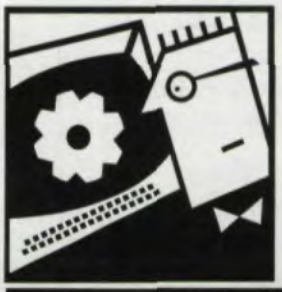
Single Flank Measuring; Estimating Horsepower Capacity

Robert E. Smith and Robert Errichello



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Address your gearing question to our panel of experts. Write to them care of Shop Floor, Gear Technology, P.O. Box 1426, Elk Grove Village, IL 60009, or call our editorial staff at (708) 437-6604.

Question: What is functional measurement and what is the best method for getting truthful answers?

The main function of gearing is to transmit uniform rotary motion and power from one shaft to another at the design ratio of the gears. If the gears do not do this, they are said to have transmission error. Therefore, a true functional measurement of gear quality would be one that evaluates errors or variations in terms of uniformity of angular motion. This would be a tangential rather than a radial measurement.

Gear quality measurement is done by either elemental or composite methods. The resulting values are compared to the customer's specification or to some national standard for compliance. Any method used has its advantages and disadvantages.

Elemental. Elemental measurements are made of discrete variations of gear characteristics, such as pitch, runout, involute, tooth alignment (lead), and tooth thickness. These measurements are typically made by a probe or stylus device that explores part of a tooth or gear.

Composite (Functional). Composite measurements are made by running two gears together (usually one is a master gear) in a manner that simulates unloaded operating conditions. The resulting measurements are a function of a composite of the elemental variations described above.

The advantage of elemental measurement is in diagnostics. Because one is measuring discrete characteristics, it is possible to sort out various causes of any problem.

The elemental method has three disadvantages. The first is that the probe cannot explore all parts of a tooth surface, nor all the teeth; therefore, some errors might be missed. The second is

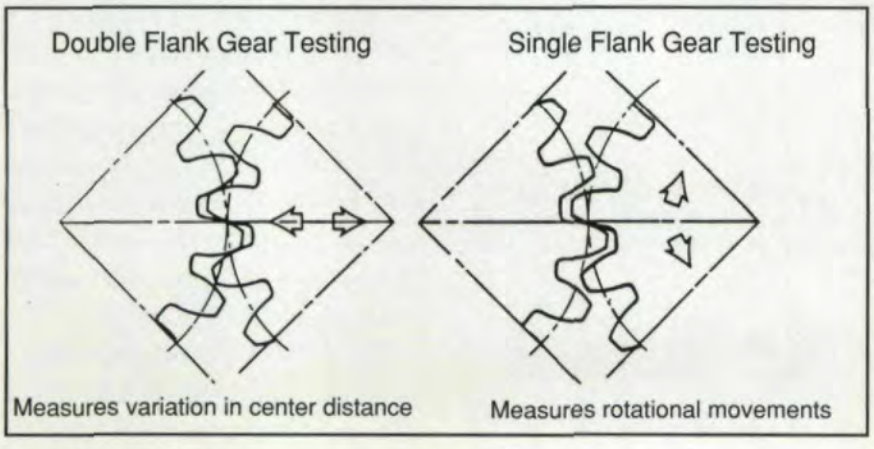

Fig. 1 - Composite gear testing.

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Table 1 - Comparison of Single & Double Flank Testing Methods

Double Flank Composite (See Fig. 2)

Advantages:

- Inexpensive equipment
- The best way to measure functional tooth thickness
- Good way to measure rough hobbed parts that are to be finished by a subsequent operation
- Fast
- Durable

Disadvantages:

- Not truly functional (radial measurement)
- Contacts both sides of teeth (not good for diagnosing involute problems)
- Doesn't measure accumulated pitch variation (a functional characteristic)
- Not good for noise control

Single Flank Composite (See Fig. 3)

Advantages

- Truly functional measurement (tangential)
- Good for positional accuracy (accumulated pitch variation)
- Good for measuring involute effects
- Good for noise control

Disadvantages:

- Relatively slow
- Equipment is more expensive and delicate

that keeping track mentally of all these discrete measurements to determine what the functional result will be is very difficult. The third drawback of using elemental gear measurement lies with the AGMA standards (AGMA 2000 A-88 and AGMA 390.03a). These standards are tolerances for runout and not accumulated pitch variation. Accumulated pitch variation is a more functional measurement than runout. (See "Shop Floor," Jan/Feb, 1991, *Gear Technology*.) Also, AGMA 2000 A-88 uses a "K" chart evaluation of involute variations. This method isn't necessarily a good control of profile variations for noise problems.

