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Technical Resources

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## AGMA Technical Paper

# Producing Profile and Lead Modifications in Threaded Wheel and Profile Grinding

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# Producing Profile and Lead Modifications in Threaded Wheel and Profile Grinding

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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

Modern gear boxes are characterized by high torque load demands, low running noise, and compact design. In order to fulfill these demands, profile and lead modifications are being applied more and more. The main reason for the application of profile and or lead modification is to compensate for the deformation of the teeth due to load, thus ensuring proper meshing of the teeth which will result in optimized tooth contact pattern.

This paper will focus on how to produce profile and lead modifications by using the two most common grinding processes, threaded wheel and profile grinding. In addition, more difficult modifications, such as defined flank twist or topological flank corrections, will also be described in this paper.

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# Producing Profile and Lead Modifications in Threaded Wheel and Profile Grinding

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## Introduction

Modern gear boxes are characterized by high torque load demands, low running noise behavior and compact design. In order to fulfil these demands gears are more and more modified in terms of profile and lead modifications. The main reasons are to compensate for the deformation of the teeth due to load, and to ensure a proper meshing to achieve an optimized tooth contact pattern (Figure 1).

Figure 2 shows typical flank modifications which may be subdivided into profile and flank modifications [1]. Both modification types are defined separately but can be superimposed. The most common modifications are profile and lead crowning in order to get a good contact pattern without having contact on both ends of the flank at either the tip or root area. Other designs are tip and root relief, and end relief. Profile or lead angle modifications are used to compensate for deformation of the teeth themselves but also shaft deformation within the gear box resulting in non parallel axes. All these modifications can be combined and thus result in complex flank modifications [2, 3].

Besides these “standard” modifications it is also possible to define so called topological modifications where each point on the tooth flank has its own amount of modification [4]. These kinds of modifications are much more difficult to produce than the standard modifications. Scores of publications deal with methods and ways of determining the optimized modification for gear sets under load considering gear box and shaft deflection as well as dynamic effects [5, 6]. This paper does not concentrate on such an approach, but describes how to produce these kinds of modifications in the two most common fine finishing technologies, threaded wheel and profile grinding.

## Threaded wheel grinding

Threaded wheel grinding is characterized by a high productivity due to the continuous process kinematic and is used mainly for small to mid size gears up to module 7 to 8 with a minimum diametral pitch of 3.175. Hence this technology is used mainly in automotive and light truck applications but also for larger gears with high numbers of teeth and small modules for instance used in printing machines or industrial gear boxes. Figure 3 shows the required kinematic for threaded wheel grinding [1].

