Software for Gearbox Development

The Influence of Bevel Pinion Retractability on Casing Design

Birgit Hutschenreiter, FVA GmbH

The FVA-Workbench is a manufacturer-neutral tool for the simulation and calculation of transmission systems.

As product development cycles become shorter, powerful modeling approaches and calculation algorithms become increasingly important. The predominantly analytical approaches in the FVA-Workbench deliver fast and reliable solutions to all important issues related to drive technology. For bodies that cannot be well described analytically, the results are supplemented by numerical methods. The intuitive modeling techniques in the FVA-Workbench guarantee consistent, valid, and manufacturable gears every time.

The calculations are developed, analyzed, and validated in research projects by Forschungsvereinigung Antriebstechnik e.V. (FVA, the German Research Association for Drive Technology). Through membership fees and public funding, the FVA is able to organize 14 million euros annually in research projects at leading German universities, chairs, and research. The FVA-Workbench serves as a platform to make this knowledge accessible to all engineers.

Load-free tooth contact simulation – the foundation for complex bevel gear calculations in the FVA-Workbench

Precise load carrying capacity calculations can be used to determine the stress, load carrying capacity, damage sums, and other characteristics of bevel gear stages. The load-free contact simulation, in particular, has the potential to significantly influence the design process.

The starting point for every calculation is the exact surface of bevel and hypoid gears and their position relative to each other. The descriptions of the tooth flank and tooth root are generated in a manufacturing simulation, taking machine settings and manufacturing deviations into account. Compensation areas are used to transform this discrete point cloud into a gapless mathematical description of the tooth surface.

The load-free tooth contact simulation is the core component of the rolling contact simulation, and can efficiently determine the key parameters of the gear. Relevant evaluation criteria include: the ease-off, the load-free working variation, the load-free contact pattern, determination of the backlash, and the axial retractability of the pinion (FVA Research Project 456 II "BECAL - Backlash and Retractability," TU Dresden IMM, Prof. Dr. Schlecht).

The **circumferential backlash** is chosen based on the gear parameters, production quality, and the relative position deviations to be expected under load. This prevents meshing interference and gear jamming. Too little backlash can lead to jamming due to relative position deviations under load, too much can lead to increased noise and reduced load capacity.

In addition to the microgeometry, the mounting position, relative position deviations under load, and specified pitch deviations of the working and trailing flanks are considered when calculating the backlash.

In practice, bevel gears always include flank modifications. Therefore, the backlash is not constant when considered across the meshing positions (see Figure 1). The difference between the minimum and maximum backlash is caused by superposition of the working variations in drive and coast operation. The theoretical foundation for the backlash calculations was developed and implemented in FVA Research Project 223/XVIII ("BECAL – Operating Clearance," TU Dresden IMM, Prof. Dr. Schlecht). The influences related to backlash calculation are being reassessed in ongoing research projects in order to better reflect the actual conditions under load.

Evaluation of the retractability of the pinion is another application for the

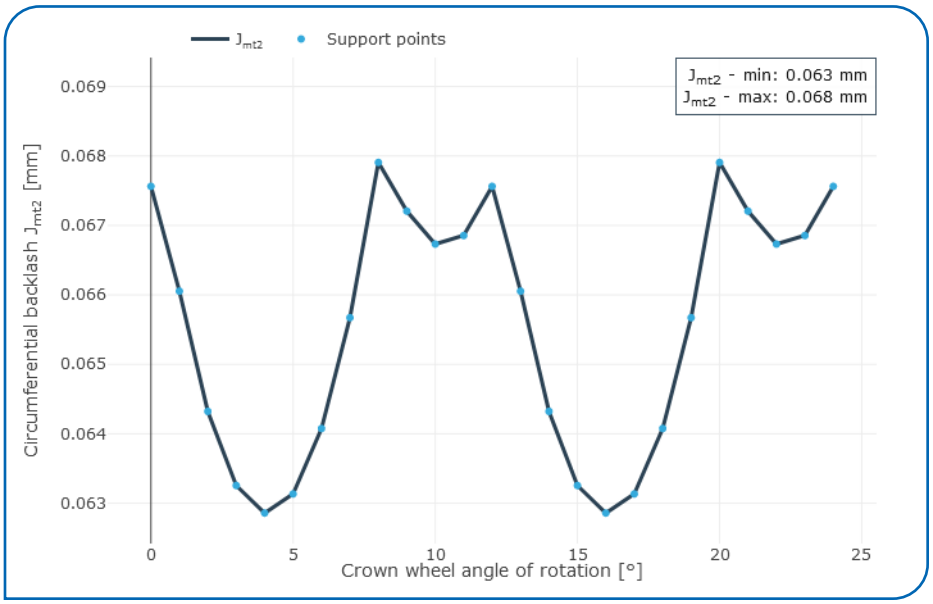


Figure 1 Representation of the average circumferential backlash over the angle of rotation of the crown wheel for 2 pitches in transverse section (graph taken from FVA-Workbench report).