The subject of composite measurement is more complex. To begin with, there are two types of composite measurement: *double flank* and

single flank (transmission error). Unfortunately, the double flank method has been so common in the past that the term "composite measurement" has become almost generic to it.

It is important to understand the difference between these two methods. Perhaps if more people understood the advantages of single flank composite measurement from a functional standpoint, it wouldn't be so rare.

For a comparison, see Fig. 1 and Table 1. Both sides of the meshing teeth are in contact for the double flank method. Only one side is in contact for the single flank method. The important differences are:

1. The double flank method measures variation in center distance, while the single flank method measures variation in rotational movements.

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2. Most gears never run with both sides of the teeth in simultaneous contact. Therefore, single flank is the truly functional method.

Question: If single flank measurement is so much better than double flank, why isn't it used more?

In the past, the technology for single flank testing wasn't readily available. Double flank equipment was simple, inexpensive, and fast, and it's human nature to prefer the easy approach. Single flank testing equipment is a newer technology and is more expensive. Also, tolerances for single flank results do not appear in the AGMA standards.

However, I have used single flank measuring instruments for the manufacture of highly accurate and smooth gears since 1955. It is still one of the first and most important tools in my consulting practice.

The use of this equipment has been more common in foreign countries. Probably no more than 25 systems are in use in the U.S., compared to well over 200 systems elsewhere; yet there are more than 300 company members of AGMA. Almost all of the existing equipment was developed and manufactured in Europe. One such instrument is made in Japan. Another system, developed in England, is now manufactured by an American company. Millions of gears are made every year by the American automotive manufacturers, and most of them are checked by double flank measuring equipment. Could this be another reason for the decline of the American gear industry?

Some types of gears are difficult to measure with any validity by elemental or double flank techniques. Enveloping worm wheels and bevel gears are among these. Much of the testing is done subjectively by the use of contact patterns. Single flank testing procedures allow quantitative measurement of the functional characteristics of these gear types. Single flank testing can be done on assembled gear trains as well as on loose gears. It is very useful for gears used in printing presses, noise sensitive products, index mechanisms, robots, antenna directors, etc.

The fact that single flank testing is slower than double flank is no longer a valid reason for not using it. With the introduction of statistical techniques, such as SPC, in the American automotive and other industies, the single flank method can be used to test small samples on a regular basis. The trend is to get away from 100% inspection, such as is usually done with double flank measurement.

Question: Isn't it time that the American gear industry gave serious thought to the use of single flank gear testing equipment?

Yes!!!

To address questions to Mr. Robert E. Smith, circle Reader Service No. 78.

Question: We have reconstructed a triple reduction parallel axis gearbox which is driven by a 200 horsepower electric motor. It is used to drive a large screw used in waste processing. We have all of the geometrical data on all three gear sets, teeth, DP, PA, helix angle, face width, center distance, etc. We know the gear materials, which are case car-

