# So What's to Know About Specifying a Gear?

## Only *Everything!*

## THE QUESTION

I am trying to specify a few .8 module metric gears and am being asked to include as many gear specifications as possible on our drawings.

For example, one of the gears we need is a .8 module 40t gear, so my plan was to say this:

**Spur Gear:** *Teeth* = 40, *Module* = .8, *PD* = 32, *Circ Tooth Thickness* = 1.17 (using this to determine backlash, but there is probably a better way)

For all other tolerances and design information, reference AGMA 2000-A88, Q8 (we found some stock gears that listed this number but don't really know what it means). I see so many different AGMA and ISO standards for gears and I'm just not sure which one I need. We haven't purchased any yet and don't want to until we know which one to use. Can you shed some light on this or point me in the right direction? I don't know why but this seems like a real mystery to us!

Thank you!

### Expert response provided by Rob Frazer, senior engineer at the Design Unit:

The position that you find yourself in is very common. Gear technology is not a particularly difficult subject to understand, but it covers many fields of expertise and thus there are many elements that need to be appreciated and understood before a full specification can be prepared that will ensure that you get gears that are fit for purpose and meet your needs.

To put it bluntly, if we don't specify gears properly we get the gears we deserve rather than the ones we actually need.

This is a challenging task for people who do not regularly specify gears. Because we have no knowledge of your specific application for fine-pitch gears, the following guidance is generic for most gears and we will assume that specifying the geometry itself is sufficient and that the life and loading is evaluated separately.

Gear standards, whether they are published by AGMA or ISO, are a very valuable source of reference material for gear designers. However these are written for people who have the relevant background gear knowledge and expertise to implement the procedures and, more importantly, interpret the results from applying the standard procedures. The AGMA information sheets and ISO Technical Reports are prepared by the expert working groups to provide guidance on implementing and understanding them. It is also of course important to ensure you are referring to the latest version of the standard. This is not helped by the fact that within AGMA and ISO publications, none fully address the specification requirements of gears.

But before you try and specify gears starting with a blank sheet of paper, there are other options that should be explored first that, although apparently more costly, may save much of your time and potentially avoid costly mistakes:

Employ a consultant to specify the gears for you. The benefits from this are that you will get a full specification that will provide you with the gears you need. The disadvantage is that you won't learn anything yourself and if you need to modify the design or experience quality problems, you will have to re-employ your consultant.

Alternatively, you can seek a reputable gear supplier who is willing to provide the design and manufacturing expertise to supply gears that will meet your needs. You would need to specify life and duty cycle (load and speed) requirements; the drive element (e. g., electric motor specification); the load characteristic; size envelope; gear shaft and gear housing tolerances; manufacturing methods; environmental conditions (temperature and humidity); preferred materials; operating backlash; noise requirements; and annual quantities. Again, if you want to modify anything, you rely on the supplier for these design changes.

The application in this example is not defined, but the 0.8 mm module gears could potentially be supplied by a catalog gear supplier who specialize in small-pitch, standard geometry gears; your question implies that you have already considered this. A number of catalog gear companies offer a range of gears that may be suitable for your requirements. They can supply small quantities of gears but may also be

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*Over **550** locations | More than **5.2** million products | Industrial maintenance training courses* suitable for larger volume manufacture and also provide guidance on suitable geometry tolerances, tooth thickness tolerances to ensure the gears operate with acceptable backlash. Using off-the-shelf or modified catalog gears often provides the cost-effective solution to prototype or small volume gear applications.

There are many commercial software programs available that can assist you to design, analyze and specify gear geometry. These range considerably in terms of complexity and cost, but the best allow users to invoke ISO and AGMA accuracy standards, use standard proportion cutting tools, define and evaluate tooth thickness (for backlash calculations) and evaluate the gear pair using stress analysis standards such as AGMA 2101 or ISO 6336. Many programs provide graphics that enable the users to properly visualize the gear pair they are specifying. The most basic of these programs is a simple automated gear calculator, while the most sophisticated programs provide help and guidance when things are starting to go wrong (Fig. 1). But users need to understand what the programs are doing and thus it is recommended that proper training is obtained prior to use. Few people are provided with sufficient training in gear technology in college and university courses, but help and guidance is provided by the AGMA in their training program (*www.agma.org*). In the U.K. the British Gear Association (BGA) has an extensive seminar program that allows those new to the gear industry to attend a series of short courses to introduce them to gear technology (*www.bga.org.uk*).