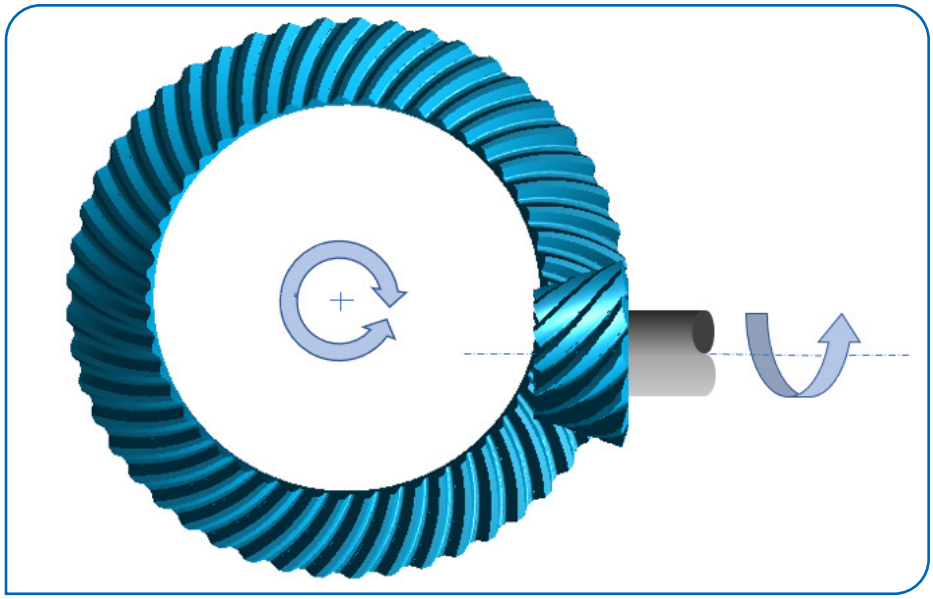


Figure 2 A pinion is retractable if can be rotated out of the mesh along the pinion axis.

circumferential backlash calculation. A pinion is **retractable** if it can be rotated out of the mesh and the pinion only moves along the gear axis. The relative position of the axis of the pinion only changes in the axial direction out of the mesh as a result. Retractability refers to both the mounting and disassembly procedures. This has an enormous influence, especially on the design of the casing. The question of whether or not the bevel pinion is axially retractable significantly influences the mounting and disassembly processes.

Retractability is calculated from the backlash. Therefore, the exact tooth form, including microgeometry and manufacturing deviations, is also taken into account here. The cutter head radius r_{c0} has the greatest influence on the retractability, as it determines the curvature of the flank in the longitudinal direction. This should be the very first thing to be adjusted in order to optimize the retractability. A larger cutter head radius increases the retractability, but is limited by economic considerations and a change in the displacement behavior, and therefore cannot simply be increased as desired.

In the FVA-Workbench, the minimum and maximum backlash over the axial displacement of the pinion are graphically represented as a result of the retractability calculation. The following three cases can occur:

- **Retractability:** The curves of the minimum and maximum backlash increase monotonously. The lowest values are located at the coordinate origin.
- **Conditional retractability:** The lowest value of the minimum backlash is negative and the lowest value of the maximum backlash is positive. This means that there are meshing positions in the corresponding axial pinion positions in which the pinion and the crown wheel do not interpenetrate. Jamming while rotating the pinion and crown wheel toward each other can only be avoided under ideal conditions. Retractability cannot be assumed without additional testing.
- **No retractability:** The minimum values are negative. This means that meshing interpenetration is calculated for all axial pinion positions with negative minimum and maximum backlashes. The gearing jams and the pinion cannot be moved axially.

The retractability results for a bevel gear with the basic geometry described in Table 1 are summarized in Figure 3.

Without retractability, the pinion can be mounted by placing it into the mesh in the axial direction of the crown wheel axis, or by lowering the crown wheel if the design allows (axial displacement of the crown wheel out of the mesh). Axial retractability of the pinion can be achieved under these conditions (see Figure 3). In this case, it should be verified that the value specified for the lowering of the crown wheel is sufficient for the retractability calculation.