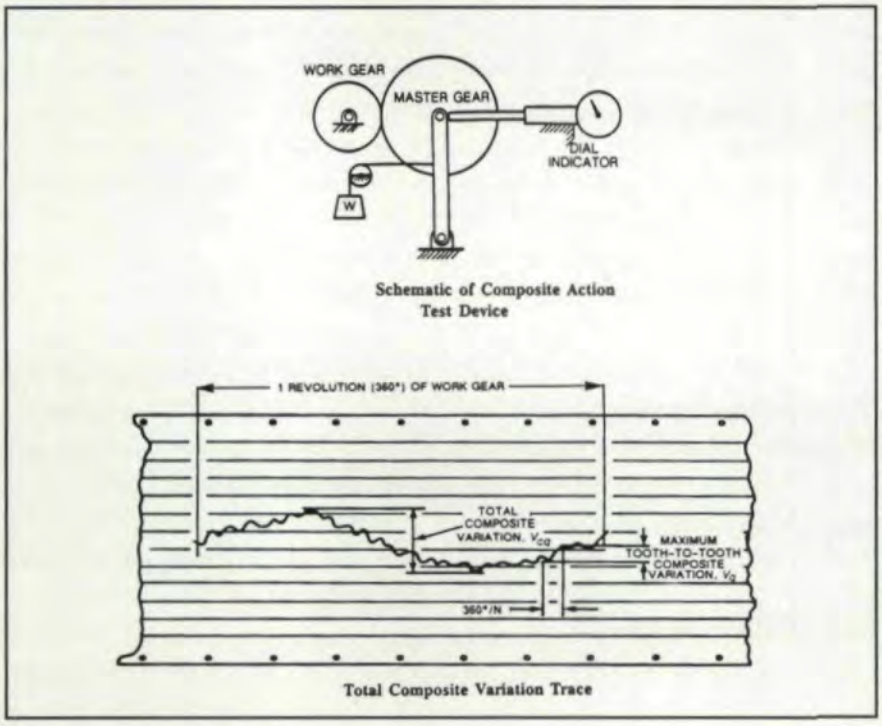
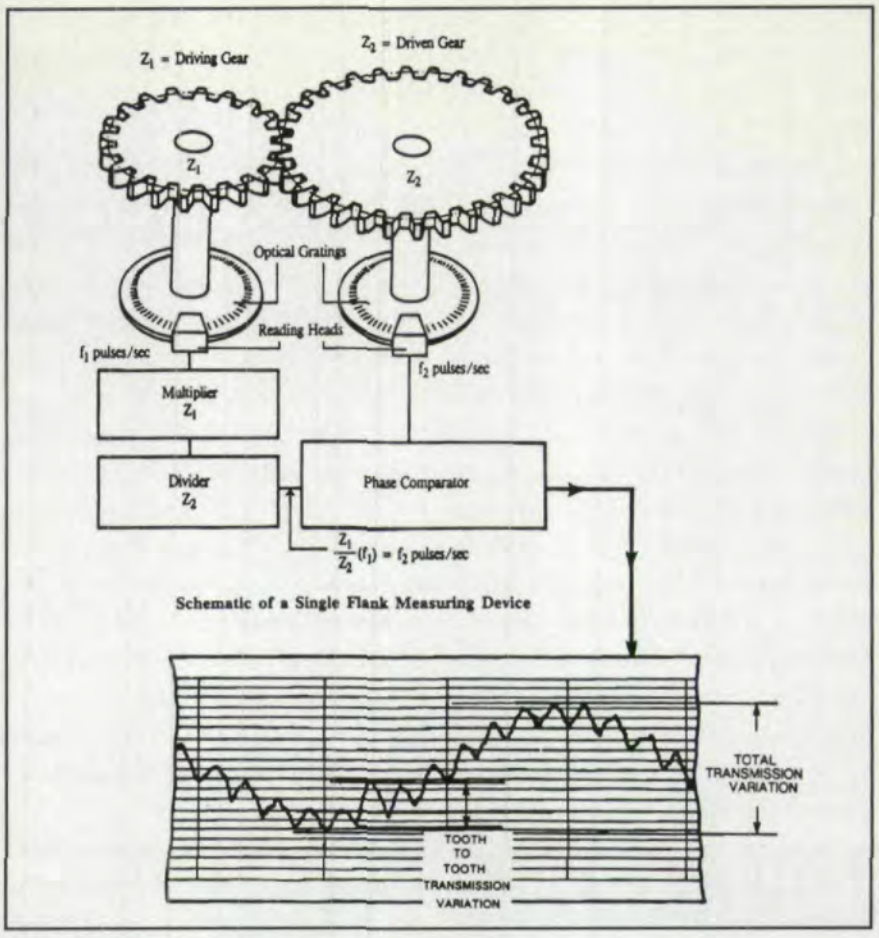


Fig. 2 - Double flank composite action measurement.



Schematic of a Single Flank Measuring Device

Fig. 3 - Single flank composite action measurement.

burized, and the gears are made to AGMA Q-9 accuracy levels. The input speed is known, and the gears operate under a lubrication system. Is it possible to predict or estimate the horsepower capacity and running hours that can be expected from this box? If so, how?

Parallel-axis gear sets can be rated using the methods described in ANSI/AGMA 2001-B88, American National Standard, "Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth," and AGMA 6010-E88, American National Standard, "Standard for Spur, Helical, Herringbone, and Bevel Enclosed Drives." These standards give equations for calculating the power capacity of gear sets based on pitting resistance and bending strength. Also, ANSI/AGMA 2001-B88, Appendix A, gives methods for evaluating the risk of scuffing and wear. In addition to the data you mentioned, you will need the geometry of the tools used to cut the gears in order to calculate the bending strength geometry factors.

The purpose of the standards is to provide common methods for rating gears for differing applications, and to encourage uniformity and consistency between rating practices within the gear industry. Although most of the calculations are straightforward, some of the factors in the equations vary significantly, depending on the application, system effects, gear accuracy, and manufacturing practice. The engineering judgment of an experienced gear designer is required to properly evaluate these factors and obtain realistic ratings.

Software is available for personal computers that automates much of the gear rating task. ■

If you have questions for Mr. Robert Errichello, circle Reader Service No. 79.