Introduction to ISO 6336 What Gear Manufacturers Need to Know

Don McVittie

This is the first of a series of articles introducing the new ISO 6336 gear rating standard and its methods of calculation. The opinions expressed herein are those of the author as an individual and not necessarily those of any organization of which he is a member.

ISO 6336 *Calculation of Load Capacity of Spur and Helical Gears* was published in 1997 after 50 years of effort by an international committee of experts whose work spanned three generations of gear technology development. It was a difficult compromise between the existing national standards to get a single standard published which will be the basis for future work. Many of the compromises added complication to the 1987 edition of DIN 3990, which was the basic document.

Fig. 1 — Countries adopting ISO Standards.

- All EC members—required by EC rules
  - France
  - Germany
  - United Kingdom
  - Benelux
- "Eastern Bloc"—required by national laws
- Japan

Fig. 2a — New symbols.

α = pressure angle
β = helix angle
ε = contact ratio
a = center distance
b = face width
z = number of teeth
u = gear ratio

Fig. 2b — New symbols.

K = General influence factor
Z = Pitting influence factor
Y = Bending influence factor
H = Subscript related to pitting
F = Subscript related to bending
γ = Subscript for combined, axial + transverse

Fig. 2c — New symbols.

$K_{H\_}$ = Face load distribution factor for pitting
ε_α = Transverse contact ratio
ε_β = Face contact (overlap ratio)
ε_γ = Total contact ratio

What does this new standard mean to gear manufacturers around the world? How will it affect your gear-related business? The answers may depend—at least initially—on where you do business and where your customers do business.

ISO is a quasi-voluntary organization with indirect government support. While it doesn't have authority like the U.N., it is the result of an international agreement to support a combined effort by the world's national standards bodies to achieve a set of unified international technical standards. Those national standards organizations pay the administrative costs of ISO through annual dues and royalties on publications.

Most nations have a national standards administrative organization that receives most of its funding from the national budget and forms the national position with regards to technical standards. The U.S. is different in that the American National Standards Institute (ANSI) is supported without government funding by its publication revenues and the dues of its member companies and individuals. It is independently governed by its own volunteer board of directors, representing the members[1]. ANSI has appointed AGMA to represent it to ISO Technical Committee 60 (TC60) for gears.

Another difference between the U.S. and the rest of the world is the mechanism by which national standards are adopted. In most countries, if an ISO standard is adopted, the law requires that it be used as a national standard. This is particularly true in developing nations that don't have the resources to develop a variety of national standards but want the quality protection of producing, buying and selling a product to an agreed standard.

In most of the major gear making nations, a national gear rating standard already exists. Will these standards be replaced by ISO 6336?

The member countries of the European Economic Community (EEC) have adopted a system of *Euronorms* to standardize products within the EEC. The EEC rules suggest that ISO standards, if they exist, should be adopted as Euronorms. It may take a few years to translate and apply, but ISO 6336 is almost certain to be the Euronorm for gear capacity calculation (Fig. 1).

At the same time, the Japanese Standards Institute (JSI) is actively translating the ISO gear standards for adoption in Japan.

That leaves the U.S. as the largest gear making nation with no plans to adopt ISO 6336 in the near future. That seems strange, but the reason is in the ANSI standards approval process, which requires a national consensus ballot, with 75% approval, to adopt a proposed national standard. Under the present ANSI rules, the U.S. gear community would have to abandon the ANSI/AGMA 2001 standard—which is proven and most are happy with—to adopt ISO 6336. There is not a 75% majority agreement to do that today.

So what should you do as a gear specifier, gear user or gear maker? The answer depends on your place in the market.

If you are an importer or exporter of gears or gear products, you'll have to look to the market for guidance. The end user usually decides which standards will be used in his application, but that decision is greatly affected by the availability of product. If the end user is offered two products, made to two different standards, how will she choose? One would hope that an informed user would make an intelligent decision based on the merits of the case. That won't happen unless someone who knows both standards helps by making comparisons, since few end users have the resources to do it themselves.

If you are a gear manufacturer using gear inspection equipment to qualify your product to a customer's requirements, you'll have to look to your customer for guidance. As the new ISO 1328 quality standard is used on newer drawings, you'll have to get new software for your inspection machines as a minimum. (See the article in May/June 1998 by R.E. Smith for more information on ISO 1328.)[2]

If you specify gears for your own products or the products of others, you'll have to learn the ISO gear rating system sooner or later. You won't necessarily adopt it without a lot of thought about its suitability for your task and the reliability of the results, but in order to make intelligent choices and deal with the questions of customers and end users regarding "which standard," you'll have to know what is required of each system.

Fig. 3a — New Meanings.

- AGMA dynamic factor K_v
    - Includes effect of pitch error
    - Does not include effect of gear inertias
    - Does not include effect of tooth stiffness
    - Not load dependent
- ISO dynamic factor K_v
    - No influence of pitch error
    - Includes tooth stiffness and gear inertias
    - Load dependent

Fig. 3b — New Meanings.

