Got a Gear Question?

Ask the Expert!

Welcome back to *Gear Technology*'s Ask the Expert—a 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 e-mail your question—along with your name, job title and company name (if you wish to remain anonymous, no problem)—to: *jmcguinn@geartechnology.com;* or, you can submit your question by visiting *geartechnology.com*.

QUESTION #1

Runout and Helix Accuracy

Regarding inspection: Why does DIN 3962 specify F beta tolerances, taking into consideration only the gear face width? Should not consideration also be given to the influence of gear diameter due to the runout?

Durval Baroca, gear process specialist
ZF do Brasil

Dear Durval,

All standards for accuracy of gears, such as DIN 3962, ISO 1328 and AGMA 2015, provide a series of classes, or grades, that assign different levels of tolerances for aspects of gear quality. These relate to analytical parameters such as involute, helix (or lead), pitch variation, accumulated pitch variation and runout.

These different levels of tolerance have been developed over time, by experience gained with different manufacturing methods such as cutting, shaving and grinding. Function in final applications has also been considered.

You mention *F* beta, which is the symbol for helix. You are indeed correct in recognizing that runout (F_r) has an influence on helix accuracy. However, it doesn't matter what causes the error; the only concern is that it doesn't exceed the tolerance—regardless of cause. The design engineer presumably determined which level of accuracy would meet his requirements for transmission error or functional life, and picked an appropriate accuracy grade.

When looking at the analytical gear inspection charts, the shape of the traces for helix—as well as the amplitude—can be very informative as a diagnostic tool. Typically, four teeth—approximately 90° apart—are inspected on both sides.

If all of the traces have a slope error and are parallel, your problem is from the cutting or grinding machine set-up.

Table 3. Test Gear Quality (without eccentricity)
(Variations in .0001 inch)

	Left flank	Right flank
Runout Variation	0.8	
Profile Variation between 10 and 40° roll angle	-0.3 to -1.1	-0.2 to -1.0
Total Index Variation	1.5	1.0
Maximum Pitch Variation	0.7	0.5
Tooth Alignment (Lead) Variation over 3.5 inch face width	-1.8 to -3.3	-3.8 to -4.3

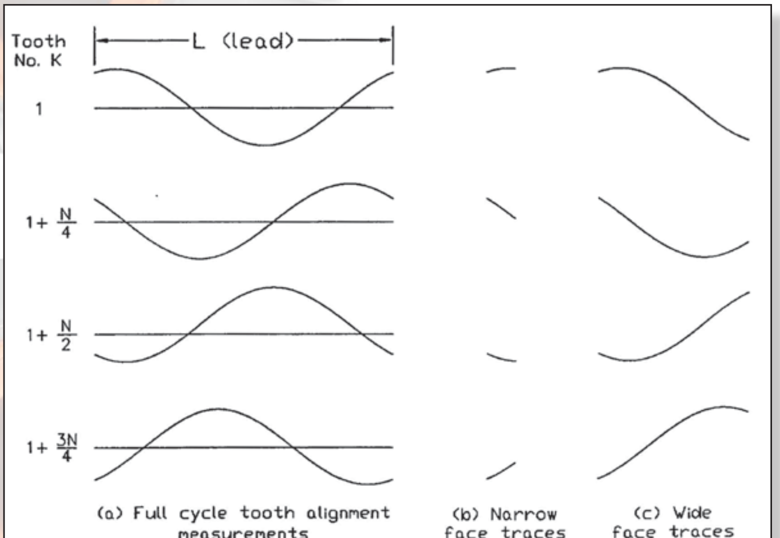

Figure 13: Tooth Alignment Measurements

If they all vary in slope direction from one trace to another, the problem is probably from runout.

An AGMA technical paper (93FTM6), "Effect of Radial Runout on Element Measurements," by Irvin Laskin, Robert Smith and Edward Lawson, explains this in detail (available at *www.agma.org*). To illustrate the effects, a gear was made of master gear quality ("Table 3"). It also was made with a 3½-inch-long face width in order to show the resulting sinusoidal-type helix traces when .0034" run-out was introduced in the inspection. Continuing with the same referenced paper, "Figure 13" shows the theoretical result and "Figure 14" shows the actual, measured results. "Figure 13" also shows what the tooth alignment would look like if it had a narrow face width; only short pieces of the sinusoidal wave would show, looking like typical helix error—but at different angles for each tooth.