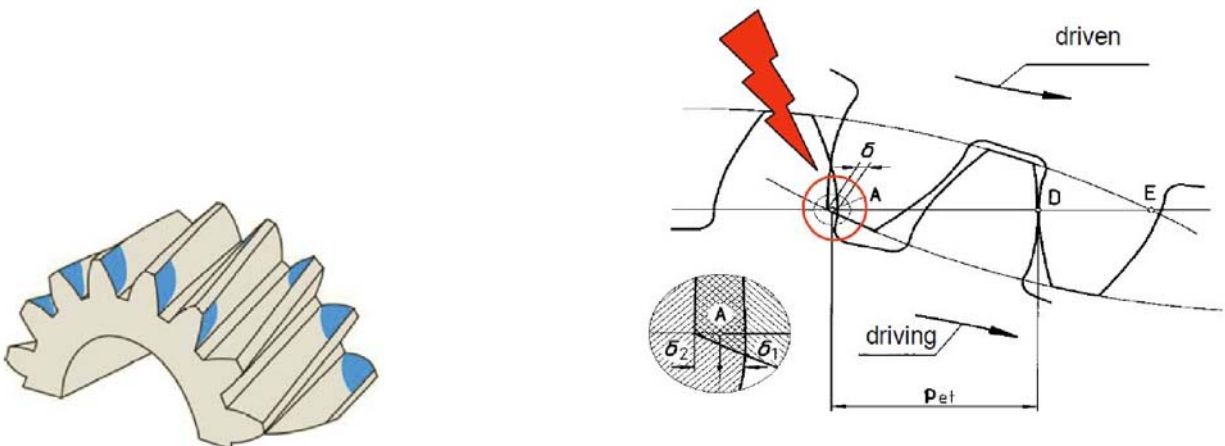


Figure 1. Reasons to modify gears

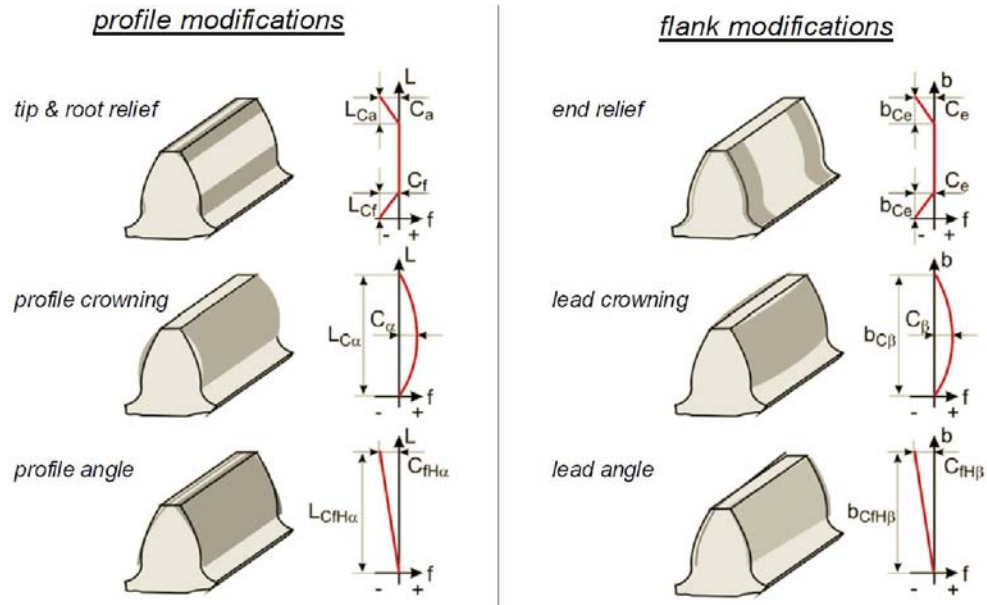
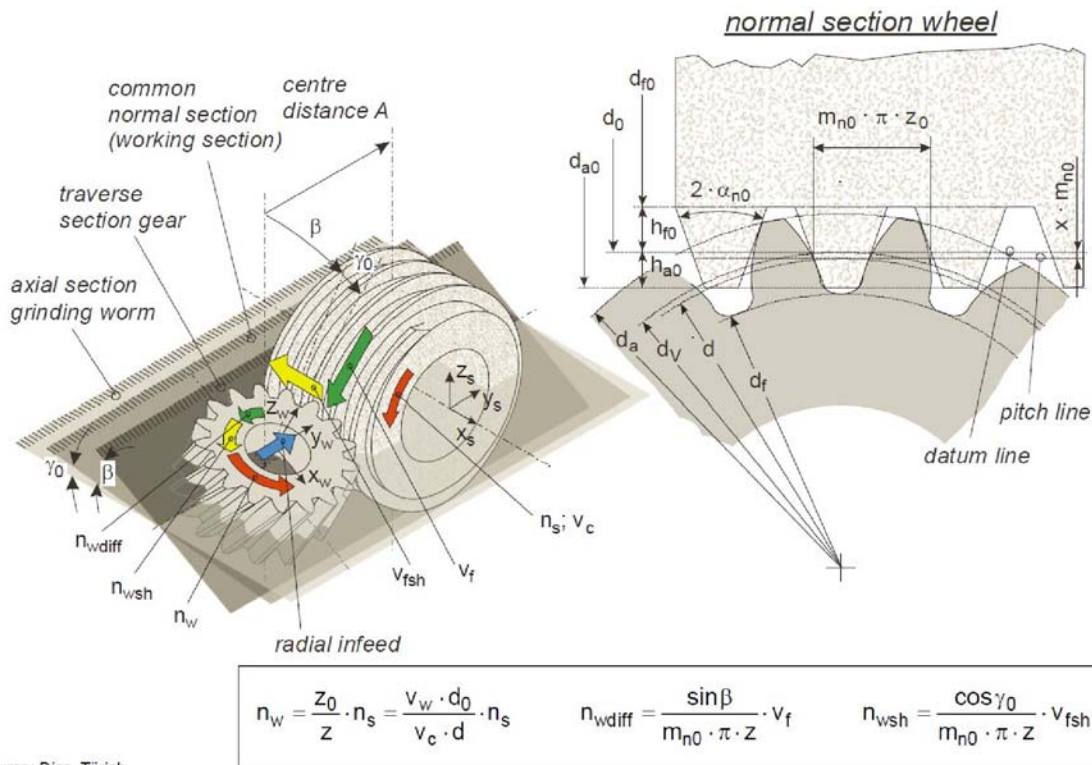