- AGMA face load distribution factor C_m
    - Not load dependent
    - Analytical method withdrawn
- ISO face load distribution factor $K_{H\beta}$
    - Load dependent
    - Analytical method required for Methods B & C
- ISO has separate factors for bending and transverse load distribution

Fig. 3c — New Meanings.

- Application factor K_A
    - Similar to AGMA, except definition
    - Uses same values as AGMA

Where Do I Begin?

It sounds like a big task, but it's fairly simple if we begin by looking at the fundamental differences and similarities between ISO 6336 and AGMA 2001. One of the best ways to learn the new system is to recalculate some of the gears you know well by the new system. I recommend that you begin by getting a good software package to calculate gear capacities by ISO 6336. AGMA is offering a good program for ISO calculation written by a volunteer committee of its members.[3]

The ISO standards use SI dimensions. If you are still uncomfortable with that, the AGMA program allows input in inch-pound units as an alternative, translating into SI for internal calculation with output in either system or both.

In addition to obtaining the software, you will probably want to become familiar with some of the conceptual differences between the standards.

First we'll have to learn some new symbols and some new meanings for familiar symbols (Figs 2a–2c). In general, the ISO symbols are highly organized, with only one meaning for

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Fig. 4 — ISO 6336 Part I, Basic Principles

- Order of calculation is important, because the influence factors are load dependent
  - K_v with the force F_tK_A
  - $K_{H\beta}$ with the force $F_tK_AK_v$
  - $K_{H\alpha}$ with the force $F_tK_AK_vK_{H\beta}$
- You must iterate to get a rating value at a required safety factor

Fig. 5 — Gear Capacity (Rating) Standards

- ISO 6336 general standard, similar in scope to AGMA 2001
  - Part 1 — Definitions and common factors
  - Part 2 — Pitting capacity
  - Part 3 — Bending capacity
  - Part 5 — Materials and allowable stresses

Where To Get Information on ISO Standards

AGMA is responsible for distribution of ISO standards related to gears. The ISO 6336 standard comes packaged with the AGMA/ISO 6336 software for $995.

The software comes with a manual that explains how to use ISO 6336 and guides the user through the more than 80 inputs required to calculate using the standard's method B.

Contact:
The American Gear Manufacturers Association
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Additional information may be obtained at the AGMA and ISO Web sites:
www.agma.org
www.iso.ch

each major symbol or subscript. There are inconsistencies, however, and it will be worth your while to check meanings in the symbols table of the standard to be sure. AGMA publishes many useful editorial documents to help you find your way. I particularly recommend AGMA 900 F96 *Style Manual for the Preparation of Standards, Information Sheets and Editorial Manuals* as a starting point.

Here are some examples of new meanings: Both ISO 6336 and AGMA use an application factor to account for variable loading, a dynamic factor to account for the dynamic loads due to gear inaccuracy and a load distribution factor to account for the unequal distribution of load across the face width of the teeth (Figs. 3a–3c).

Since the ISO dynamic factor and the load distribution factors are load dependent, it is not possible to directly calculate the capacity of the gear set unless you know the load, which depends on those factors. ISO 6336 calculates a safety factor at a given load, based on allowable stress divided by applied stress rather than rated load or power. If you need to know the rated power at a given safety factor, it is necessary to iterate with variable load until the required safety factor is achieved. It's really best to have a good computer program to shorten the calculation time. The load dependency of the influence factors requires that they be applied in the correct order (Fig. 4).

Three basic rating methods are recognized, in order of decreasing accuracy:

- Method A—Full-scale testing or a verified, detailed mathematical model. This recognizes the validity of the development programs typical of the aircraft and vehicle industries, but no standard methods are specified.
- Method B—A detailed calculation method, standardized to allow comparison of a design to test or field data from similar designs. This is the core of the standard and the method programmed by the AGMA committee.
- Method C—Simplified methods which are sufficiently accurate for a restricted field of use or a narrow range of geometrical configurations.

The ISO standard is divided into four parts, covering common factors, pitting resistance, bending resistance and gear materials (Fig. 5). The general theory is very similar to AGMA 2001, using fundamental Hertzian surface stress for pitting and a simplified cantilever beam with stress concentration factors for bending, so you will be able to follow the general principles without trouble. The differences come in the greater detail of the ISO analysis, which require more design data, e.g. blank geometry, lubricant viscosity and tooth finish values as input information. We'll cover those topics in upcoming issues as we go through the sections of the standard in detail. ○

Next issue: Details of ISO 6336-1, General influence factors. Application Factor, Dynamic Factor, Load Distribution Factor and tooth stiffness.

1. Bartels, N. "Standard Issues," *Gear Technology*, Nov/Dec 1996.
2. Smith, R.E. "AGMA and ISO Accuracy Standards," *Gear Technology*, May/June 1998.
3. Stott, W.R. "Gear Teeth With Byte," *Gear Technology*, Jan/Feb 1998.