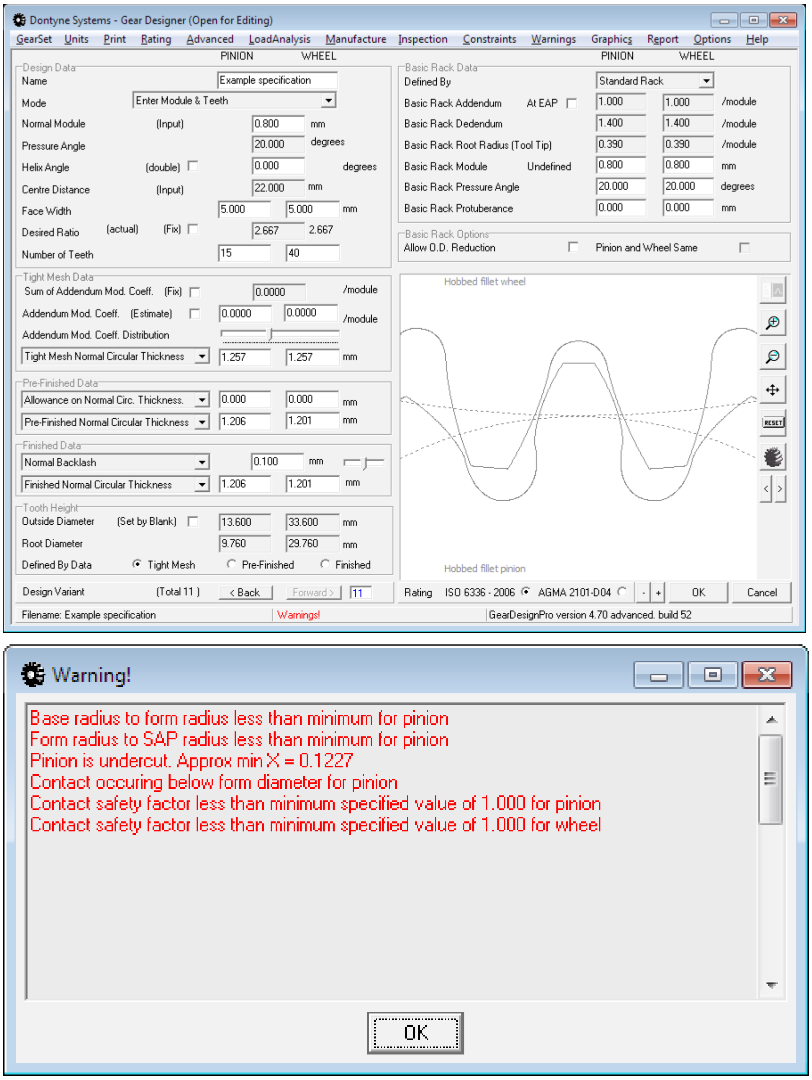


**Figure 1** **Example of a software package used to develop a gear specification with built in warnings when you approach normal geometry limits (courtesy Dontyne Systems Ltd).**

The strategy adopted by the Design Unit (at Newcastle University, U.K.) for specifying gears is that you provide unambiguous data relating to the geometry of the finished gear. Our policy is not to specify the details of the manufacturing procedure and thus a full gear specification comprises seven elements:

1. The nominal basic macro gear geometry (module, tooth number, helix angle, tip diameter, root diameter, face width, addendum modification coefficient). ISO 21771 provides formula for these parameters.
2. The specification of microgeometry corrections to the tooth flank (tip relief, helix crowning) on gears that are transmitting significant amounts of power or have stringent noise and vibration requirements.
3. Cutting tool geometry data (depth, pressure angle, cutting tool tip radius used to cut the tooth root region, grinding allowance or backlash allowance). AGMA 1003 and 1006 provide information of the proportions of tooth for fine-pitch gears and plastic gears.
4. Tooth thickness data specifying the tooth thickness tolerances to ensure operating backlash is achieved when the gear is manufactured and assembled. We normally define gear circular tooth thickness indirectly because measuring a circular arc length is difficult. We use parameters such as dimension-over-pins or span size over several teeth. Refer to ISO 21771 for tooth thickness calculations. AGMA 2002 provides guidance on tooth thickness tolerances. There is no ISO standard directly related to tooth thickness allowance and backlash.
5. A gear geometry accuracy specification is defined by ISO or AGMA tolerance classification standards. Two methods are commonly used here:
   a. The measurement of individual errors (profile, helix or tooth alignment, pitch errors, radial runout of the tooth space and tooth thickness). AGMA 2015-1 (replaced AGMA 2000) specifies allowable limits for different tolerance classes and is similar to ISO1328-1. Note that these do not provide guidance on which tolerance grade to pick. For most applications, precision-cut gears of grade 7 or better (lower grade number) are achievable, with molded, fine-pitch gears of grade 9 to grade 10 commonly specified. The tolerances that are specified must consider power transmission, noise and tolerance build-up of the assembled gear assembly. The accuracy of the gear is verified by measurement with CMMs or dedicated gear measuring machines and fine-pitch gears of 0.4 mm module can be easily measured (Fig. 2). The process provides feedback to show that the gears comply with the accuracy specification and also identify what has gone wrong with the manufacturing process.

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Figure 2 Klingelnberg P65 with a 0.5 mm diameter probe Inspecting a 0.7 mm module gear in accordance with ISO1328-1 (the minimum standard probe is 0.3 mm diameter).

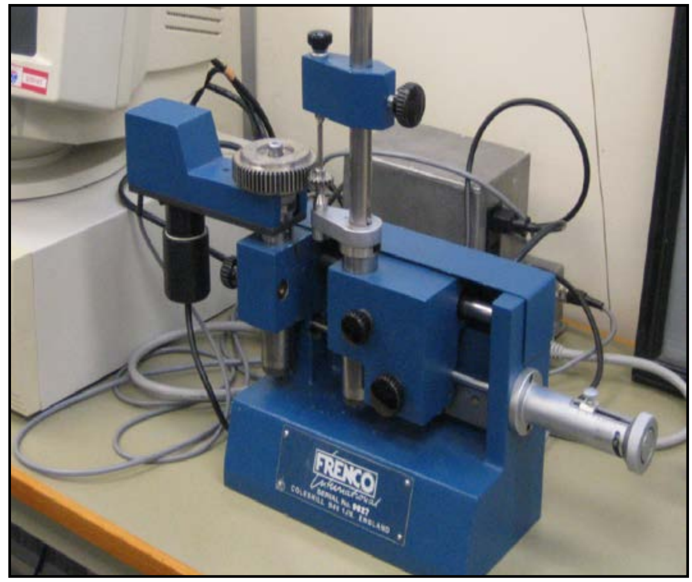


Figure 3 Frenco-dual flank roll tester for measuring composite Radial deviations in accordance with ISO1328-2.

b. The second method is the measurement of radial composite errors or dual-flank errors, and is commonly used to control fine-pitch gear tolerances. The method involves meshing a product gear with a precision-ground master gear (a minimum of 3 accuracy grades better than the product gear) under light load with zero backlash, and recording the change in center distance as the gears rotate. AGMA 2015-2 and ISO 1328-2 both provide allowable tolerances for gears of 0.8 mm module, and the quality grades mentioned above equally apply to this measurement method. This also provides a method of measuring tooth thickness by specifying upper and lower indicator limits based on maximum and minimum center distance values.

6. Material specification, including material type and where appropriate the range of acceptable hardness values and case depth requirements.
7. The datum axis that is used to define the gear geometry and provide a functional location for the gears when in service.

A typical realization of a gear specification is illustrated in Figure 4 for ISO 1328-1 grade 9 gears, assuming quality is controlled by helix, profile, pitch tolerances and tooth thickness, defined by dimension over balls or pins. An alternative specification using ISO 3128-2 for dual-flank testing measurement strategy is illustrated in Figure 5.

