

Gear Inspection:

Troubleshooting Tips

YOU INSPECT YOUR GEARS TO MAKE SURE YOU'RE PRODUCING THE BEST PRODUCT YOU POSSIBLY CAN. SHOULD YOU DETECT A PROBLEM, THIS CHECKLIST WILL HELP YOU QUICKLY DETERMINE THE SOURCE.

By Dennis Gimpert



In the June 2005 issue of *Gear Solutions* we presented an article titled “An Elementary Guide to Gear Inspection,” which was followed by “A New Standard in Gear Inspection” in October. Then, in the February 2006 issue, “Guarding Against Gearing Deviations” was published. These articles can be downloaded from the magazine’s Web site [www.gearsolutionsonline.com]. In this article we will focus on the practical side of gear inspection; in particular, what you should do when you measure certain errors during the hobbing process.

Size Variation

During gear hobbing the size of a gear is measured throughout the production run as a process control by the operator. As shown in Figure 1, this measurement is normally done using balls or pins of a specified diameter to contact the gear tooth profile at the pitch diameter. For larger gears a span measurement over several gear teeth will be done.

If excessive size change occurs during production, check the following items:

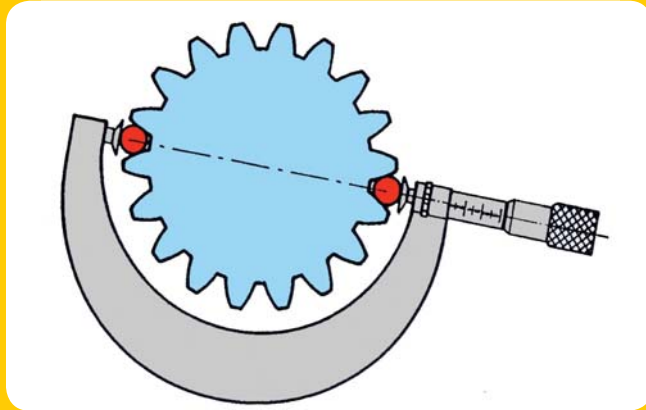


Figure 1: Measurement over pins

1) Size changes from a "cold" morning startup to normal operating temperature. The machine system may be thermally unstable. Record the size change over time versus temperature of the machine and/or cutting fluid. A "warm up" period may be required for your particular machine. Also, certain gear machines have thermal sensor(s) for automatic adjustment of the machine size,

and this system may have failed.
2) Size changes during hob shifting. Check that the cutter has been properly sharpened without gash lead error. Due to the cam relief in a hob, any gash lead error will create a conical shaped hob. This will cause a size change in the part as the hob is shifted from one end to the other. The gash lead error will be approximately 2.5 times the taper error. Measuring the outside diameter of the hob at several points across the face is a quick way to determine if gash lead error is present.

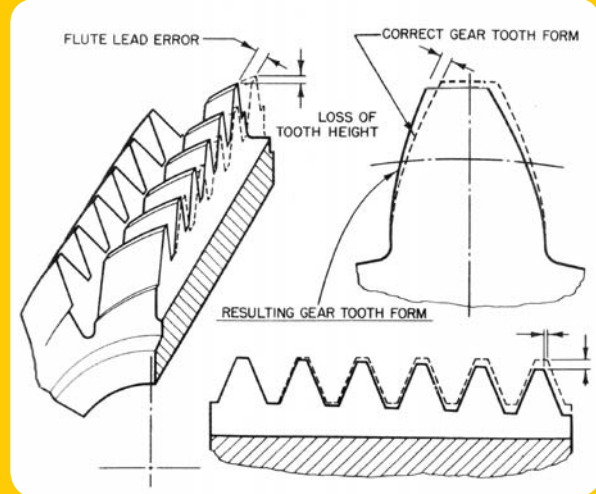


Figure 2: Hob gash lead error

3) Size changes from part to part. On a mechanical hobbing machine this can be caused by an error in the positive stop for center distance. With a long travel indicator measure the actual center distance from piece to piece and look for variation. Another cause of this problem could be a hob slide that is normally clamped after hob shifting that has failed to clamp.

