

Tooth Meshing Stiffness Optimisation Based on Gear Tooth Form Determination for a Production Process Using Different Tools

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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

The variation of the tooth meshing stiffness is a source of noise and the exact calculation of tooth form is important for the stiffness determination. For this purpose, software was written with the concept of an unlimited number of tools such as hobs, grinding disk, and honing defining a manufacturing sequence. The tooth shapes after each step to show the material removal, sliding and rolling vectors to optimize the tool life are determined. Additionally, meshing stiffness variation can be improved by optimization of final gear geometry with a calculation of the contact path under load. From this information the meshing stiffness is derived making it possible to study the effect of a proposed profile correction of a gear under different loads. Calculations with AGMA2001 or ISO6336 check the point with the highest root stress. Effect of a grinding notch is also included.

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Introduction

The methods used in gear production are in constant development. In recent years form grinding (an alternative to the classic meshing grinding) has become the trend. Another example is a method used mostly in automotive industry: to improve the working life of tools and in order to get tooth form with higher root strength, gears are produced using up to three different pre-cutters plus a final honing or grinding process. One of the latest tendencies in the development of optimized gears is to apply a special wave-form-like profile modification during the finishing process for the reduction of transmission error.

These production methods require the development of appropriate calculation methods. In this paper the calculation of the resulting tooth form is described when several tools are used. Then, based on this tooth form, the effective meshing stiffness (under load) and the stress calculation are discussed.

The variation of the tooth meshing stiffness during operation induces a deviation in the rotation-angle of the output gear from the nominal transmission ratio (transmission error) causing vibrations and noise. The meshing stiffness variation can be improved through optimization of the gear geometry (transverse contact ratio ε_α and overlap ratio ε_β), but the type of profile modification is also very important for the stiffness under load.

The current calculation method for the tooth resistance following either AGMA2001 [1] or ISO6336 [2] is based on the assumption of a tooth form produced by one tool in a meshing process. The method includes, when using a tool with protuberance, also a production process with a pre-cutter (with stock allowance for finishing) and final grinding or honing process.

This implies that the formulas in AGMA or ISO resistance calculation methods can not be applied with gears produced by form grinding or other non-conventional methods. The problem is that for the cal-

culation of the tooth root stresses some values such as tooth thickness and root rounding must be known. The calculation method assumes that the tooth form is not exactly known, and therefore presents formulas which permit calculation of the tooth form just in the considered section of the tooth. These formulas assume production through a meshing process. But in principle, if the tooth form is given, the tooth can be calculated by directly using the formulas proposed by the standards. Therefore, if the tooth form calculation is integrated into the resistance calculation software, AGMA or ISO standards can be used for any production method.

Tooth form calculation with different tools

In most of the available gear calculation software it is possible to calculate the tooth form when using a standard tool (hob, generating cutter or gear type cutter). Normally it is also possible to introduce a grinding allowance and so simulate a 2-step production process (cutting, then grinding). Answering frequent requests of users of the widely recognized gear calculation software KISSsoft [3], it was decided to implement a new approach for tooth form calculation in the software.

An unlimited number of tools such as hob, cutting tool, gear-type cutter, grinding disk (generating or form grinding), and honing wheel can be defined in any sequence desired. The tooth shape can be visualised after every step, and different shapes can be superimposed to show the material removal from one step to another. The manufacturing process from tool to gear is also visualised, and sliding and rolling velocity vectors are indicated (to optimise the tool life).

Fig. 1 shows the different stages in getting to the definitive tooth form when using two cutters and a final rectifying process. For the gear with a pressure angle $\alpha_n 20^\circ$, a pre-cutter with $\alpha_n 25^\circ$ is used. This leads to an increase of the tool service life and creates a better rounding of the tooth root. As the flank form should be identical to the final design, the base diameter d_b of the gear has to remain identical. Therefore the module of the tool must be increased by $\cos(20^\circ)/\cos(25^\circ)$ for the pre-cutter.