In conclusion, the specification of gears requires a detailed knowledge of gear geometry, manufacturing methods, inspection methods, material and the functional requirements of the application. Every gear designer has his or her own preferred method, but asking the right questions, using the appropriate standards and support software ensures it is possible to specify gears reliably.

**Dr. Rob Frazer** *is a senior engineer at the Design Unit, the Gear Technology Centre at Newcastle University in the U.K. Frazer is head of the U.K.'s National Gear Metrology Laboratory and is responsible for gear design and gear analysis within the Unit. He also serves as chair of BSI MCE-5, the U.K. committee responsible for over 90 gear-related standards and is the U.K. representative on the ISO Gear Accuracy Committee (ISO TC60 WG2). Frazer is actively involved in delivering the British Gear Association's training seminar program in the U.K.*

| GEARDATA | |
|---|---|
| **Basic Geometry** | |
| Number of teeth | 40 |
| Normal module | 0.800 |
| Reference pressure angle | 20.000 |
| Ref.helix angle (left) | 0.000 |
| Addendum Mod. coefficient | 0.0000 |
| Nominal tooth depth/Mn | 2.400 |
| **Reference Data** | |
| Facewidth | 5.000 |
| Tip Diameter | 33.600 |
| Root Diameter | 29.760 |
| Topping | |
| Base helix angle | 0.000 |
| Reference Diameter | 32.000 |
| Base Diameter | 30.070 |
| **Finished Tooth Thickness** | |
| Ball Diameter | 1.440 |
| Dimension over balls (nom) | 34.022 |
| Dimension over balls (max) | 34.022 |
| Dimension over balls (min) | 33.943 |
| **Flank Tolerances** | |
| Reference axis | datum bore A |
| Accuracy Standard | ISO 1328-1/95 |
| Grade | 9 |
| Adjacent pitch tol | 20 µm |
| Cumulative pitch tol | 57 µm |
| Profile tol | 21 µm |
| Helix tol | 25 µm |
| Tool tip radius | 0.312 |
| **Meshing Information** | |
| Mating gear | |
| Centre distance nominal | 32.000 |
| Start of active profile dia | 30.851 |
| Contact ratio | 1.714 |
| Normal backlash max | 0.160 |
| Normal backlash min | 0.100 |
| **Material & Heat Treatment** | |
| Through Hardened (V) | |
| Surface hardness | 200 Hv |
| Angles are in ° and distances in mm unless otherwise stated | |

Figure 4 Example gear specification for ISO 1328-1 accuracy gears.

| GEARDATA | |
|---|---|
| **Basic Geometry** | |
| Number of teeth | 40 |
| Normal module | 0.800 |
| Reference pressure angle | 20.000 |
| Ref.helix angle (left) | 0.000 |
| Addendum Mod. coefficient | 0.0000 |
| Nominal tooth depth/Mn | 2.400 |
| **Reference Data** | |
| Facewidth | 5.000 |
| Tip Diameter | 33.600 |
| Root Diameter | 29.760 |
| Topping | |
| Base helix angle | 0.000 |
| Reference Diameter | 32.000 |
| Base Diameter | 30.070 |
| **Finished Tooth Thickness** | |
| Ball Diameter | 1.440 |
| Dimension over balls (nom) | 34.022 |
| Dimension over balls (max) | 34.022 |
| Dimension over balls (min) | 33.943 |
| **Flank Tolerances** | |
| Reference axis | datum bore A |
| Accuracy Standard | ISO 1328-2/97 |
| Grade | 9 |
| Single composite tol | 11 µm |
| Total composite tol | 56 µm |
| Tool tip radius | 0.312 |
| **Meshing Information** | |
| Mating gear | |
| Centre distance nominal | 32.000 |
| Start of active profile dia | 30.851 |
| Contact ratio | 1.714 |
| Normal backlash max | 0.160 |
| Normal backlash min | 0.100 |
| **Material & Heat Treatment** | |
| Through Hardened (V) | |
| Surface hardness | 200 Hv |
| Angles are in ° and distances in mm unless otherwise stated | |

Figure 5 Example gear specification for ISO 1328-2 accuracy gears.