Composite Inspection Error

During gear hobbing a composite inspection is normally conducted throughout the production run as a process control by the operator. This is accomplished on a simple rolling machine using a master gear with the product gear.

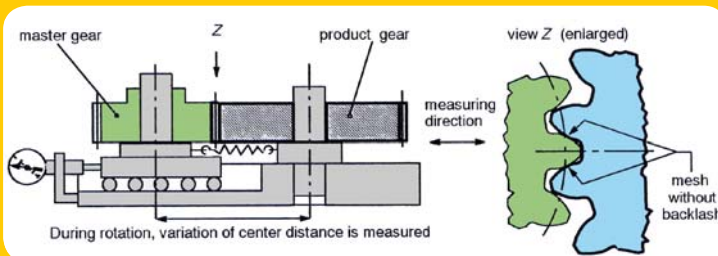


Figure 3: Schematic of gear rolling process

Composite error will occur as two conditions. First as a tooth-to-tooth error, and second as a once per revolution error of the test gear. The once per revolution error is commonly known as TCE, Total Composite Error, and is defined by the AGMA as the Radial Composite Variation.

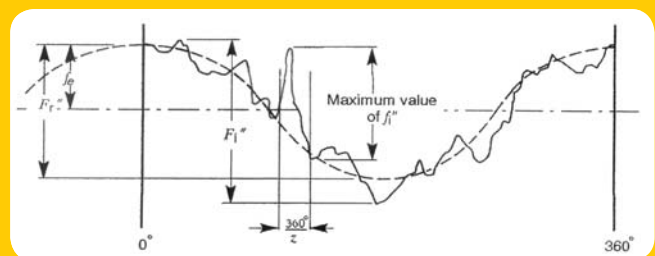


Figure 4: Graphical record from composite inspection

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Composite Error condition #1: Large f_i'' and Uniform Tooth-to-Tooth Errors

- 1) The large f_i'' is typically a dirty condition or a nick on a gear tooth. Nicks are normally caused by material handling problems. Adding a tip chamfer to the design of the gear tooth profile, and hob, will reduce this type of damage.

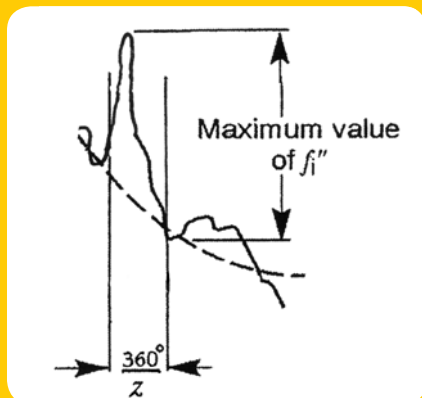


Figure 5: Dirty or nicked tooth on gear

- 2) A uniform but excessive tooth-to-tooth error that repeats each $360^\circ/Z$ (where z is the number of teeth in the part) is typically caused by the cutting tool and involute error.
 - a) The hob has not been mounted correctly, or the hob arbor is damaged.

- b) The hob has been sharpened incorrectly.
- c) Poor quality hob.
- d) The hob was shifted beyond its useful face width and is no longer generating the involute correctly. This may occur on one flank and will thus indicate an error in one direction of rotation.

- 3) Tooth-to-Tooth error can be caused by the hobbing machine.

- a) The hob spindle has axial and/or radial runout.
- b) End support for the hob arbor is damaged or worn.
- c) Improper installation of index change gears on a mechanical hobbing machine.

Composite Condition #2: Non Uniform Tooth-to-Tooth Errors

- 1) The hob is worn.
- 2) The hobbing machine work spindle index drive system is damaged, worn, or has excessive backlash.
- 3) The index change gears are damaged or installed improperly on a mechanical hobbing machine.

