GOT A GEAR QUESTION?

Ask the Expert!

Welcome back to *Gear Technology*'s Ask the Expert!—our popular regular feature intended to help designers, specifiers, quality assurance and inspection personnel in addressing some of the more complex, troublesome gearing challenges that never cease to materialize—whether on the drafting table or the shop floor. Simply email your question—along with your name, job title and company name (if you wish to remain anonymous, no problem)—to: *jmcguinn@geartechnology.com;* or submit your question by visiting *geartechnology.com*.

QUESTION

Measurement of Involute Master

I am a calibration technician that has been saddled with finding how to measure some involute masters.

I have a print for them, but it only references, doesn't tolerance.

Am I to assume that the dimensions listed on the print are not important and therefore not necessary to measure? Or am I just looking at an improper print?

I am very new to gears, and am having some difficulty understanding them to this point.

Figure 1 115 mm base circle diameter involute artifact (courtesy Robert E. Smith).

Figure 2 Internal gear artifact (courtesy Robert E. Smith).

Response from Robert E. Smith, Robert E. Smith & Co., Inc.

To begin, the term "involute master" can be taken two ways.

There are involute *masters* that are actually just one flank of an involute tooth shape; this is probably the most common type. These are used to calibrate and determine the uncertainty of analytical type gear measuring instruments.

There are also involute *master gears*; these are actual, complete gears—made to very high accuracy—for double-flank and single-flank composite testing.

Point one. The involute master described in No. 1 above can be made from a drawing that only specifies the geometry— not the accuracy tolerances. It is not important that they be made to a specified tolerance or accuracy grade; it is only important to measure what it actually *is* and to what uncertainty. After it is made, it has to be measured by either an accredited laboratory or by an analytical-type instrument that has been certified with traceability to a national gear metrology laboratory.

In recent years, we have created our national gear metrology capability at the Oak Ridge Metrology Center, at the Y-12 National Security Complex. Artifacts of involute, helix, pitch, etc. are measured here with an uncertainty of less than 36 millionths of an inch (0.9 microns). One can have artifacts measured and certified at the Y1-2 Lab or by other labs that have been accredited by traceability to the National Laboratory.

In the process of setting up our National Gear metrology capability, an AGMA-directed committee wrote new standards for the calibration of gear measuring instruments. These later were submitted to the ISO standards association as a work project on international standards. This evolved into the creation of ISO 18653–2003 as the

international standard for the calibration of gear artifacts and gear measuring instruments. It is also available as an identical document: ANSI/AGMA/ISO 18653–A06.

Point two: Involute master gears—as described above—are complete gears of a specific DP and design to mate with a product gear being manufactured. These are used in a rolling-type gear tester for the measurement of double-flank or single-flank composite deviations.

Standards have also been written that describe the procedure for calibration of these master gears. The current document is ANSI/AGMA 2015–2–A06; it describes the tolerances for various grade levels of master gear accuracy. These can be measured by analytical-type gear instruments or by composite measurements when running against a qualified "grand" master gear.

It is highly recommended that the questioner obtain these calibration standards before trying to do any calibration activity on gear artifacts or master gears. It is also very important to understand the concept and application of "uncertainty" when doing a calibration. This is well-described in the ANSI/AGMA/ISO18653–A06 standard; in fact, the end-user of the artifacts should be well aware of the effect of uncertainty on their final product tolerances in manufacturing.

Figure 3 Helix (lead) artifact (courtesy Bruce Cox).

Robert E. Smith
Robert E. Smith & Co., Inc.

Gear industry consultant **Robert E. Smith**—R. E. Smith & Co., Inc. (resmith.co@worldnet.att.net; gearman@resmithcoinc.com)—possesses a half-century of hands-on experience and knowledge. A 1998 recipient of AGMA's E.P. McConnell Award, Smith'sdistinguished career includes almost 40 years at Gleason Corp. in a variety of important positions, including stints as gear methods and new product engineer. Smith is a longtime AGMA member and currently serves on its Gear Accuracy and Calibration (chairman/ISO delegate) committees. Educator (Rochester Institute of Technology) and prolific author, Smith also finds time—since 1991—to serve as a valued Technical Editor for Gear Technology.

Response from Steven Lindley, Rexnord Gear Group

Without seeing your print, I am going to make the assumption that you have an involute master gear and desire to do an analytical check (involute, helix and pitch) of the master gear. There are two very helpful sources on master gears. AGMA 2000-A88 *Gear Classification and Inspection Handbook,* Section 8 (inch), Section 8M (metric) and AGMA 2015-2-A06 "Accuracy Classification System: Radial Measurements for Cylindrical Gears, Annex A," have very detailed information on master gears. Even if what you have is an involute master artifact, the artifact is based on some type of gear geometry with a specified number of teeth, diametral pitch or module, pressure angle, helix angle and tooth thickness. This is basic information that would be required to calculate the base circle diameter.

