

A Closed and Fast Solution Formulation for Practice Oriented Optimization of Real Spiral Bevel and Hypoid Gear Flank Geometry

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TECHNICAL PAPER

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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:

If a very specific and systematic method is applied to spiral bevel and hypoid gear correction, a new possibility exists to accurately and quickly design and manufacture high quality gearsets. All generated data can be archived on a diskette, saved in machine control memory or stored in a central host computer. The described algorithm is based on a differential geometry calculation which is to activate about simple and intuitive input graphics. Gear experts are able to use the newly developed computer programs for optimization of the theoretical analysis results just as for correction of the real gearset in the workshop.

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1. Introduction

Previously known calculation methods permit the compensation of nominal - actual deviations on flank surfaces of spiral bevel and hypoid gear sets on the basis of correction matrixes. These are expanded forms of well known proportional changes, e.g., manual ABC corrections.

The newly developed method described in this paper functions on the basis of data obtained through a one-time theoretical flank generation using a bevel gear simulation program. Due to its universal validity, this vectorial computation method is applicable in all presently known spiral bevel and hypoid gear manufacturing processes. Yet the method is based on a highly visual and transparent model which may be described as three spatial triangular vectors in a Cartesian coordinate system.

Although calculations are referenced to the design point P, they also cover the environment of P through an information series:

- spiral angle gradient along the flank line
- spiral angle gradient along the profile
- pressure angle gradient along the profile
- Ease-Off Topography as a second order surface

Realizable modifications are divided into corrections of the first order with double flank compatibility and single flank corrections of the second order.

The true value of a calculation formula as a tool for the gear manufacturer is best demonstrated by its usefulness in practical application. Hence, four different practice oriented "start-up" possibilities for flank modification calculations

were developed - each of which, in turn, is backed by sophisticated mathematical formulas.

In addition to nominal - actual compensation (according to 3-D measuring), flank topography modification and tooth bearing offset, the most interesting (for the gear manufacturer) and simultaneously the most demanding correction method from the point of view of gear theory is that of tester compensation. Based on two different settings of the bevel gear tester for the best coast and drive tooth bearings, the vectorial calculation method can determine a gear machine setting with which the two initially contradictory tooth bearing positions shown on the tester appear exactly and simultaneously in the theoretical mounting position.

All algorithms discussed are available as modern, modularly constructed FORTRAN programs in both main line computer and PC versions. **Figure 1** shows a program flow diagram of the bevel gear optimization software. Design begins with the SPIROA program which yields the basic gear data, design dimensions, cutterhead and blade geometry as well as the setting of a virtual basic machine.

A data package (File.AAA) produced from the foregoing data serves as input for the KEGSIM0 program for zero calculation of the flank surfaces and for tooth bearing analysis. Should gear characteristic modifications be desired subsequent to an initial tooth bearing analysis, the required modifications can be executed with the ABCKORR correction program - this being the actual subject matter of the present paper. To determine whether the modifications lead to the desired result, the KEGSIM analysis program is now run once again. Since the correction values are actualized during each KEGSIM run, the vectorial calculation method converges on the desired solution during each new run even

for difficult bevel gear geometries.

