

AN 'ELEMENTARY' GUIDE TO GEAR INSPECTION



IN ADDITION TO CHECKING PART SIZE AND QUALITY, GEAR INSPECTION PROVIDES INSIGHTS INTO THE MANUFACTURING PROCESS ITSELF, INSURING THAT YOUR OWN PROCEDURES ARE PROPERLY CONTROLLED.

By Dennis Gimpert

Gear inspection begins with the everyday tasks on the shop floor and extends into the manufacturing laboratory for complex analytical gear evaluation. Some, or all, of these procedures are necessary to maintain process control and to produce parts to the required quality. In particular, inspection can help control the following:

- Size of the gear
- Quality of the gear
- Fixture mounting on the machine
- Machine set-up
- Part blank quality
- Accuracy of the cutting tool
- Mounting of the cutting tool
- Correct sharpening of the cutting tool
- Heat treat process
- Condition of the production equipment

The following information summarizes the basic elements of gear inspection beginning with the most simple and leading to the more complex.

Size Inspection

The traditional method of inspecting a gear for correct size is the measurement over pins or balls with a micrometer. Pin measurement provides an accurate and convenient method of determining tooth thickness of a gear of any diameter within the capacity of the available micrometers. For larger diameter gears a span measurement or gear tooth calipers can be used. Composite testing can also provide a measurement of gear tooth size. Size measurement is used to provide the correct backlash when the gear is mounted with its mating gear at operating center distance.

Runout Inspection

Runout is the maximum variation of the distance between a surface of revolution and a datum surface, measured perpendicular to that datum surface. Runout of a gear can be measured with a dial indicator over a pin or ball placed in successive tooth spaces. On modern CNC gear measuring machines this inspection can be provided in a fully automatic cycle. Runout measurement is used to assure correct backlash and minimum variation of rotary motion.

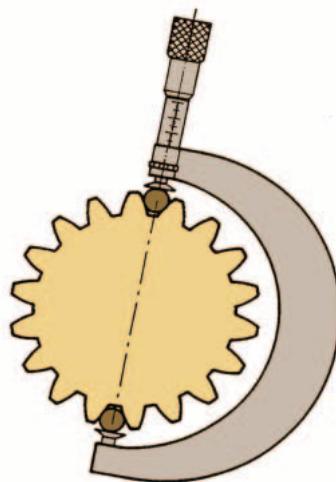


FIGURE 1 — Measurement of size with micrometer and pins or balls.

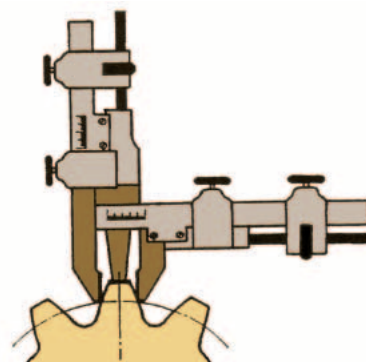


FIGURE 2 — Measurement of size with tooth caliper.

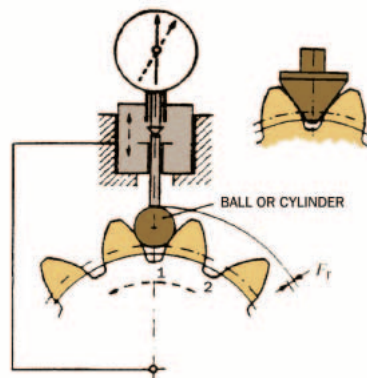


FIGURE 3 — Runout inspection with ball, pin, or anvil.