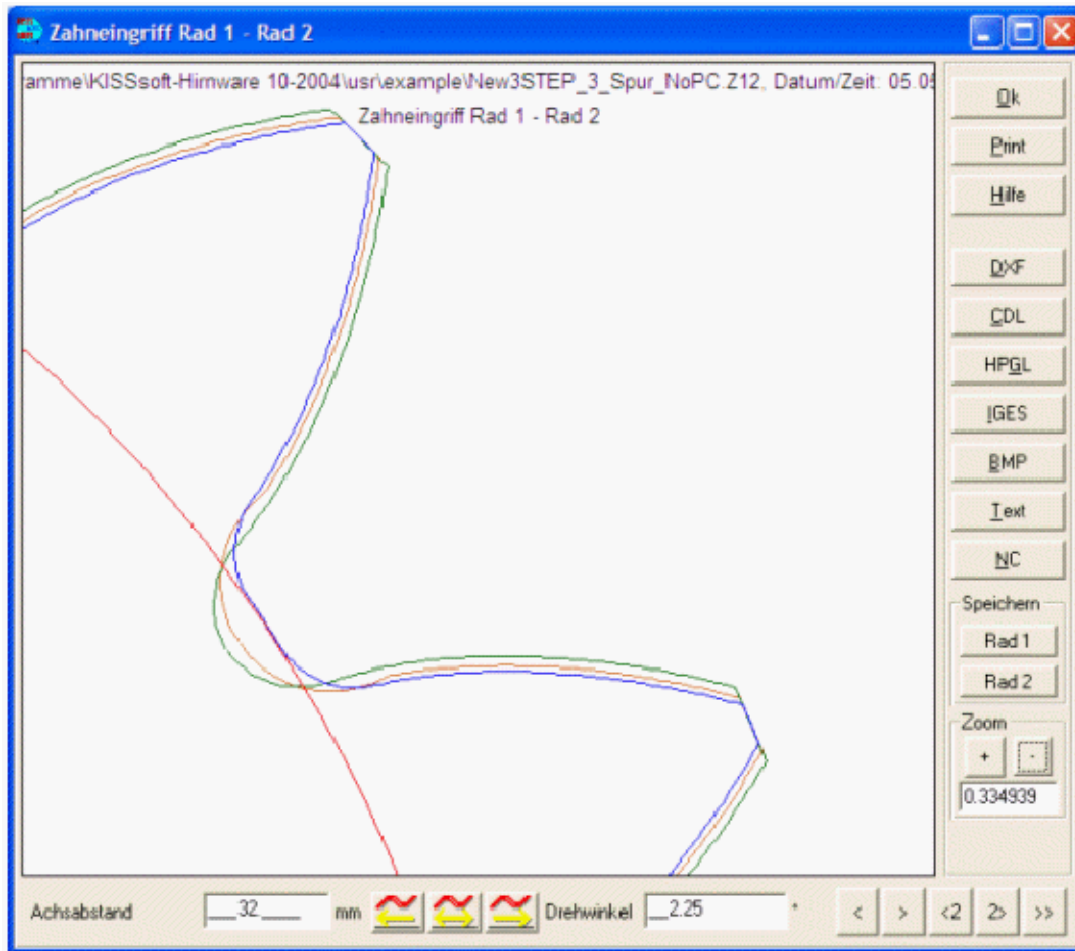


Figure 1. Tooth form generated with a 3-tool production cycle

- 1: Pre-cutter $m_n=1.0368$, $\alpha_n = 25^\circ$ (green)
- 2: Protuberance-Cutter $m_n=1.0$, $\alpha_n = 20.0^\circ$ (brown)
- 3: Final rectifying process (blue)

Some additional features of the tooth form calculation are:

- Tool service life: For the improvement of the tool service life (no. of gears cut until the tool has to be re-sharpened or replaced) the display of the specific sliding on the tool cutting flank is very important (fig. 2). There are many factors influencing the tool service life. One of them is the local specific sliding on the tool. A high negative specific sliding on the tool implies that a short section on the cutting edge of the tool produces a large section on the gear. This means that this part of the tool is highly utilized and consequently subject to high wear. As shown in fig.2, a pre-cutting-tool with higher pressure angle (as in fig.1) has a significantly reduced specific sliding.
- Grinding notch: For the root strength it is important to know if through the grinding process a so called "grinding notch" (ISO6336-3, factor Ysg) results. Therefore during the calculation of the grinding process, the notch has to be recognized. Such a notch can reduce considerably the safety factor for bending stress. In KISSsoft, the corresponding data is automatically transferred to the resistance calculation and the notch factor is included in the results.