technology

NVLAP®

National Voluntary Laboratory Accreditation Program

ISO/IEC GUIDE 25:1990
ANSI/NCSL Z540-1-1994
ISO 9002:1987

Scope of Accreditation

Revised 7/8/1999

CALIBRATION LABORATORIES

NVLAP LAB CODE 105000-0

OAK RIDGE METROLOGY CENTER

Grid Plates

Range	*Best Uncertainty (±)*[note 1]	*Remarks*
600 mm x 800 mm	0.6 μm + 0.45 Lμm; L is length in meters	CMM (optical)

NVLAP Code: 20/D18

Gears

Range	*Best Uncertainty (±)*[note 1]	*Remarks*
to 6" Diameter	0.9 μm	Involute Profile
to 6" Diameter and Infinite Lead	0.8 μm	Tooth Alignment
to 6" Diameter and 99" Lead	0.9 μm	Tooth Alignment
to 6" Diameter and 32" Lead	1.1 μm	Tooth Alignment
to 6" Diameter and 16" Lead	1.2 μm	Tooth Alignment
to 6" Diameter and 11" Lead	1.4 μm	Tooth Alignment
to 6" Diameter (pin offset)	0.7 μm	Pin Master
to 6" Diameter (pin diameter)	0.5 μm	Pin Master
to 6" Diameter (pin roundness)	0.3 μm	Pin Master

March 31, 2000
Effective through

For the National Institute of Standards and Technology

Figure 11 NVLAP Accreditation of National Center for Gear Metrology

Future Plans

During the 1999 AGMA Fall Technical Meeting, the COGM met to discuss the future of gear metrology. The committee decided that the NGMC should begin offering calibrations that meet the ISO 1328 -1 and ISO 1328-2 standards, and their corresponding technical reports ISO/TR 10064-1 and ISO/TR 10064-2. Another topic of discussion was, what type of gear calibration would be needed next. It was generally agreed that bevel gears would need direct traceability and that runout should be calibrated on index and master gears. If you would like to have input in the next COGM meeting, contact Bill Bradley at AGMA.

A proposal has been submitted to AGMA to establish traceability and uncertainty for bevel gears.
The measurement decomposition method would be used to determine the uncertainty. In this method, a gage pin located at the same angle as the gear tooth would be used to determine the accuracy of measuring a pattern of points. An angle block would be used to simulate the cone angle of the gear tooth and a rotary table would be used to check the pitch of each gear tooth. The measurements from each of these setups, the repeatability of an actual bevel gear (at different locations on the CMM), and other considerations such as temperature variation would constitute the total measurement uncertainty of a bevel gear (see Figs. 12-14).

The X, Y, Z contact points and I, J, K surface normal vectors would need to be supplied by the gear manufacturer so that the same coordinates could be simulated in the uncertainty measurements. Gleason has loaned a bevel pinion and a bevel gear to the NCGM to begin uncertainty testing (see Fig 15).