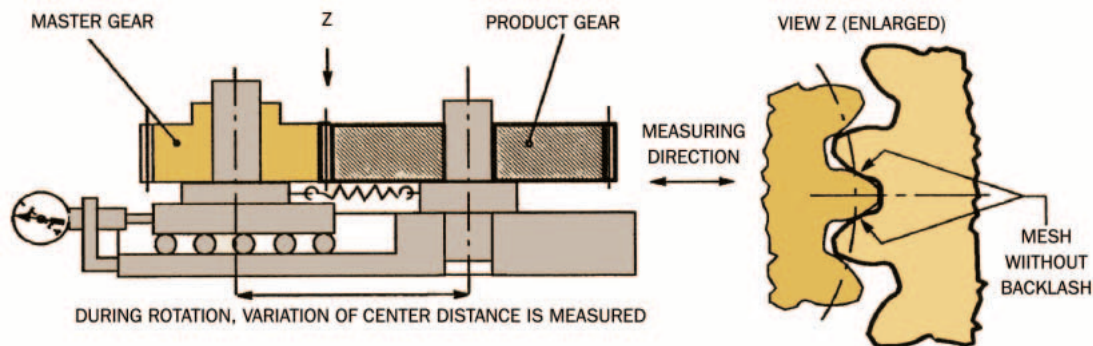


FIGURE 4 — Schematic concept of gear rolling device.

Composite Inspection

The composite test of a gear is a method of inspection in which the work gear is rolled in tight double flank contact with a master gear. AGMA defines this type of inspection as "radial composite deviation." No backlash is provided, as the work gear is spring-loaded against the reference gear on the inspection machine. The composite action test is made on an inspection instrument that

will allow variation in the center distance during rolling. This variation in center distance will yield a "tooth-to-tooth" and a "total composite" indication that can be read on a simple dial indicator or recorded graphically.

Composite inspection is a useful shop-friendly tool to determine the general quality of a gear including size, runout, tooth-to-tooth rolling action, and to detect nicks. It is not an appropriate method to determine individual tooth flank errors.

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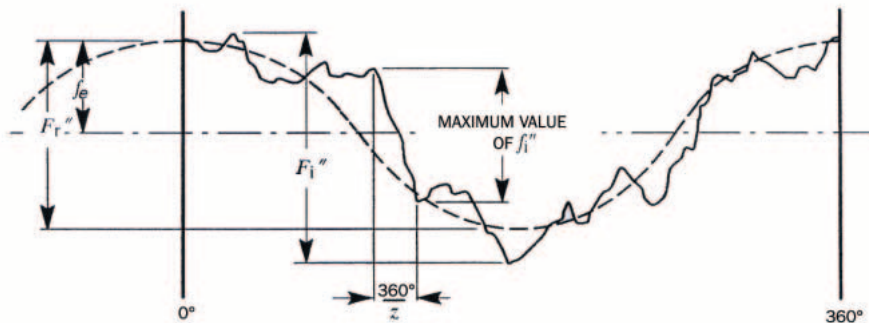


FIGURE 5 — Graphical record from composite inspection.

Profile Inspection

Profile is the shape of the gear tooth curve and is measured from the root to the tip of the gear tooth. The functional, or operating, portion of the profile is the area that is in actual contact during tooth mesh. Typically, this area is from just above the root fillet to the tip of the tooth. On most parallel axis gears, the shape of the profile curve is an involute. In practice, an appropriate measuring machine aligns the

measuring probe on the test gear in the middle of the gear face. Most gear measuring machines use the generative principle to create a reference profile to compare to the gear's actual profile. The profile is traced and recorded graphically, with a correct unmodified profile being represented as a straight line on the chart.

Incorrect profile will cause a non-uniform rolling action of the gear, which may cause a large tooth-to-tooth error, uneven loading, and noise problems. In extreme cases, premature gear failure may occur.

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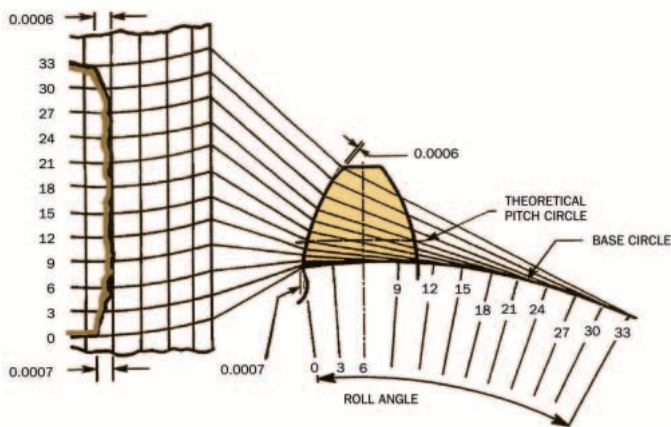


FIGURE 6 — Profile inspection with degrees of roll, roll angle.

