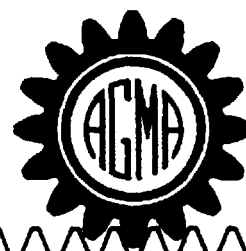


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Detection of “Hidden Runout”

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American Gear Manufacturers Association



TECHNICAL PAPER

Detection of “Hidden Runout”

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

There is a gear geometry variation, here called “hidden runout”, which resembles runout in its effect on transmission error and the resulting vibration, noise, and positional accuracy of a drive train, but which is not revealed in the standard runout measurements by ball-check or double flank composite testing. This paper describes this often unrecognized variation, its source in improper manufacturing methods, and its effect on gear performance. It then identifies the inspection methods that can be used to detect and measure this condition. Test gears are used to illustrate the manufacturing and inspection issues.

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DETECTION of "HIDDEN RUNOUT"

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1.0. INTRODUCTION.

1.1. "Hidden Runout". Runout is certainly a bad influence on gear quality and all other elements of gear geometry such as involute, lead, pitch variation, etc. However, it is somewhat of an enigma. If it exists in a gear, it is bound to degrade the performance, yet if it does not exist, the gear isn't necessarily good. Runout, by itself, can create a transmission error at once per revolution of a gear. Still, gears can be made that have little or no runout, but a large transmission error at once per revolution. This is the result of accumulated pitch variation (or total index variation), rather than runout. Hence the term "hidden runout" or actually a form of accumulated pitch variation. The authors independently decided on the use of the term "hidden runout". They discovered later, coincidentally, that an early paper also used this term. Bohle^[1] used two terms; "hidden runout" and "variable velocity" gears when discussing the occurrence of this phenomenon relative to some shaved gears.

If a gear has runout, it will have a large accumulated pitch variation. If it does not have runout, it may still have a large accumulated pitch variation that is the result of runout somewhere in

the manufacturing process. If a certain amount of runout in a gear is undesirable, the same amount of accumulated pitch variation will be just as undesirable, even if it has little or no runout.

1.2. Radial vs. Tangential effects. Runout is a radial phenomenon and accumulated pitch variation is a tangential phenomenon. Gears work in a tangential direction, rather than radial. Therefore accumulated pitch variation is more directly related to transmission error. It isn't runout, per se, that is the culprit, but it is the resulting accumulated pitch variation.

The main purpose of gearing is to transmit uniform rotary motion from one shaft to another, under their operating conditions. If this motion is not uniform, the gears are said to have transmission error.

1.3. Dangers of "Hidden Runout". The problem with hidden runout is that it is not detected by the inspection methods that are in most prevalent use. A "ball check" of runout (V_r), Figure 1, will not find it and neither will "double flank composite" testing of total composite error (TCE, V_{cq}), Figure 2. Both of these methods measure gear quality in a radial direction, rather than tangential. They, therefore, will miss the most important characteristic which is transmission error (a

tangential measure). These inspection methods can pass a gear as a very high quality level, but they will have poor performance such as positional inaccuracy or variable velocity. Note: Figures 1, 2, and 4 are from AGMA 2000-A88, Gear Classification and Inspection Handbook.

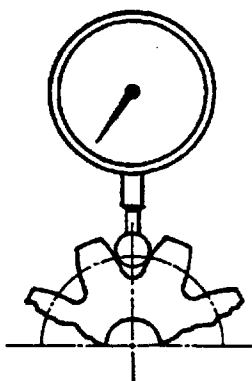


Fig 1 Runout Check, Over Pin, Ball Probe

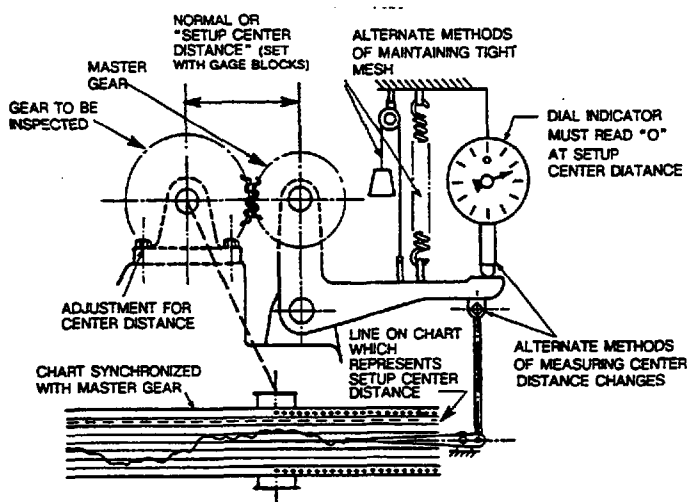


Fig 2 Gear Rolling Fixture (Double Flank Testing)

2.0. DESCRIPTION OF HIDDEN RUNOUT.

A gear of the type described above, with "hidden runout", will have the following characteristics:

2.1. Near Uniform Tooth Thickness and Tooth Space Widths. Any tooth thickness or space width measured around such a gear will have very little difference in size. It may be only .0001" to .0002". However, there will be a difference in the tooth flank positions. This is a sinusoidal variation that has only a small difference between any two

adjacent flanks, but accumulates in an increasing or decreasing manner to a relatively large total position error. This explains why the double flank composite test, or a ball check of runout, shows very little variation. At the same time, the index variation test will show these large accumulations of very small individual errors.

2.2. Mathematical Explanation.

2.2.1. Objectives. The objectives of the mathematical analysis are:

- (a) to provide an explanation of the inspection data taken from gears with "hidden runout"
- (b) to give the quantitative relationship between the condition that causes this form of apparent runout and the inspection results, along with any influence from the gear design data and the test set-up data.
- (c) to reveal, if possible, how the inspection results can be used to recognize the presence of this condition as something different from the conventional type of runout.

2.2.2. Model Gear. The first step in the analysis is to define an idealized model of the gear with this apparent runout and the conditions which caused it. In this model, there is first an ideal gear in its pre-finished state, with identical teeth uniformly spaced around some initial center, with this center offset from the center to be used in later processing and inspection. This first-stage model gear corresponds to the "rough hobbled" gear with runout described in paragraph 3.1.

Next, this gear is subjected to a finishing operation about this offset second center, with the operation removing material so that new tooth spaces are created with the following characteristics:

- (a) the tooth spaces are now all identical with a constant radial distance from the new "finishing" center.
- (b) relative to the new center, the position of the center of each tooth space is the same as that of the pre-finished tooth space. This implies that at the individual tooth space, equal thicknesses of material were removed from the two adjoining tooth flanks.

This finished model gear corresponds to the shaved gear and the ground gear described in paragraph