Figure 2. Typical flank modifications



source: Diss. Türich

Figure 3. Kinematic in threaded wheel grinding

A machine for threaded wheel grinding needs several axes to perform the required kinematic. First of all the gear to be ground and the threaded grinding wheel have to be swivelled into a certain angle which is the sum of the gear helix angle  $\beta$  and the wheel lead angle  $\gamma_0$ . Both, gear and wheel are

mating together like a gear set. Hence the rotation of the wheel  $n_s$  which results in the cutting speed  $v_c$  (red arrows in Figure 3) and the rotation of the gear  $n_w$  have to be synchronized. In order to remove material from the teeth the gear or the wheel needs a radial infeed motion (blue arrow) perpendicular to

the gear axis. Besides that the wheel has to perform an axial feed motion (green arrow) along the gear axis. In case that the gear is helical as shown in this figure, it must fulfil an additional rotational movement in order to follow the lead. Since the contact area between the wheel and the gear is smaller than the wheel width, a fourth motion is required (yellow arrow) to shift the wheel along its face width, thus using the full face width. This is the so called shifting and can be done continuously during the axial movement or discontinuously after a grind cycle. All of the above described movements must be synchronized precisely in order to achieve good gear quality [1]. This synchronization is done by the machine axis following the mathematical equations presented in the bottom section of Figure 3.

When cutting the wheel and the gear along the working section we get the normal section shown on the right hand side of Figure 3. Here one can see the rack profile of the wheel characterised by the wheel pressure angle  $\alpha_0$  and the lead which is module  $m_{n0}$  times  $\pi$  times number of threads  $z_0$ . Due to the mating movement this rack profile is finally generating the involute shape of the gear. The shown kinematic will result in a perfect gear without any kind of modifications.

The above mentioned flank modifications can be achieved by using threaded wheel grinding. Thus all profile modifications have to be generated by the dressing tool since this is defining the exact shape of the rack profile. All flank modifications are produced by the machine kinematic (Figure 4). In case the gear needs a certain profile modification such as crowning, a corresponding shape has to be dressed into the rack profile in order to generate the required amount of profile crowning during the grind cycle [7].

Figure 5 shows two different dressing principles used in threaded wheel grinding [7]. The left hand side shows the most common method using dressing discs which are copying their shape into the rack profile. Hence the shape of the profile modification must be known when designing and producing such a dressing disc. A typical result using such dressing discs is shown in Figure 6. The profile on left and right flank includes a tip relief as well as a slight profile crowning. The flexibility of such a dressing tool is very limited and in principle can only be used for one type of gear but due to the line contact between the dressing tool and the grinding wheel the dressing operation is relatively short (3.9 min for example shown in Figure 6).

#### flank modifications

*crowning, taper or end relief are defined by the machine kinematic*

#### profile modifications

*crowning, tip or root relief are defined by the dressing tool*

- master dressing gear
- dressing disc

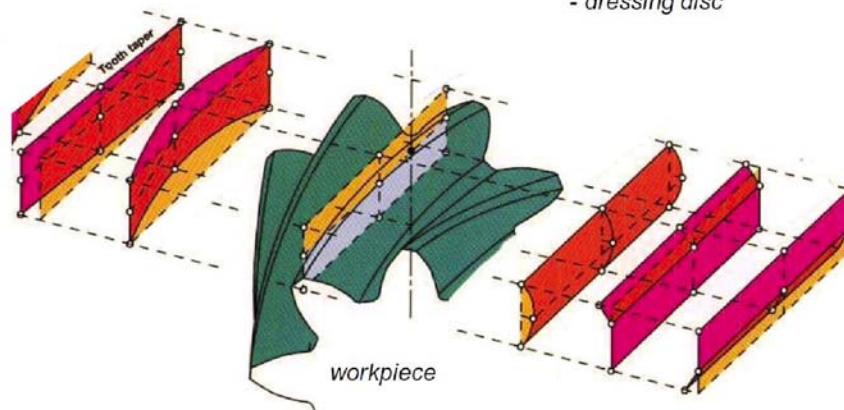


**Figure 4. Modifications in threaded wheel grinding.**