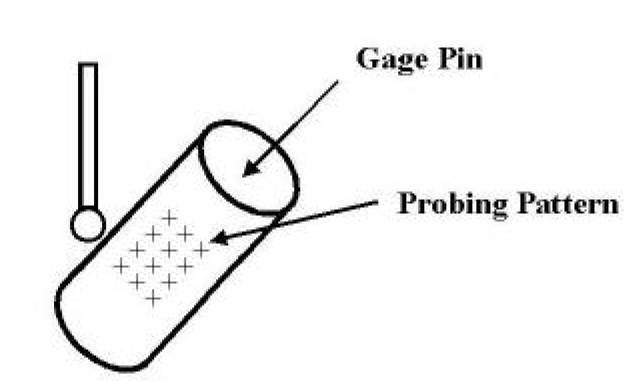

Figure 12 Probing Pattern on Gage Pin

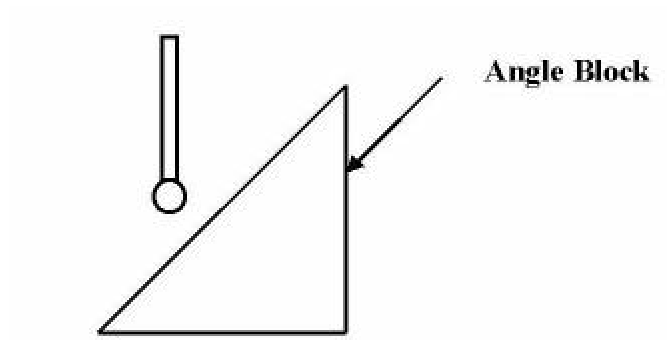

Figure 13 Cone Angle Check Using Angle Block

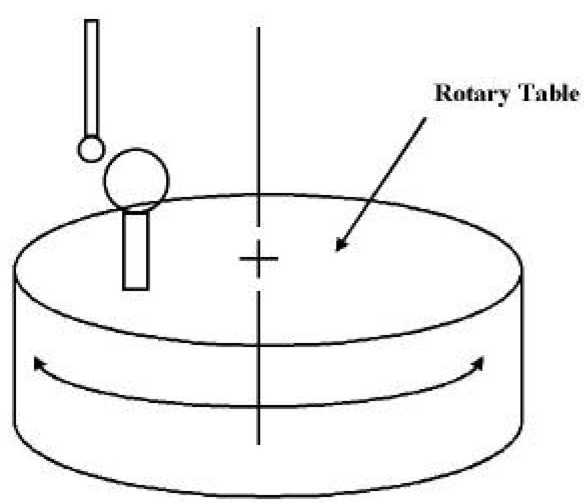

Figure 14 Pitch Check Using Rotary Table

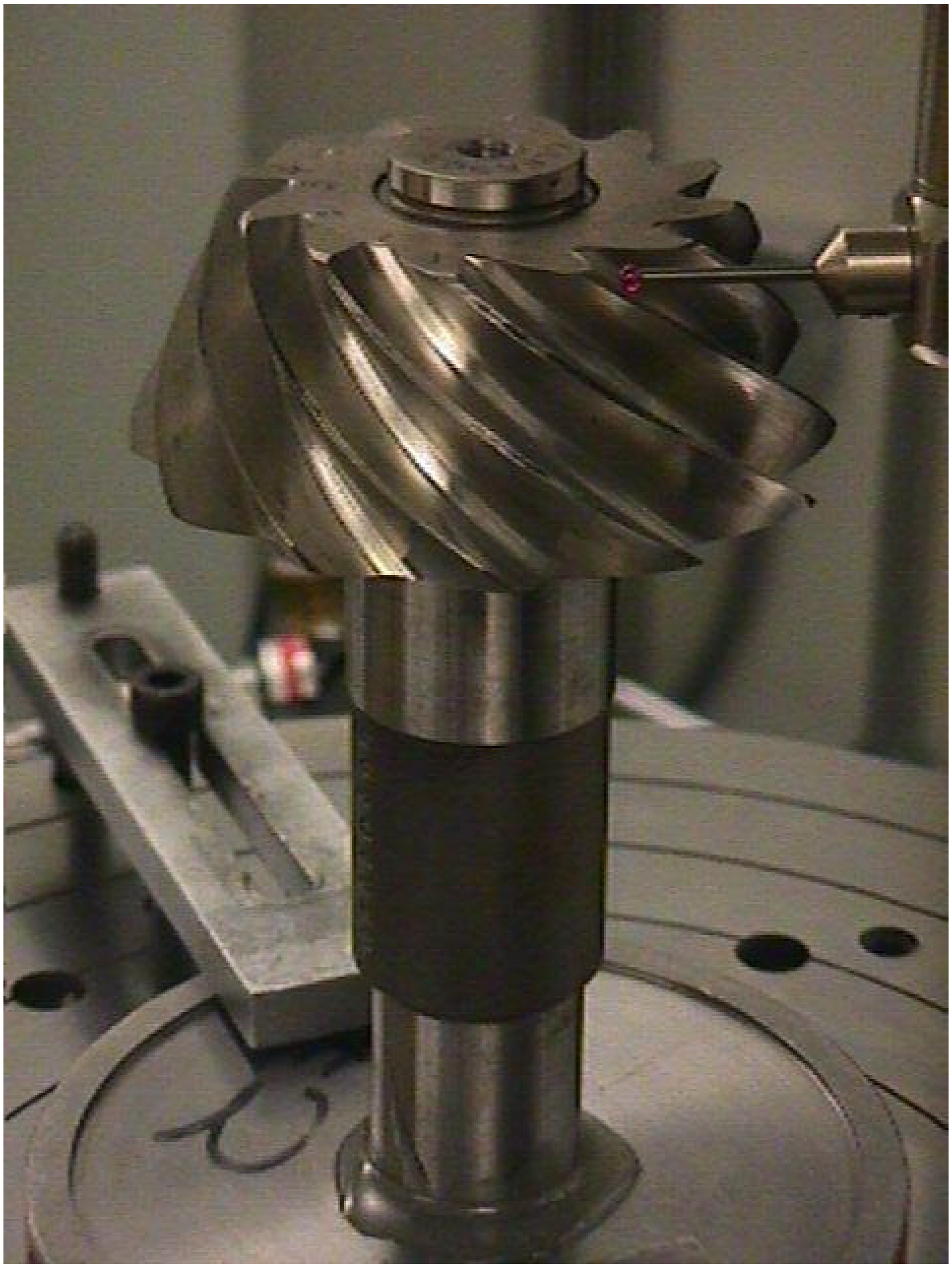

Figure 15 Bevel Pinion on Loan from Gleason

References

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