AGMA and ISO Accuracy Standards

Robert E. Smith

Background

The American Gear Manufacturers Association (AGMA) is accredited by the American National Standards Institute (ANSI) to write all U.S. standards on gearing. However, in response to the growing interest in a global marketplace, AGMA became involved with the International Standards Organization (ISO) several years ago, first as an observer in the late 1970s and then as a participant, starting in the early 1980s. In 1993, AGMA became Secretariat (or administrator) for Technical Committee 60 of ISO, which administers ISO gear standards development.

ISO Organization

ISO has over 215 technical committees, with members from over 75 nations. Technical Committee 60 (TC 60) has several working groups (WGs) assigned to different standards, such as gear accuracy, gear ratings, nomenclature, etc. The gear accuracy standards were developed by WG 2. In addition to TC 60 and WG 2, AGMA convenes (chairs) about 20% of the working groups in TC 60.

ISO Accuracy Standards

The pre-existing ISO standard for gear accuracy is known as 1328-1975. This is a single document, covering all aspects of cylindrical gear accuracy.

The new standard has been split into several documents; tangential tolerances, radial tolerances, and several information sheets. The first two, 1328-1 and 1328-2, are standards, and the information sheets are known as Technical Reports (TRs). All have been approved by member nations, and most are currently in print.

The new documents are known as:

1. *ISO 1328-1. Cylindrical Gears–ISO System of Accuracy. Part 1: Definitions and Allowable Values of Deviations Relevant to Corresponding Flanks of Gear Teeth.* This standard deals with pitch variations (single and cumulative), profile (involute), helix (lead) and tangential composite variations (single flank).

2. *ISO 1328-2. Cylindrical Gears–ISO System of Accuracy. Part 2: Definitions and Allowable Values of Deviations Relevant to Radial Composite Deviations and Runout Information.* This standard deals with radial composite variations (double flank) and radial runout.

3. *ISO TR 10064-1. Cylindrical Gears–Code of Inspection Practice. Part 1: Inspection of Corresponding Flanks of Gear Teeth.* This Technical Report deals with methods of measurement and interpretation of data relative to 1328 Part 1.

4. *ISO TR 10064-2. Cylindrical Gears–Code of Inspection Practice. Part 2: Inspection Related to Radial Composite Deviations, Runout, Tooth Thickness and Backlash.* This Technical Report deals with the methods of measurement and interpretation of data relative to 1328-2. It also covers tooth thickness and backlash.

5. *ISO TR 10064-3. Cylindrical Gears–Code of Inspection Practice. Part 3: Recommendations Relative to Gear Blanks, Shaft Center Distance and Parallelism of Axes.*

6. *ISO TR 10064-4. Cylindrical Gears–Code of Inspection Practice. Part 4: Recommendations Relative to Surface Texture and Tooth Contact Pattern Checking.*

AGMA to ISO Differences

The current accuracy standard for cylindrical gears in AGMA is ANSI/AGMA 2000-A88. This was issued in 1988 and used the same tolerances as the previous AGMA 390.03 standard. Some of the notable differences between the AGMA and ISO standards are these:

1. Numbering System. The AGMA system of numbering for different classes of quality is from Q3 through Q15, in order of increasing precision. In other words, the higher the number, the higher the quality of accuracy (smaller tolerance). The ISO system is just the opposite. It consists of 13 accuracy grades of which 0 is the smallest tolerance and grade 12 is the lowest accuracy or largest tolerance. **A word of caution:** When specifying an ISO accuracy class, one must specify per ISO 1328 Part 1 or 2 with its date 1996 or 1997, respectively. The tolerances specified in these new replacement standards are different from the ones specified in the old ISO 1328-1975 for the same class numbers.

It is impossible to define a direct comparison between any AGMA and ISO accuracy grade. For example, one might find the same tolerance for one parameter, such as pitch variation, at a given module and diameter. Yet the tolerance will be different at other modules or diameters for the same class. A rule of thumb that can be *used with caution* is to subtract an

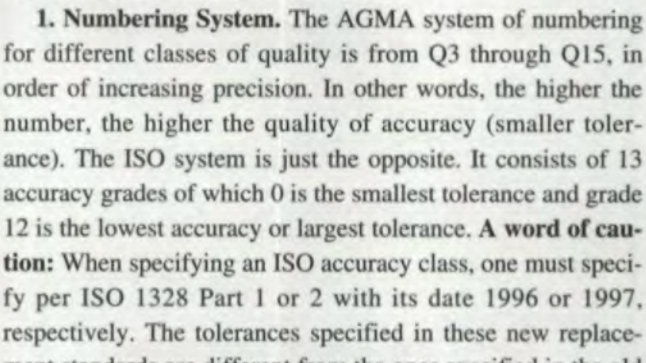

Fig. 1 – Tolerance comparison, single pitch variation, f_{pt}, AGMA Q 10 and ISO grade 7, module 8.

