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Analysis of Ripple on Noisy Gears

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Analysis of Ripple on Noisy Gears

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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

A low noise level is an important quality feature in modern gearboxes for passenger cars. But a troublesome noise can have many causes. The noise origination and transmission is amongst others affected by the design layout, by the actual deviations of the components, by the assembly of the components and also by the mounting situation of the complete gearbox.

Damages, form errors and displacement errors or ripples are often present on the flanks of a gear, if it is found to be the cause of problems in a noise check. Especially ripples or 'ghost frequencies' of a gear are problematic, because up to now they rarely can be detected on a gear measuring device but only in a relative complex single-flank roll checking procedure.

A new evaluation method now allows to identify and to describe ripples on the flanks of gears based on the results of a normal gear measurement. The deviation curves were approximated by sine functions, the results are displayed graphical and by characteristic values. A combination of the deviation of each measured point with its rotation angle allows an evaluation equal to a rolling with the mating gear. The results show a very good correlation to a noise check and to a single-flank roll check.

The application of the software is demonstrated by practical examples of the manufacturing methods generating grinding, honing, broaching and shaving. Vibrations of machine tool and ripple generating influences in the manufacturing process can be verified down to a level of a few tenth micrometers. At the same time this method is well suited to describe long-wave form deviations like an ovality or a 3- or 4-fold ripple caused by the clamping or by a square blank.

With this new evaluation method gears can be tested in an early state of production for known, critical ripples and conclusions can be drawn on the state of machine tool, cutting tool and clamping device.

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Introduction

In modern passenger car transmissions, a low noise level is an extremely important quality feature. Noise generation is influenced by many variables, ranging from the structural design, to deviations in the components, to the mounting position of the finished transmission. If, during a noise test, a gear is identified as the cause, the problem can often be attributed to damage, irregularities in position or geometrical variations, or to geometrical ripples on the tooth flanks [1] [2]. This paper presents a closer examination of ripple. The development of ripple is influenced by such factors as deviations in the tool, the stiffness of the work fixture, the parameters of the manufacturing process, and of course, excitations and natural frequencies of the tool machine [1]. See Figure 1.

Gear measurement

Inspections of gear geometry are generally carried out during production on gear measuring devices that use a probe to trace the tooth flanks at individual points or on curves (Figure 2, left). By conducting such individual error tests, it is possible to arrive at definite conclusions with respect to the quality of the gearing and corrections for the production process [3] [4] [5]. This holds true to the extent that the errors occur over large areas and systematically on a number of teeth, as is the case for a great deal of production errors.

If damage occurs on individual teeth, however, or if the behavior of the gear is to be inspected as installed in the transmission, a working inspection is used. Here, a complete inspection of the tooth flanks is carried out by rolling with a high-quality master gear (figure 2, right). All errors of the gear act as a composite, in the form in which they have an effect when the gear is generated. A spectral analysis of the single flank generating signal reveals vibrations over the angle of rotation, which are caused by ripples on the tooth flanks and are also known as ghost frequencies [6]. Extended outfitting of the measuring device allows noise testing using structure-borne sound sensors and generation at higher rotational speeds and under load.