Composite Condition #3: Excessive Once per Revolution Error, F_i''

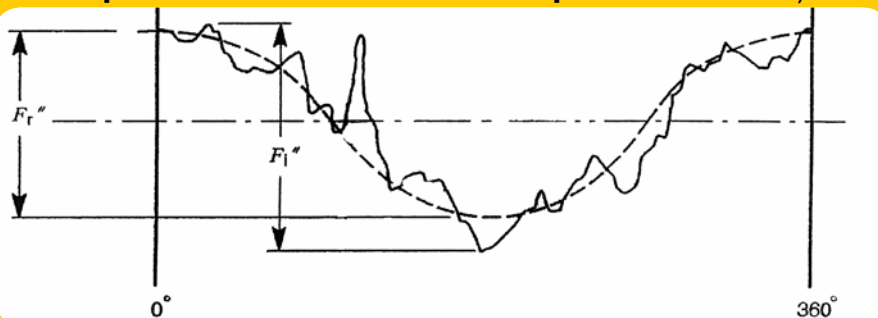


Figure 6: Total composite variation, F_i''

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- 1) The work piece blank has radial runout or the blank has face wobble, resulting in excessive axial runout.
- 2) The work piece mounting fixture has radial or axial runout.
- 3) The gear teeth have excessive lead variation.
- 4) The hobbing machine work spindle or index drive system is worn or has runout.

Composite Condition #4: Once per Revolution Non Uniform Error

- 1) The index change gears are damaged or installed improperly on a mechanical hobbing machine.
- 2) The hobbing machine work spindle or index drive system is worn or has runout.

Profile Inspection Error

The following examples show the different types of profile errors that can occur, with an explanation of the probable cause.

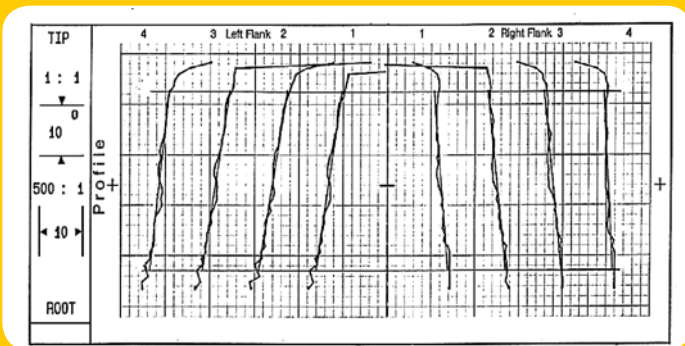


Figure 7: Profile inspection with negative tip tooth

1) Incorrect hob sharpening. The hob has been sharpened with positive rake error making the hob tooth larger toward the outside diameter and the gear tooth smaller.

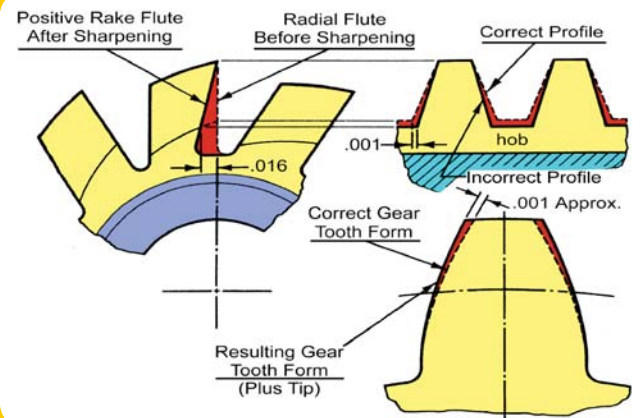


Figure 8: Hob sharpened with positive rake

2) Incorrect swivel angle setting on the hobbing machine.
3) Bad hob.

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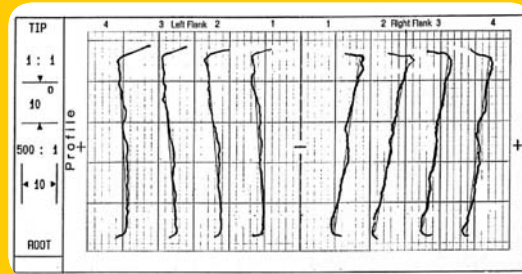


Figure 9: Profile inspection with positive tip

- 1) Incorrect hob sharpening. The hob has been sharpened with negative rake error, making the hob tooth smaller toward the outside diameter with gear tooth larger. This is the opposite of the condition shown in Figure 8.
- 2) Incorrect swivel angle setting on the hobbing machine.
- 3) Bad hob.