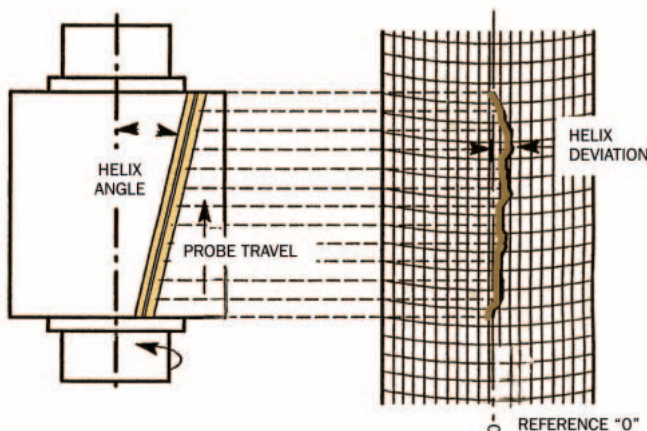


FIGURE 7 — Graphic charting of helix deviation.

Helix Inspection

AGMA's current inspection handbook defines "helix deviation" (formerly tooth alignment variation and lead variation) as the difference between the measured helices to the design helices. In practice an appropriate measuring machine aligns the measuring probe on the test gear at the pitch circle diameter and the "lead" is traced and recorded graphically, with a correct unmodified helix being represented as a straight line on the chart. Helix measurement is used to determine correct face contact between mating gears. Incorrect helix will create uneven loading and noise.

Pitch or Index Inspection

Spacing is the theoretical true position of each tooth around the circumference of the gear. Pitch deviation is the difference between the theoretical position and the actual position of each tooth. These values can be plus or minus. Index variation is the displacement of any tooth from its theoretical position relative to a datum tooth.

Total pitch variation and total index variation are identical values and are generally referred to as "accumulated spacing." Total index variation is the maximum algebraic difference between the extreme values of index variation.

Two distinct methods are available to arrive at tooth "spacing." One utilizes a single-probe measuring device with a precision indexing system. This indexing system can be electronic, as on a CNC measuring machine, with an encoder-controlled rotary axis. It can also use mechanical devices such as index plates, circular divider, or optical scales. The second system utilizes two probes to obtain successive data from adjacent tooth flanks as the gear is rotated. The data obtained from the two-probe system must be mathematically corrected to obtain spacing values. It is recognized today that the single probe system is the most accurate and the preferred system.

"THE AGMA STANDARDS REFERENCED IN THIS PAPER ARE PRESENTLY THE MOST ADVANCED GEAR SPECIFICATIONS AVAILABLE IN THE WORLD."

Index measurements are used to determine the correct spacing of gear teeth. Spacing error is the principle source of gear noise due to total pitch variation or accumulated spacing. Although the main component of total pitch variation is from part runout, it may not be possible in all cases to detect this from a simple runout or composite inspection check.

Single Flank Inspection

Single flank inspection appears to be identical with the composite, or double flank, inspection technique. In fact, it is quite dif-

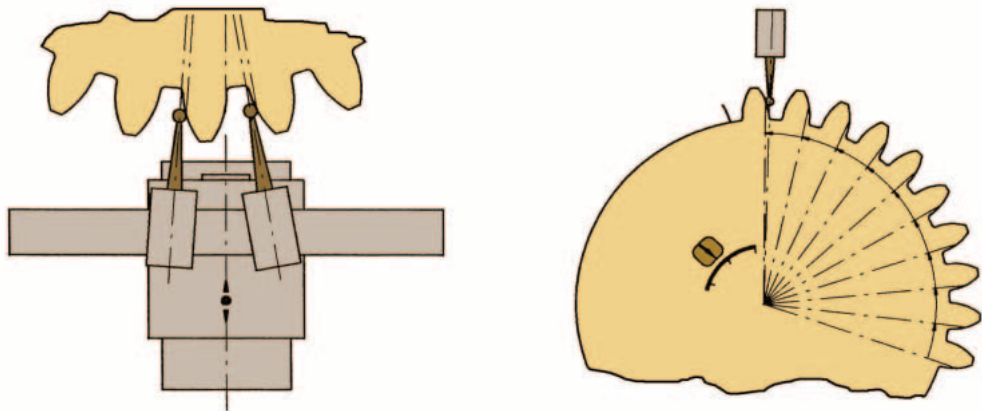


FIGURE 8 — Pitch measurement using a pitch comparator and angular indexing.

