# Determining Lead Error on A Crowned Pinion

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*Question submitted by Daniel Braasch*
*Frisby P.M.C., Inc.*
*Elk Grove Village, IL*

**Q:** How do you determine lead error on a crowned pinion when using analog gear checking equipment like a Höfler EFR630 ?

*Answer submitted by Robert E. Smith*
*President, R.E. Smith & Co., Inc., Rochester, NY, and Technical Editor,* Gear Technology *magazine.*

**A:** It is assumed that the EFR630 is not equipped with a computer for data analysis, and that all analysis is done manually. Also, how one analyzes the chart depends upon the accuracy system being used, such as AGMA, ISO, DIN, in house, etc. Each system has its own rules.

In the AGMA system, such as AGMA 2000-A88, "K" charts are used. The intention, in AGMA, is that the crown has to be evaluated in addition to the lead variation tolerance (the crown is not part of the lead or tooth alignment tolerance). Clause 9.5 in AGMA 2000-A88 discusses the "K" chart evaluation of unmodified gear teeth. Appendix C and Figure C-6 (Figure 1 in this article) attempt to show how crown is evaluated in addition to tooth alignment variation. However, it turns out to be confusing and doesn't clearly achieve the desired results. Note that the "functional face" is the face width minus any chamfer or rounding on the ends of the teeth.

In the author's opinion, DIN and ISO do a better job of evaluating crown and helix error. They both use a slope and form evaluation method. DIN 3960 says that the entire face width is used as the tooth trace test range, $L_\beta$. Common sense, however, says not to include any end chamfers, or rounding. DIN 3961 mentions reducing the face width by 10% at each end before evaluation. ISO 1328 Part 1 - 1995, uses the same methods of evaluation, but is more realistic in regard to the evaluation