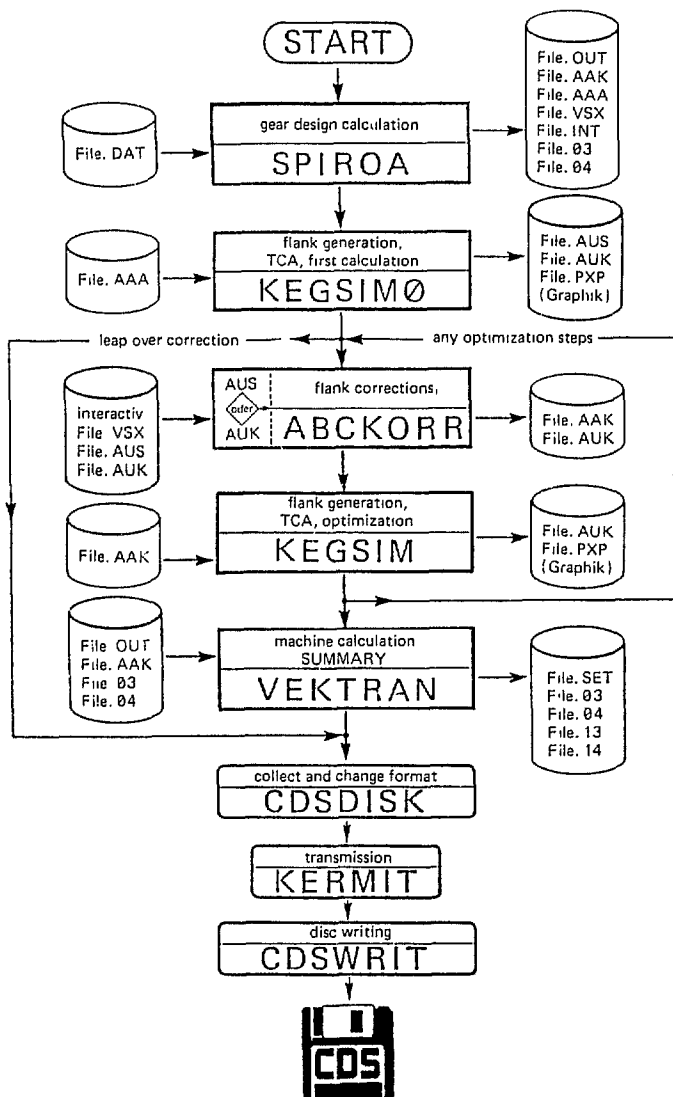


Figure 1: Bevel gear optimization program chain, from design to disk

In order to utilize all the possibilities available to gear manufacturing, such as 3-D measurement, nominal - actual compensation, tooth bearing offsets, topography modification and tester compensation, all necessary information must be collected with CDS DISK, transferred with KERMIT to a personal computer and written onto a 3 1/2" disk with CDS WRIT.

2. Exact simulation of bevel gear production

The KEGSIM calculation program for generation and analysis of bevel gear flank geometry of all Oerlikon designs is based on the bevel gear calculation chain developed at the Machine Tool Laboratory of the Technical University of

Aachen as commissioned by the *Forschungsvereinigung Antriebstechnik /FVA/1,2,3,4/*. **Figure 2** illustrates the graphical output of the KEGSIM geometry calculation.

The two vertical sequences show the analysis of the coast flank paring, left, and the analysis of the drive flank paring, at the right in Figure 2. The Ease-Off-Topography (top) shows the deviation of the present pair from the crowning free conjugated gear. In other words, flank line and profile corrections as well as longitudinal and profile crowning, and also all higher value flank surface modifications are recognizable in the Ease-Off presentation. The ordinate values are applied over the spatially located projection of the gear flanks (polar projection of flanks on axis section planes analog to cross sections as presented in technical drawings).

The generation simulation for individual flank pairs is carried out using a fictitious marking paste thickness of 0.006 mm and delivers the tooth bearings for single meshing. In the center of the tooth bearing, the Mean Point is indicated with a star. It represents the only uncorrected flank point and is the center of contact under both load free and loaded conditions. The Path of Contact passes through the Mean Point as the leading generation line. The direction of the Path of Contact coincides with the first primary direction of curvature. The contact lines that have been drawn in are calculated for 20 discrete generation settings. The direction of the contact lines through the Mean Point coincides with the second primary direction of curvature.

A generation deviation is calculated for each of the 20 generation settings from the Ease-Off-Topography over the Path of Contact, resulting in the path of a single-flank gen-

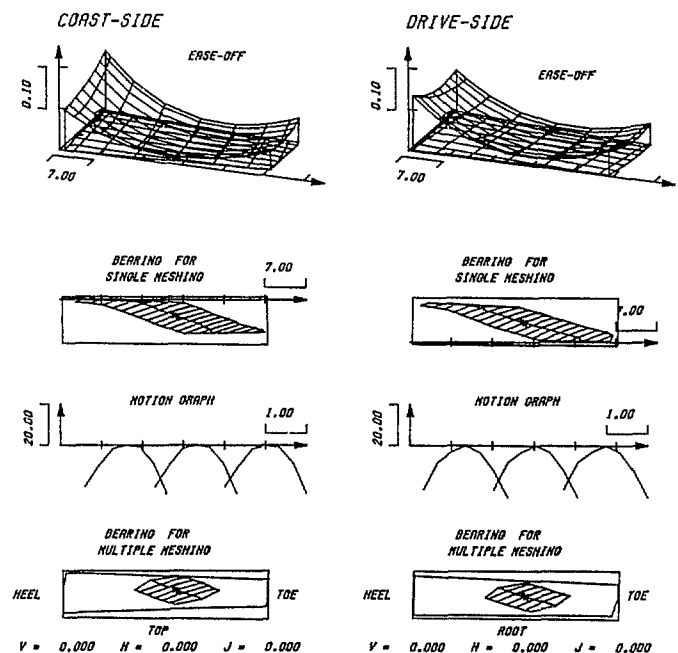


Figure 2: Graphic output of a flank generation with calculated tooth contact analysis