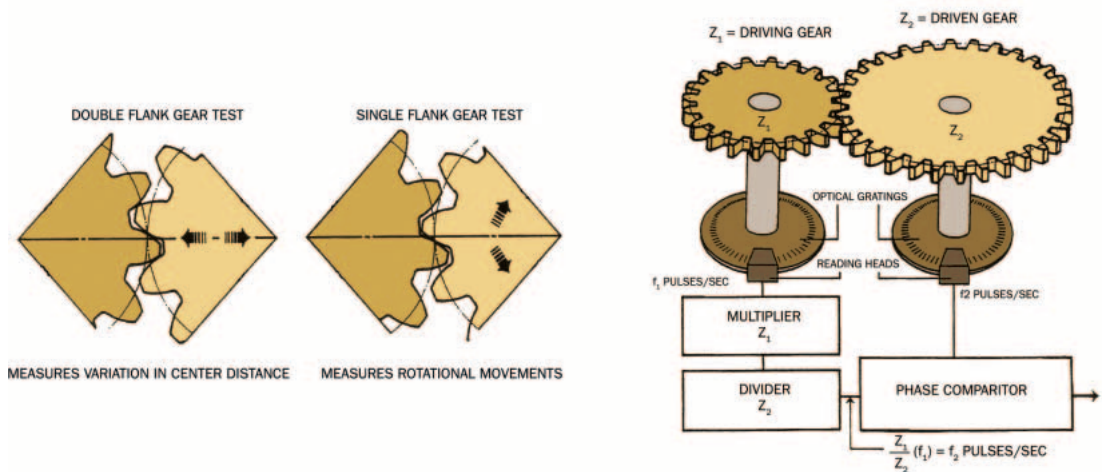


FIGURE 9 — Difference between double and single flank inspection.

ferent due to the fact that the test gear is rolled at its design center distance and backlash with a master or reference gear. This closely simulates the operation of the actual gear.

A single flank inspection instrument utilizes encoders on the two axes of rotation either as a fixed or portable unit. The rotational data from each encoder is then processed electronically, and the resulting phases are compared with each other to yield a phase differential. This will indicate errors of rotational motion from the ideal constant angular velocity of perfectly conjugate gears. The results of this phase difference are graphically recorded as an analog waveform, similar to a composite inspection chart.

The most important aspect of single flank inspection is its ability to measure profile conjugacy. The data is also related to profile variation, pitch variation, runout, and accumulated pitch variation.

Single flank testing does not eliminate the need for analytical inspection of helix deviation, and it is not as effectively applied to gear sets with increased contact ratios such as helical gears.

Summary

The AGMA standards referenced in this paper are presently the most advanced gear specifications available in the world. AGMA has worked with ANSI and with ISO to achieve this and presently chairs the ISO Gear Committee. The AGMA standard is a valuable specification not only to specify the level of gear accuracy but also to establish criteria between a vendor and a supplier, to measure accuracy capability of gear production equipment, or as a machine tool acceptance standard. Other specifications exist such as the

German Standard, DIN, the British Standard, BS, and the Japanese Standard, JIS. Independent standards also exist based upon the experiences of individual manufacturers.

Wenzel GearTec, M & M Precision Systems, Klingelnberg, and other manufacturers offer modern CNC controlled gear inspection machines to measure and record gear errors. Each of these company's machines are CNC controlled and, as such, offer additional capabilities to measure other part parameters as well as the cutting and finishing tools that produce the gear teeth. The CNC machines also offer the ability to link the measured data to a computer system for automatic interpretation. A current development is to offer CMM type inspection machines with gear inspection capability. 

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REFERENCES

Materials contained in this paper are extracted from AGMA ISO 10064-2 "Cylindrical Gears—Code of Inspection Related to Radial Composite Deviations, Runout, Tooth Thickness, and Backlash" and ANSI/AGMA Standards 2015-1-A01

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