Reader Dialogue: Functional Measurement of Gears; More Good Gear Books

Robert E. Smith
Robert Errichello

From time to time, the editors of "Shop Floor" receive correspondence from readers relating to particular articles they have written for past issues. As one of the purposes of this column is to provide a forum for the exchange of ideas, we reproduce here two of these letters and their replies. The subject of the first is the functional measurement of gears. (See *Gear Technology*, Sept/Oct, 1991, p. 17.) Robert E. Smith writes the reply.

From: Dr. Awny Y. Attia, Professor of Machine Design, Ain Shams University, Cairo, Egypt.

...I believe that the aim of functional measurement is to determine the deviations from uniformity of motion between two gears in action as they run and function. From the design point of view, besides running accuracy, functional errors are used to determine the maximum momentary tooth load when running at speed. They are the instantaneous deviation from correct relative angular displacement and are usually specified as a percent of the gear ratio. The value of the functional error is that it changes according to the changes in many factors, such as resultant manufacturing errors, errors in assembly, and eccentricities in bearings. Under load, more functional errors, caused by teeth deflections and torsional deflections of shafts and gear bodies, are added. When running at speed, more functional errors are added, generated from the dynamic increase in tooth load, inertia of the gears, and attached masses and vibrations of the geared system.

In my opinion, there is no fixed value for the functional error in a pair of gears in mesh, as this value is changing according to this multitude of factors. This has been proven to me in many investigations where the functional errors were measured by photocells. Elemental and roll measurements do not give any indication of errors in functioning, but are very useful as a fast check on dimensional tolerances and the fulfillment of the product according to certain standard specifications.

I remember that in a gear firm, I picked some gears that had been rejected for having pitch errors exceeding the limits of tolerances, and I assembled them in pairs, those having positive errors with those having negative errors. Functional measurements of these pairs sometimes gave more accurate running than that of unrejected gear pairs. I am trying to design a set up for functional measurement of gears based on assembled metrology, hoping to give values of functional errors of any pair of gears in mesh in geared systems.

Bob Smith replies: Professor Attia is just taking what I said a step further to the measurement of assembled gears. In the Sept/Oct column, I was mainly

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talking about the functional measurement of unassembled gears at the time of manufacture. The AGMA and ISO quality standards are written for unassembled gears.

When gear pairs are run in their actual assemblies, other factors do add to the functional characteristics. As Professor Attia points out, it is possible to put two gears together, each of which is out of elemental tolerance, and have them function perfectly well. For example: two gears can have excessive "positive tip" profile errors, but they will run together quietly. I have seen this happen many times. The profile errors complement each other in such a way that the gear "pair" is conjugate. They just happen to end up with a different pressure angle than specified. If the gear "pair" was measured by single flank methods, it would show good functional characteristics. If the gears were assembled in a gear box with relatively light loads, as many applications are, they would run just fine. If the application has loads such that the teeth deflect considerably, they would not run as well.

However, single flank transmission error measuring instruments can be applied to loaded gear boxes also. As Professor J.D. Smith of Cambridge University commented in the Nov/Dec issue, (See *Gear Technology*, Nov/Dec, 1991, "Viewpoint," p. 9) tests can and have been run at operating loads and speeds. This takes into account gear and housing errors and deflections, as well as dynamic conditions (vibration). Single Flank transmission error measuring instruments already exist that can do this.

The second letter, regarding Top Ten Books for Gear Engineers," comes from **Dr. George W. Michalec, consulting engineer of Pleasantville, NY.**

Dr. Michaelic writes: I read with interest your article, "The Top Ten Books for Gear Engineers," in the current issue (May/June, 1992) of Gear

Technology. The coverage is both wide and in good detail. It should be helpful for many engineers.

A disappointment is that my book, *Precision Gearing, Theory and Practice,* published by Wiley in 1966, did not make the top ten. I assume you are familiar with it. Although it is now "old" I still encounter engineers who asked for it. Unfortunately, after three printings, Wiley has ceased publication, and it has been out of print since 1989. About ten years ago it was printed in China, both in English and Chinese. Thirty thousand of the latter were printed and sold out. Pleasingly, I was presented with a copy.

One of the main thrusts of this gear book is identification and handling of gear errors using statistical probabilistic techniques. An intent of the book was to teach engineers statistical mathematics applied to gearing. Some of the

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statistics present in Chapter 5, "Gear Train Performance and Error Analysis," are original. To my knowledge, the treatment of gear errors and their sources is unique, and I have not seen the equivalent in any other gear book.

I write this information with the hope that it is of interest. Also, that should you in the future choose an eleventh book, you would consider it.

Bob Errichello replies: Of course I am familiar with Dr. Michalec's excellent book. After arbitrarily deciding to limit the number of books to ten, I was faced with the unhappy task of eliminating certain useful texts.

Although the book is a treatise on statistical analysis of gear errors, I felt that the *Gear Handbook* and *Gears for Small Mechanisms* gave adequate treatment to the subject, while covering many other issues of concern to readers. With these considerations in mind and to remain within the scope of the article, I reluctantly dropped Dr. Michalec's book from the list. ■

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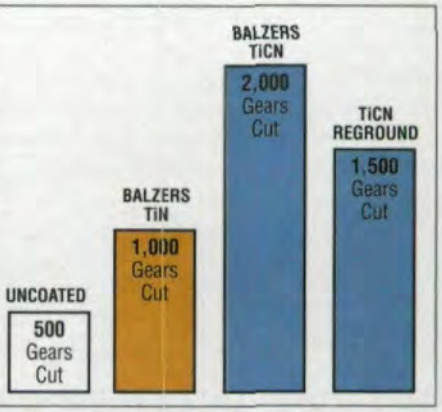

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