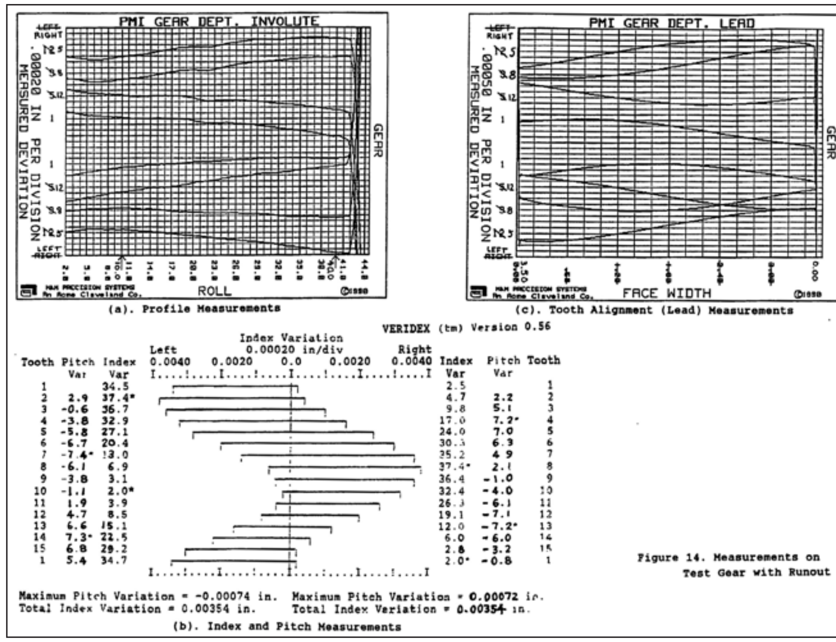

Figure 14. Measurements on Test Gear with Runout

This gear, as checked with runout of 88.9 micrometers, would meet a DIN Class 11. The tolerance for helix for this DIN Class–11 gear would be 100 micrometers; the measured maximum *F* beta equals 73.6 micrometers.

In conclusion, it only matters whether the traces fall within the allowable limit for any prescribed grade or class. Looking at the characteristic of the traces can be useful when determining what to fix in bringing the gear within tolerance.

The above remarks also apply to involute traces that are either parallel or have varying slopes.

Best regards,

Robert E. Smith

Robert Smith is a *Gear Technology* technical editor and gear industry consultant (*gearman@resmith.com; www.resmithcoinc.com*), and is an active member of AGMA's Gear Accuracy and Calibration committees.

QUESTION #2

Maximum Number of Teeth in a Shaper Cutter

How can I determine the maximum number of teeth in a shaper cutter to avoid trimming or rub on up-stroke when cutting an internal gear?

Marv Snider, senior manufacturing engineer
Allison Transmission

Dear Marv,

The easy answer is to direct you to Table 12 in my book, *An Introduction to Gear Design* (available for free download at my website, *www.beytagear.com*). This chart (reprinted here) was developed using the method described in professor Earle Buckingham's landmark book, *Manual for Gear Design*, Section 2—"Spur and Internal Gears" (The Industrial Press, copyright 1935; copyright renewed 1962; reprinted 1981). On pages 40–43, Buckingham describes those places where interference or trimming can occur and presents mathematical methods for determining whether or not they occur for a given cutter and gear combination. Unfortunately, many manufacturing engineers are not familiar with Buckingham's book, or are unable to obtain a copy of it. Check online book sellers for a used copy.

Guidance may also be available from your cutter supplier or machine builder. I developed Table 12 *(page 46)* to avoid having to perform the calculations frequently and to aid in the design of parts that are manufacturing-friendly. It helps avoid tooth numbers that require special cutters.

Best regards,

Charles D. Schultz, PE

Charles Schultz is a *Gear Technology* technical editor and gear industry consultant (*chuck@beytagear.com*; *www.beytagear.com),* and is an active member of AGMA's Helical Gear Rating, Epicyclic Enclosed Drives and Wind Turbine Gear committees.

continued

ASK THE EXPERT

Table 12
Shaper Cutter Teeth vs.
Minimum Internal Gear Teeth
to Avoid Interference

# teeth (Nc) in cutter	# teeth in internal gear (Ng) 14.5° FD	20°FD	20°Stub	25°FD	30° FF	30° FR
3	15	11	11	10	9	9
4	18	13	13	12	12	10
5	20	15	15	14	13	11
6	22	17	16	15	14	12
7	24	19	17	17	16	13
8	26	21	18	19	17	14
9	28	23	20	21	18	15
10	30	24	22	22	19	16
11	32	26	23	23	20	17
12	34	27	24	24	21	18
13	36	29	25	25	22	19
14	38	31	26	26	23	20
15	39	33	27	27	24	21
16	41	34	28	28	25	22
18	44	36	30	30	27	24
20	47	38	32	32	29	26
21	49	39	33	33	30	27
24	54	42	36	36	33	30
25	55	43	37	37	34	31
27	58	45	39	39	36	33
28	59	46	40	40	37	34
30	62	48	42	42	39	36
over 30	Nc +32	Nc + 18	Nc + 12	Nc + 12	Nc + 9	Nc + 6

Note: Small shank cutters (Nc<10) do not produce a true involute form.

CLARIFICATION

In the May *Gear Technology* Ask the Expert feature, we failed to mention that Robert Wasilewski, design engineering manager at Arrow Gear Company and one of our valued Experts, also serves as current chairman of the AGMA Bevel Gearing Committee. *Gear Technology* regrets the omission.

Do you have a **GEAR-RELATED QUESTION?**

Send it to Jack McGuinn, senior editor, at *jmcguinn@geartechnology.com*, or visit ***www.geartechnology.com*** to post your question via our online form.