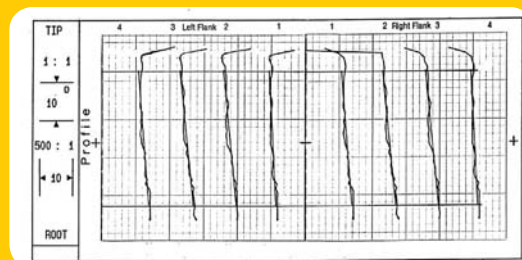


Figure 10: Profile inspection with leaning teeth

- 1) Incorrect hob sharpening. A hob sharpened with gash lead error will cause both a leaning profile and size change as the hob is shifted. See Figure 2.
- 2) Loose hob head swivel on the hobbing machine.

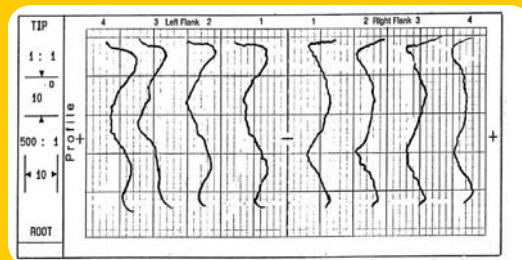


Figure 11: Profile inspection with uniform wave

- 1) Hob had runout when mounted. The hob runout can be caused by a bad cutter, damaged arbor, or dirty mounting conditions.
- 2) Incorrect hob sharpening. The hob was sharpened with runout during the mounting on the sharpening machine or sharpening

arbor. Extreme gash to gash spacing error on the hob.

- 3) A loose or worn hob arbor end support on the hobbing machine.
- 4) Excessive backlash in the hob spindle system on the hobbing machine.
- 5) Excessive backlash in the work spindle system on the hobbing machine.

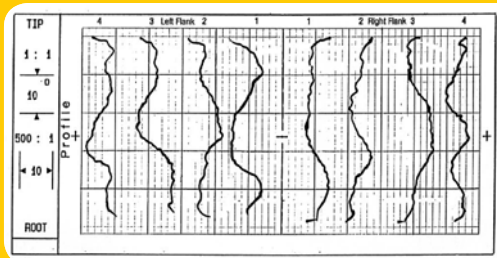


Figure 12: Profile inspection with non-uniform wave

- 1) A loose or worn hob arbor end support on the hobbing machine.
- 2) Excessive backlash in the hob spindle system on the hobbing machine.
- 3) Excessive backlash in the work spindle system on the hobbing machine.
- 4) Hobbing machine system in poor overall condition.

Helix Deviation Inspection Error

Helix error can be caused by the gear blank, the fixture, the machine setup, and machine damage or misalignment. The following examples show the different types of helix errors that can occur, with an explanation of the probable cause.

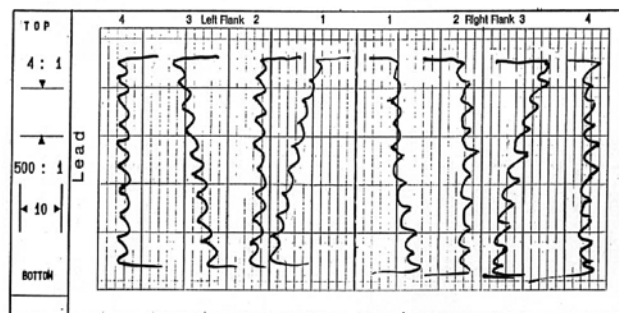


Figure 13: Helix inspection with wobble

- 1) Part blank bore not perpendicular to the face of the blank.
- 2) Part blank faces not parallel.
- 3) Fixture not accurate, or misaligned.
- 4) Tailstock misaligned, or center loose or damaged on the hobbing machine.
- 5) Inspection arbor problem.
- 6) Worm spindle bearing problem on the hobbing machine.

