

Difference in the Local Stress of the Gear Tooth Root Based On Hobbing Cutters and Pinion Cutters

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American Gear Manufacturers Association



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ABSTRACT:

Differences of the tooth root geometry are caused if a pinion shaped cutter is used in the gear production instead of a hob. These differences also lead to a different stress concentration in the tooth root. The tooth root stresses are exactly calculated with the Singularity Method (variant of Boundary–Element–Method) for both production methods and their differences are discussed. The approximate calculation of stress concentration with the stress parameter $2\rho_{Fn} / s_{Fn}$ (on 30° – tangent) is proved to be applicable.

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0. Introduction

To take into account the stress concentration in gearings, useful reference material was created by measurements, numerical investigations with the aid of the finite element method (FEM) and the boundary element method (BEM), derivations with the aid of conformal mappings and photoelasticity /1/ /2/ /3/ /4/ /7/. It was partly introduced into the calculation standards ISO 6336/03, AGMA 908-B89, DIN 3990 and TGL 10545 (ed. 1989). To the principal quantities influencing the stress concentration belong the ratio of radius of curvature ρ_{Fn} of the fillet curve to the tooth root thickness s_{Fn} , i. e. the parameter $2 \rho_{Fn}/s_{Fn}$, and the bending moment arm in proportion to the tooth root thickness h_F/s_{Fn} . With common manufacturing tools and in the range of usual gearing geometries, the inclination of the profile adjacent to the root fillet curve and the change of the radii of curvature in the root fillet curve are other influencing quantities. Both quantities are of secondary importance in comparison with those mentioned for the standardized gearing.

If for the representation of the dependence of the stress concentration (Y_{Sa}) or of the tip factor ($Y_{FS} = Y_{Sa} \cdot Y_{Fa}$) the number of teeth z and the addendum modification factor x (in case of manufacturing with a hob or rack cutter with a constant tool tip radius ρ_{a0}) are chosen, also the change of the tooth root curvature and the different slope of the profile are taken into account. There is to be assumed that the calculation was carried out directly for the range of tooth numbers and the

addendum modification range and was not derived from a generalized equation containing only the principal stress concentration parameters $2 \rho_{Fn}/s_{Fn}$ und h_F/s_{Fn} . For the direct calculations mentioned a special variant of the BEM, the Singularity Method, proved to be suitable, which allowed a large number of numerical calculations /3/ /4/.

In the standards usually applied, the stress concentration factor (stress correction factor) Y_{Sa} or the tip factor Y_{FS} are stated in this form for the manufacturing with a hob and a rack cutter for a specific tool tip radius ρ_{a0} in diagrams (or equations). Also for the stress concentration parameter $1/q = 2 \rho_{Fn}/s_{Fn}$ and h_F/s_{Fn} equations are given by ISO 6336/03 taking the hob or the rack cutter as the basis. In some cases, however, the manufacturing technique with pinion cutter is used. Very frequently, it is not taken into account that in this connection considerable differences in the tooth root geometry may occur in comparison with the manufacturing with a hob. Those differences lead to influences on the load capacity of the root which cannot be neglected.

The aim of this contribution is to demonstrate the differences in the tooth root geometry when pinion cutters are used instead of hobs or rack cutters. The influencing of the tooth root stress concentration is to be determined and the use of the cross-section at the 30° -tangent is to be proved for it. Moreover, the contribution is intended to find unfavourable combinations of parameters. Without doubt, results of this set of problems already exist /8/ /9/. But meanwhile very precise and effi-

1. Fundamental Knowledge

1.1. Tooth Root Geometry

Tooth Root Thickness

The tooth root thickness s_{pr} is determined according to fig. 1. A different kind of presentation was given by, e. g., Hirschmann /5/. For the first time the tooth root thickness for a tangent to the root fillet was derived by Hofer /6/.

$$s_{Fn} = 2 \cdot X \quad (1)$$

$$X = r_{w1} \cdot \sin \varphi - (\Delta h / \sin \psi + e_{a0}) \cdot \cos \theta \quad (2)$$

The perpendicular distance Y from the root cross-section, given by the tangent angle θ , to the gear centre, is

$$Y = r_{w1} \cdot \cos \varphi - (\Delta h / \sin \psi + e_{a0}) \cdot \sin \theta \quad (3)$$

from $\varphi_{\min} = \pi/z_1 - z_0/z_1 \cdot \Delta\alpha$ (4)

$$\text{to } \varphi_{\max} = \pi/z_1 + z_0/z_1 \cdot (\alpha_M - \Delta\alpha - \arccos(r_{b0}/r_{w0})) \quad (5)$$

Table 1 contains individual specification quantities for equations (2) to (5). Index 0 and index 1 designate the pinion cutter (tool) and the gear to be made (gear blank), respectively. Figures 2 and 3 explain other quantities. The designations have been chosen in accordance with DIN 3960, DIN 3990 or ISO 701.

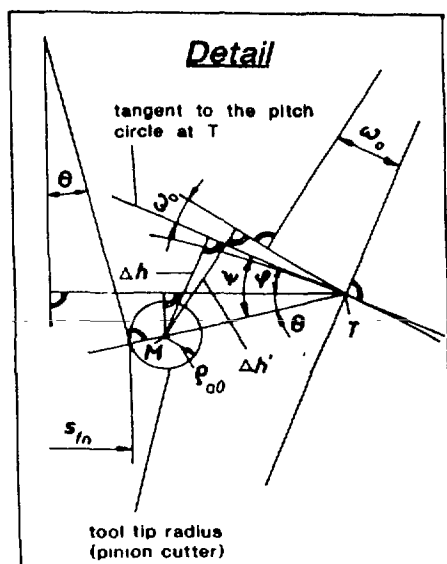


Figure 1: Generation of the fillet curve by means of a pinion cutter - Derivation of the tooth root geometry