AGMA or ISO class number from 17 to find the corresponding class in the other system. This should only be used to get the mind thinking in a similar *range* of accuracy, not a specific class. For example, think of AGMA classes in different ranges of overall quality: 1) Low — Q3 to Q7, cast, molded, some cut; 2) Medium — Q8 to Q9, most cut; 3) High — Q10 to Q11, shaved and honed; 4) Precision — Q12 to Q15, ground. The above statement should be taken only in general terms. The "Rule of 17" should also be used in these general terms only.

2. Format of Standards. In an AGMA or ANSI document, the standard portion is a legally binding requirement. Anything that appears in an appendix or annex is for information only and is not legally binding. In ISO documents, a standard such as ISO 1328-1 has three categories of information. The main body of the standard is legally binding the same way as in AGMA. However, there are two types of annexes: Informative and normative. An informative annex is for information only and is not legally binding. A normative annex can contain requirements, such as tolerances, that can become binding if the methods or parameters within the annex are specified.

AGMA also issues information sheets. The Technical Reports associated with the 1328, Parts 1 and 2 standards are called Type 3 and might be considered more like AGMA information sheets.

3. Tables vs. Formulas. AGMA 2000 A-88 uses formulas for the basis of tolerances. These tolerances are then based on a continuous curve. Tables of tolerances are included only as a convenience for the shop users. The tolerances in ISO 1328-1 are based on the tables, rather than a formula. Formulas are included, but are based on ranges of modules (m), diameters (d) and face width (b), as shown in the tables. When applying the formulas, the given parameters m, d and b are to be introduced as the geometric mean values of the relevant range limits and not the actual values. If, for example, the actual module is 7, the range limits are $m = 6$ and $m = 10$, and the allowable deviations are calculated with $m = (6 \cdot 10)^{0.5} = 7.746$. This causes an unusual looking graph of tolerances with steps in it. (See Fig. 1). This also causes some unusual circumstances, where a minute change in diameter or module can cause a big change in tolerance if the change moves the example gear into the next step.

4. Runout and Accumulated (Total Cumulative) Pitch. AGMA 2000 A-88 uses pitch variation and radial runout for the control of the short and long term accuracy of the placement of teeth around a gear. Pitch variation is a tangential measurement, and runout is a radial measurement. ISO 1328-1 uses single pitch variation and total cumulative pitch variation. Both of these parameters are tangential in nature. Radial runout has been relegated to an informative annex in 1328-2. In the author's opinion, the ISO approach is better. Gears function tangentially, not radially. Also, after a gear has had a subsequent finishing operation, such as shaving, or with some methods of grinding, runout can be a very deceiving parameter of gear quality or accuracy. The finishing operation can reduce runout to a minimum, yet still leave a significant amount of accumulated pitch variation. (See AGMA Technical Paper 95-

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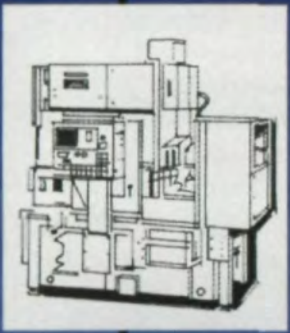

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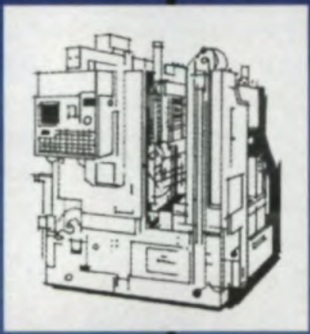

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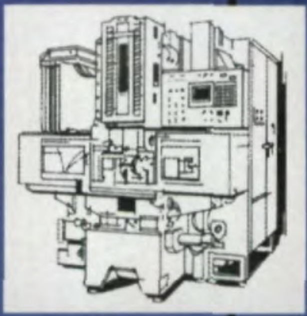

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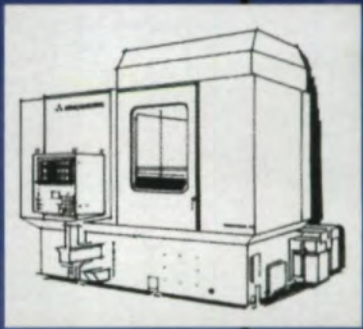

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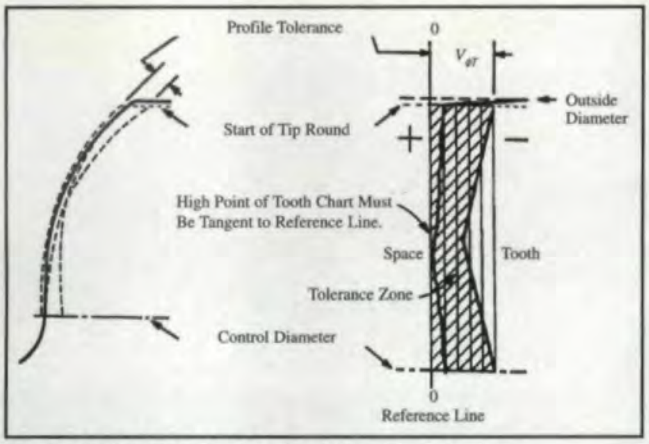

Fig. 2 – AGMA "K" Chart method of profile evaluation.