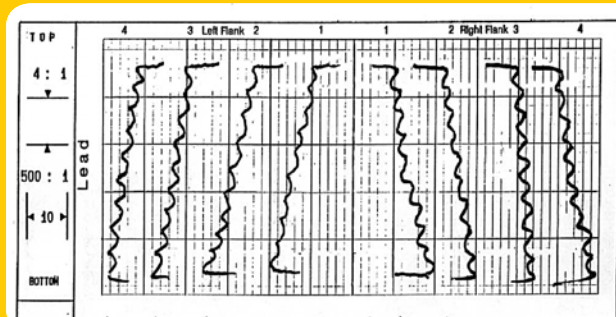


Figure 14: Helix inspection with taper

- 1) Tailstock misaligned on the hobbing machine.
- 2) Hobbing machine misaligned.

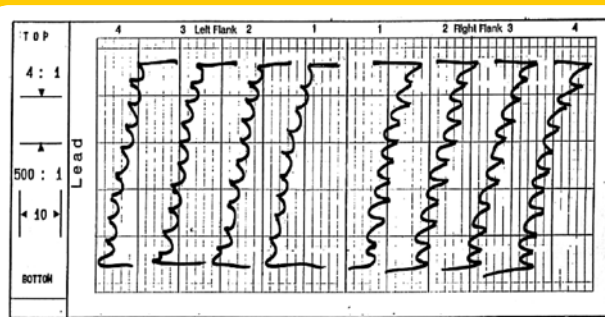


Figure 15: Helix inspection with angular error

- 1) Tailstock misaligned on the hobbing machine.
- 2) Hobbing machine misaligned.
- 3) Incorrect differential change gears or helix value (CNC).
- 4) Loose or work hob arbor end support on the hobbing machine.
- 5) Incorrect helix checking machine settings.

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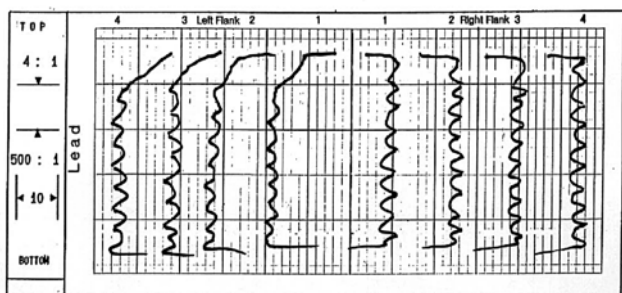


Figure 16: Helix inspection with breakout error

- 1) Tailstock loose or worn.
- 2) Part slipped in the fixture.
- 3) Fixture not clamped properly.
- 4) Hob arbor end support improperly installed or worn on the hobbing machine.
- 5) Hob saddle gibs out of adjustment.
- 6) Backlash in the cutter spindle drive system on the hobbing machine.
- 7) Backlash in the work spindle drive system on the hobbing machine.

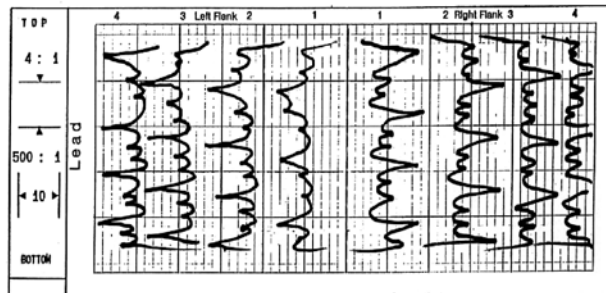


Figure 17: Helix inspection with periodic error

- 1) Runout of multiple thread hob.
- 2) Thread to thread spacing error on multiple thread hob.
- 3) Feed screw or bearings of the feed screw on the hobbing machine.

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Summary

The examples shown in this article are isolated to a particular error for sake of clarity. In actual troubleshooting multiple problems will occur and compound the complexity of the resulting inspection charts. These examples should be used as a guide in the solution to your problem, with the goal of step-by-step correction of each error identified.

Acknowledgment

Some material contained in this paper is 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 "Accuracy Classification System—Tangential Measurements for Cylindrical Gears" with permission of the publisher, the American Gear Manufacturers Association [www.agma.org].



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