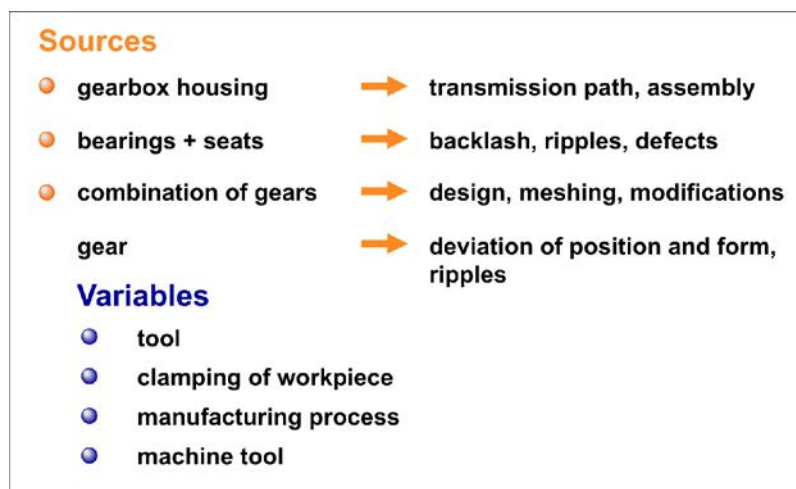
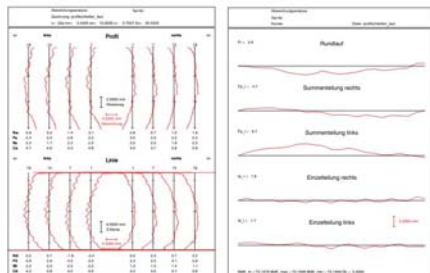


Figure 1. Sources of noise caused by a transmission

Single error inspection



Composite inspection / noise inspection

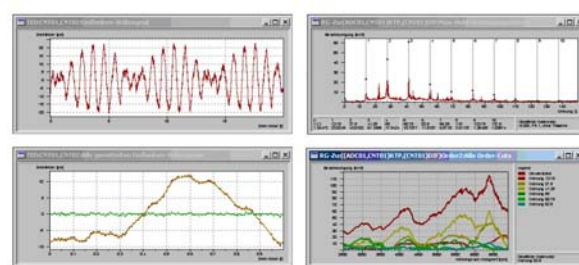
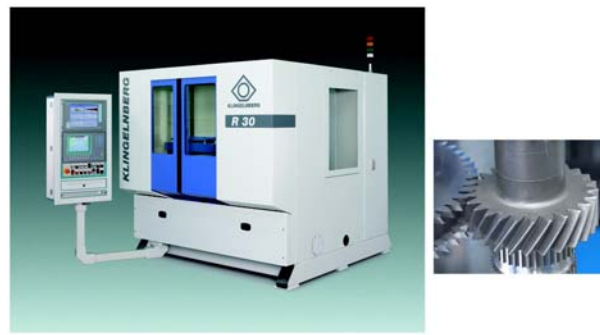


Figure 2. Inspection procedures when facing noise problems

When facing common noise problems, it is desirable to be able to easily identify ripples on the tooth flanks in the early stages, in order to intervene in the production process [7]. To this end, a software tool for ripple analysis has been developed, making it possible to describe ripples in a deviation curve based on the results of an individual error test.

Calculation of ripple

The most important step in the ripple calculation is the calculation of the amplitudes of compensating sine wave functions in a selected frequency range. The compensating sine wave with the largest amplitude is considered the first dominant frequency, and is plotted on the profile and displayed as a parameter. This dominant sine wave function is then eliminated from the deviation curve, and the remaining deviations are re-analyzed [8]. After 10 cycles, this ultimately produces a frequency spectrum of the 10 maximum amplitudes. In Figure 3, the first dominant frequency in each case is plotted on the deviation curve. With this type of analysis, each flank is evaluated independently of the others; often, the calculated frequencies of individual teeth are not precisely identical due to form variations.

When analyzing a gear's running behavior, it is interesting to link the deviation curves so as to resemble the way in which they mesh during the rolling process [9]. For a specific angle of rotation, Figure 3 shows the intersection of the gear with the plane of action. During the rolling with the mating gear, all points at the intersection curves of the flanks in this position would ideally come into contact with the plane between the working tip and root circle. The measured curves of the profile and line measurement are also plotted. Owing to the overlap, it is possible to assign 2 profile measuring points and 2 tooth trace measuring points each to the current angle of rotation. It becomes evident here that the ratio of measuring points to actual contact points is always extremely unfavorable. A conclusion based on these few measuring points is therefore only possible if they are representative of the entire flank. If the gear does not even contact in the measured areas, for example, the calculated ripples will not be functionally effective, of course.