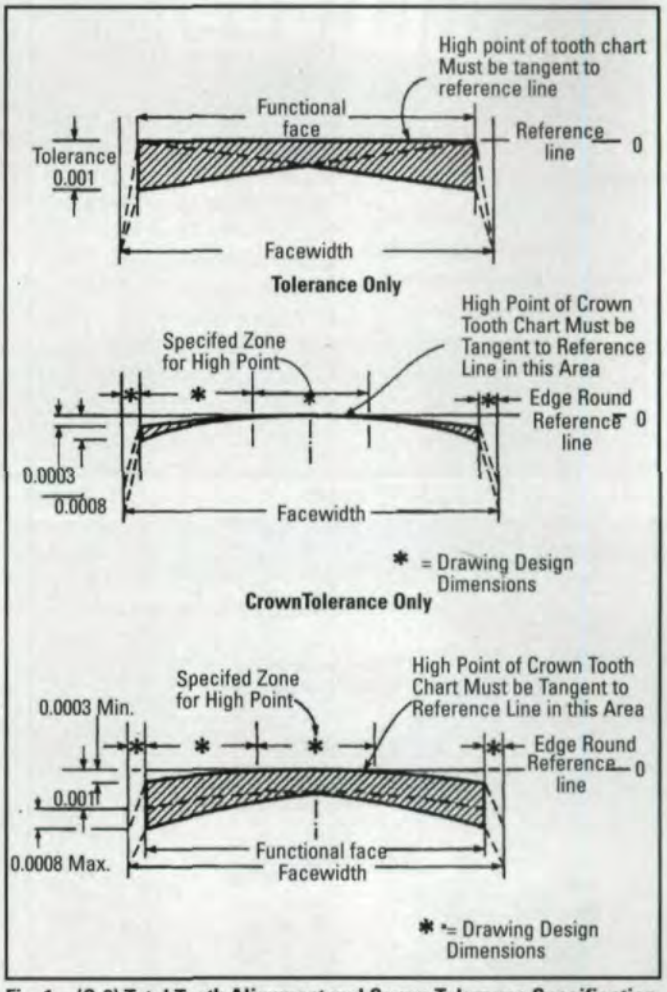



**Fig. 1—(C-6) Total Tooth Alignment and Crown Tolerance Specification.**

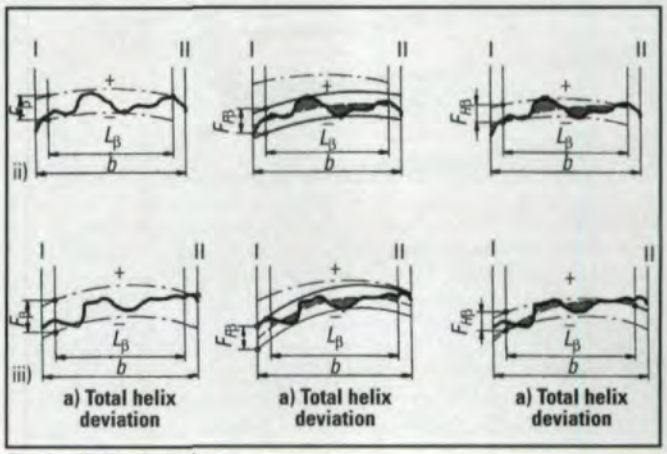
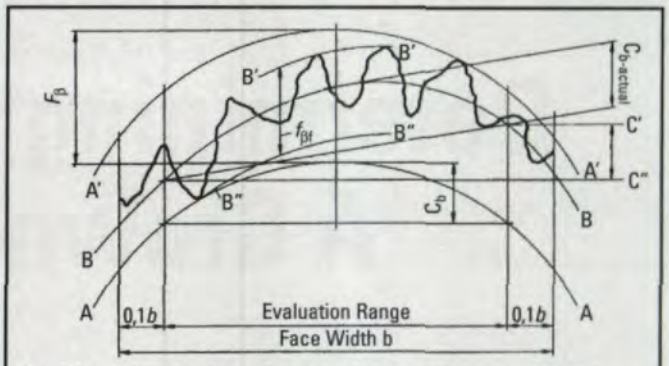



**Fig. 2—Helix deviations.**




| | |
|---|---|
| AA, A'A' | Corrected base lines bounding the test pattern within the evaluation range. |
| BB | Averaging actual tooth flank. |
| B'B', B"B" | Actual tooth traces bounding the test pattern within the evaluation range. |
| C'C', C"C" | Non-corrected nominal tooth traces through the points of intersection of the averaging actual tooth trace BB with the boundary lines of the evaluation range. |
| $F_i$ | Tooth trace total deviation; results from the distance apart of the corrected base lines AA and A'A' as measured at right angles to the chart feed. |
| $f_{Hi}$ | Tooth trace angle deviation; results from the distance apart of the nominal tooth traces C'C' and C"C". |
| $f_{fi}$ | Tooth trace form deviation; results from the distance apart of the actual tooth traces B'B' and B"B" as measured at right angles to the chart feed. |
| $C_b$ | Nominal crowning |
| $C_{b\text{-actual}}$ | Actual crowning |

**Fig. 3—Tooth trace test pattern for narrowed tooth trace test range.**

range, $L_\beta$. In ISO 1328, the evaluation range is specified as the face width minus 5% or a length equal to one module, whichever is smaller, at each end.

When using a computer analysis system, the evaluation is automatic. ISO fits a "design" curve (that is the crown shape) to the trace and then evaluates form and slope errors relative to that (Figure 2). When using an analog recording system, the evaluation is done manually. DIN 3961, Figure 3, demonstrates a method of manually evaluating crown, form, and helix error separately, showing an exaggerated amount of waviness in the tooth trace. This is to illustrate the various parameters: crown, form, and helix error. To do a manual analysis, draw lines near the end of the trace that represent the evaluation length, $L_\beta$, then fit a curved line through the mean of the waviness that is superimposed on the crown curve. Form error is the bandwidth of the waviness (shown as $f_{\beta f}$ in the figure). Slope is the helix error (shown as $f_{H\beta}$ in the figure). Crown is $C_{b\text{-actual}}$ in the figure. This may not be as precise as computer analysis, but it can still be very accurate and useful. Certainly, it is much better than using a modified "K" chart.

Of course, crown should have minimum and maximum values specified, in addition to the lead or helix tolerance. ○

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