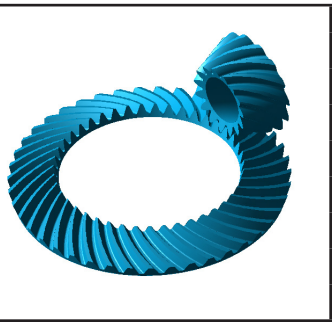
Calculation of retractability in the design phase makes it possible to draw important conclusions on the design as well as the requirements for the gearbox environment (casing). If the pinion is not retractable in the initial bevel gear design, the design can be adapted until retractability is achieved. The FVA-Workbench can quickly and efficiently calculate the effectiveness of these changes.

About FVA GmbH:

FVA GmbH is a joint venture of VDMA (Verband Deutscher Maschinen- und Anlagenbau, the Mechanical Engineering Industry Association) and FVA e.V. (Research Association for Drive Technology). Founded in 2010, FVA GmbH works hand-in-hand with top-level German research institutions and leading companies from the drive technology industry toward the active

Table 1 Basic geometry of the bevel gear being examined

Basic geometry parameters	Pinion	Crown wheel
Number of teeth	15	43
Normal module	3.18 mm	
Shaft angle	90°	
Hypoid offset	0.0 mm	
Face width	35 mm	35 mm
Average pinion cone distance	88.41 mm	88.41 mm
Average helix angle	35°	-35°



transfer of knowledge gained from FVA research projects into industrial practice. The company's core competencies are the development of calculation and simulation software for drive technology, preparation and transformation of established legacy code structures into modern software architectures, professional service and support, and technical seminars and conferences. **PTE**

www.fva-service.de

Birgit Hutschenreiter,
FVA GmbH.

For Related Articles Search
gear design
at www.powertransmission.com

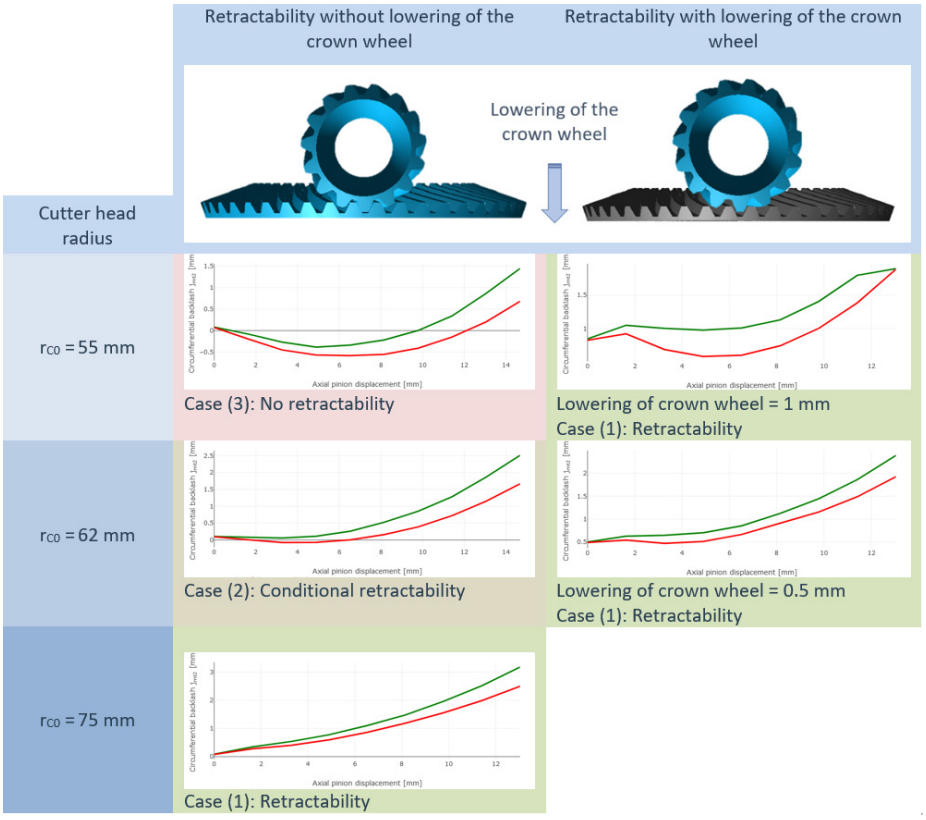


Figure 3 Influence of the cutter head radius and lowering of the crown wheel on retractability.