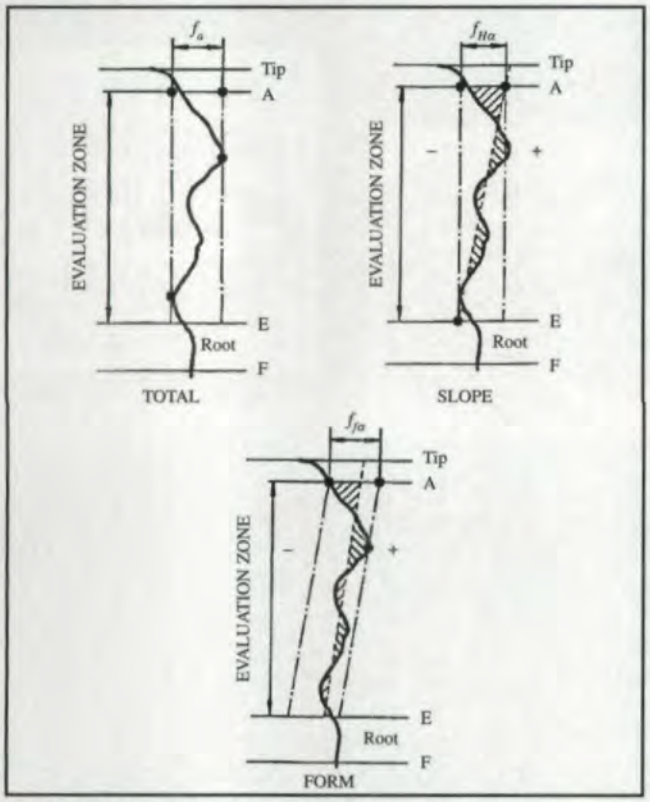

Fig. 3 – ISO Total, Form and Slope methods of evaluation.

FTM 1 by R. E. Smith, *et al.*, "Detection of Hidden Runout," for further details on this subject.)

5. "K" Charts vs. Slope, Form and Total. AGMA 2000 A-88 uses the familiar "K" charts for the evaluation of involute and tooth alignment (lead) data (see Fig. 2). ISO 1328-1 uses a rectangular tolerance zone in the main body of the standard for "total" deviation. However, an informative annex uses "slope" and "form." The problem with AGMA "K" charts and the rectangular tolerance zone of ISO is that they are like "go/no go" gages. They are not useful for today's statistical process control techniques. Also, the zones are wide enough to allow for the effects of runout on the profile or lead errors. For this reason, they are not very discriminating as far as determining the real involute or lead errors, independent of runout. The technique described in ISO 1328-1 allows the determination of slope and form deviations. These are useful for the determination of factors that have an influence on functional characteristics of the gears. For example, slope and mean slope are useful for the control of noise excited by gears.

The method of determining slope and form is described in ISO 1328-1, and the suggested tolerances are listed in an informative annex of the standard. For unmodified tooth forms, they are determined by using a least-squares-straight-line fit to the actual trace within a specified evaluation zone (see Fig. 3). The slope deviation ($f_{H\alpha}$) is the slope of the least squares line. The form deviation ($f_{f\alpha}$) is the bandwidth of the irregularities of the trace around the slope line. The total is F_α. If the tooth is a modified tooth form, other techniques for the best fit line are used. See ISO 1328-1 for a more detailed description.

6. Comparative Lead Tolerances. Tooth alignment (lead) is a very important parameter relative to life on highly loaded gears. For large diameter, higher accuracy gears, ISO is more restrictive on allowable lead tolerances. In addition, lead (or helix) tolerances are specified in the transverse plane in ISO 1328-1, while AGMA 2000 A-88 specifies them normal to the helix. Both are given in the base tangent plane.

Adoption of ISO Standards in the U.S.

Where do we go as far as adoption of ISO gear accuracy standards? The AGMA Inspection and Handbook Committee is now addressing that question. It is currently working on a bevel gear accuracy standard. This is AGMA 2009 AXX. Even though ISO has no bevel gear tolerance standards, the AGMA committee has endeavored to follow ISO practice for cylindrical gears as much as possible. So far, this practice has not met with complete agreement. The committee is now starting to rewrite AGMA 2000-A88. Again, the concept is to try to use ISO as much as possible.

Both ISO and AGMA are consensus standards. This means that they are arrived at by consensus of a large number of participants. This doesn't mean that everyone agrees with everything that results. For example, the AGMA committee feels that the ISO standard is too restrictive with some tolerances in the very small diameter or fine pitch region. The current feeling is that the tolerances are not relevant to current capabilities or practice. At this time, the outcome of this disagreement is not known. As far as the rewrite of AGMA 2000-A88, the work is just beginning. Whether AGMA decides to adopt ISO or a modified version of it remains to be seen.

Committee Participation

If anyone has strong feelings about standards issues, he or she should participate in their development. Everyone should feel free to get his interest on the table for consideration. It is also a great learning experience to participate on such committees. For further information, call AGMA Headquarters, 703-684-0211, attn. Bill Bradley.

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