Your drawing may give some type of master gear class code that will drive the tolerances. AGMA 2000-A88 uses Master Gear Class 1, 2, 3, 4 and 5. AGMA 2015-2-A06 uses only two classes of master gear—M1T and M2T; each of these standards has tolerance tables based on the class of master gear. There are also formulas in these documents to calculate the tolerances. The drawing should have at minimum module or diametral pitch, pressure angle, number of teeth, helix angle, hand of helix angle and tooth thickness. The drawing may also have listed a test radius and a base diameter. All of these are important dimensions for the inspection of the gear.

Two other documents that have pertinent information about master gears are AGMA ISO 10064-5-A06: Code of Inspection Practice, Part 5: Recommendations Relative to Evaluation of Gear Measuring Instruments, and ANSI/AGMA ISO 18653-A06 Gears: Evaluation of Instruments for the Measurement of Individual Gears. Each of these documents will give guidance and some methods on master artifacts and machines to measure such artifacts. Dependent upon how in-depth you wish to go, there are also calculations for measurement uncertainty and different methods and practice.

Steven Lindley
Rexnord Gear Group

Steven Lindley is a gear engineer for Rexnord Gear Group and current chairman of the AGMA Gear Accuracy Committee.

Response from Bruce Cox, Bruce Cox Engineering

Gear artifact measurements are defined in the standard ANSI/AGMA ISO 18653—Gears: Gear Evaluations of Instruments of the Measurement of Individual Gears—and the parameters measured on gear artifacts are defined in the standard ISO 1328: Cylindrical Gears: ISO System of Flank Tolerance Classification, Part 1: Definitions and Allowable Values of Deviations Relevant to Flanks of Gear Teeth. Unfortunately, the ISO 1328 standard is still being revised at this time. The types of gear artifacts are helix (lead), involute, pitch, run-out and tooth thickness. Artifacts may be workpiece-like—such as an accurate gear (*see photos*).

Figure 4 Master gear artifact (courtesy Robert E. Smith).

Basically, what are measured are the datums, such as centers, journals, or the bore to establish the centerline of the gear artifact. Next, width of the feature to be measured is established to set the coordinate system in the center of the artifact. A point on the feature is measured to set the rotation of the coordinate system to zero. Finally, the feature is measured on the artifact and the deviation from the nominal value is recorded.

In the case of the involute artifact, a series of points are taken in the center of the tooth shape from the root to the tip and compared to the nominal point values defined from the base circle diameter marked on the artifact and plotted on a graph of roll length vs. deviation. From this plot you can calculate the total, slope and form deviation. These values can be compared to the calibrated values of the artifact to help determine your measurement uncertainty for this feature.

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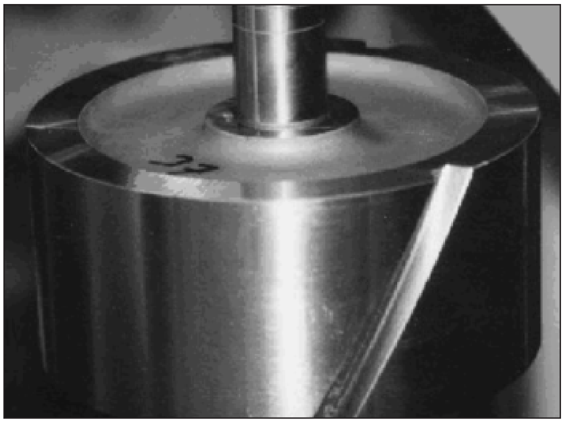

Figure 5 **Tooth thickness artifact (courtesy Bruce Cox).**

In the case of the helix artifact, the measurements are from the bottom of the tooth to the top at the pitch diameter along each flank. The deviations from the nominal values are plotted and compared to calibrated values in the same way as in the involute artifact.

In the case of the pitch/run-out artifact, the pitch measurements are one point at the center of each gear tooth flank at the pitch diameter referenced to the first tooth. Index deviation is the difference between each measured circular arc position on each tooth flank and the theoretical circular arc position from the first tooth flank measured. Pitch deviation is the difference in circular arc position of each successive tooth flank. The total-pitch deviation (maximum minus the minimum) and the single-pitch deviations are recorded and compared to calibrated values. Run-out is the axial distance from the center of the artifact to the center of a ball contacting both tooth flanks at the same time. The total run-out deviation and the single run-out deviations for each tooth gap are recorded.

In the case of the tooth thickness artifact, the circular arc width across the tooth or the tooth gap is measured at the pitch diameter—usually at the top, bottom and middle of the artifact.

The master gear artifact combines the features of all of the above artifacts.

Bruce Cox

Bruce Cox owns and operates Bruce Cox Engineering *(bcoxengineering.com)*. He is the former technical manager of the Oak Ridge Metrology Center at the Y-12 National Security Complex in Oak Ridge, Tennessee.