Importance of Contact Pattern in Assembly of Bevel Vs Cylindrical Gears

QUESTION

Why is there so much emphasis on the tooth contact pattern for bevel gears in the assembled condition and not so for cylindrical gears, etc? Any information would be greatly appreciated.

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Expert Answer Provided by: Dr. Hermann J. Stadtfeld, Gleason Corp.

Bevel and hypoid gears commonly use a cantilevering pinion. This means the pinion has, for example, two tapered roller bearings located on the shank — behind the heel — with no bearing support on their toe end. While the ring gear is supported on both sides, this presents a situation that allows the pinion to bend in the plane of the ring gear rotation, and in a plane that is defined by the pinion axis and is perpendicular to the first plane. In other words, a three-dimensional displacement of the pinion vs. the gear takes place during regular operation. This phenomenon increases in severity in cases where the gearbox housing is not of steel, but rather from a material with only a fraction of the modulus of elasticity of steel — such as aluminum alloys. The situation of relative displacement of bevel and hypoid transmissions — even in cases of optimal straddle bearing location — is a magnitude larger than in situations of spur and helical gears because of the three-dimensional force situation.

Cylindrical gears have only one major assembly parameter that is the center distance. There are four assembly parameters for bevel and hypoid gears (Fig. 1). Offset "E" and root angle "Alpha" are given by the gearbox design. The pinion axial position "P" has to be adjusted relative to the bearing shoulder behind the pinion heel to the theoretical value in order to make the crossing point of the axes match the theoretically predetermined position; i.e., the position found in the roll testing machine as the optimal build position — regarding tooth contact and noise. This rather complicated angular configuration with a possible pinion cone "P" optimization and the presence of gearbox tolerances requires an individual adjustment of the gear cone "G". The gear cone adjustment is mainly done to re-establish the desired backlash, which changes if the pinion position should be optimized. In cases where the tooth contact moved too far away from the required position, a pinion cone correction (using bearing shoulder shims of different thickness), in connection with a re-adjustment of the gear cone, must be performed. Because of the high three-dimensional displacements of the pinion position relative to the gear, bevel and hypoid gears receive a combination of length crowning, profile crowning and flank twist (Fig. 2). Modern bevel and hypoid gears even use higher-order corrections with the aim of minimizing the sensitivity regarding contact movement under load while also increasing load-carrying capacity.

Spur and helical gears — in automotive transmissions, for example — are arranged between two parallel shafts. Under load the gears at the end of the shafts might change their center distance by small increments — mostly caused by the transmission housing deformation — while the shaft inclination is still acceptably small. The gears towards the center of the shafts will change their center distance by higher amounts, while the inclination is negligible. The involute profile will prevent edge contact at top and root, if the contact ratio in profile is above 1.00. Load concentration at the ends of the teeth is prevented by the face contact ratio of helical gears. Spur gears are corrected with a first-order end-relief (Fig. 3, left) (in case of hobbing or

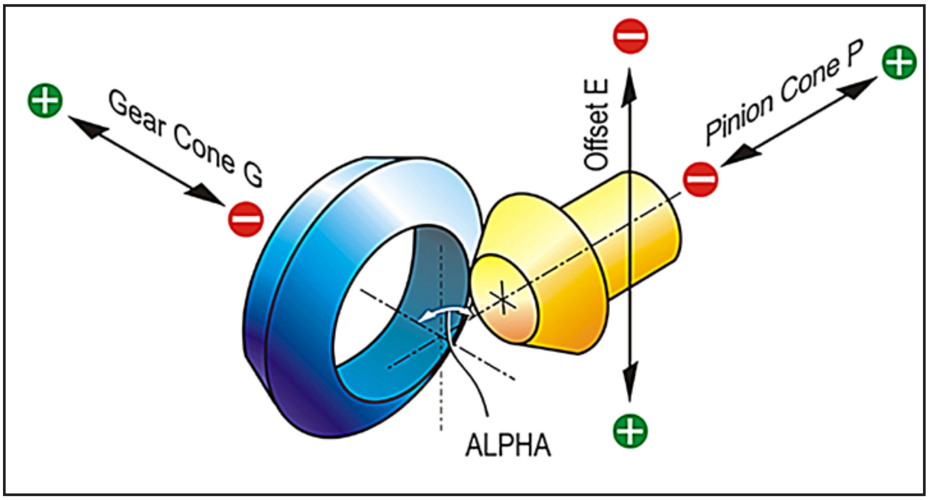

Figure 1 Bevel gearset — axial, vertical and angular adjustments.

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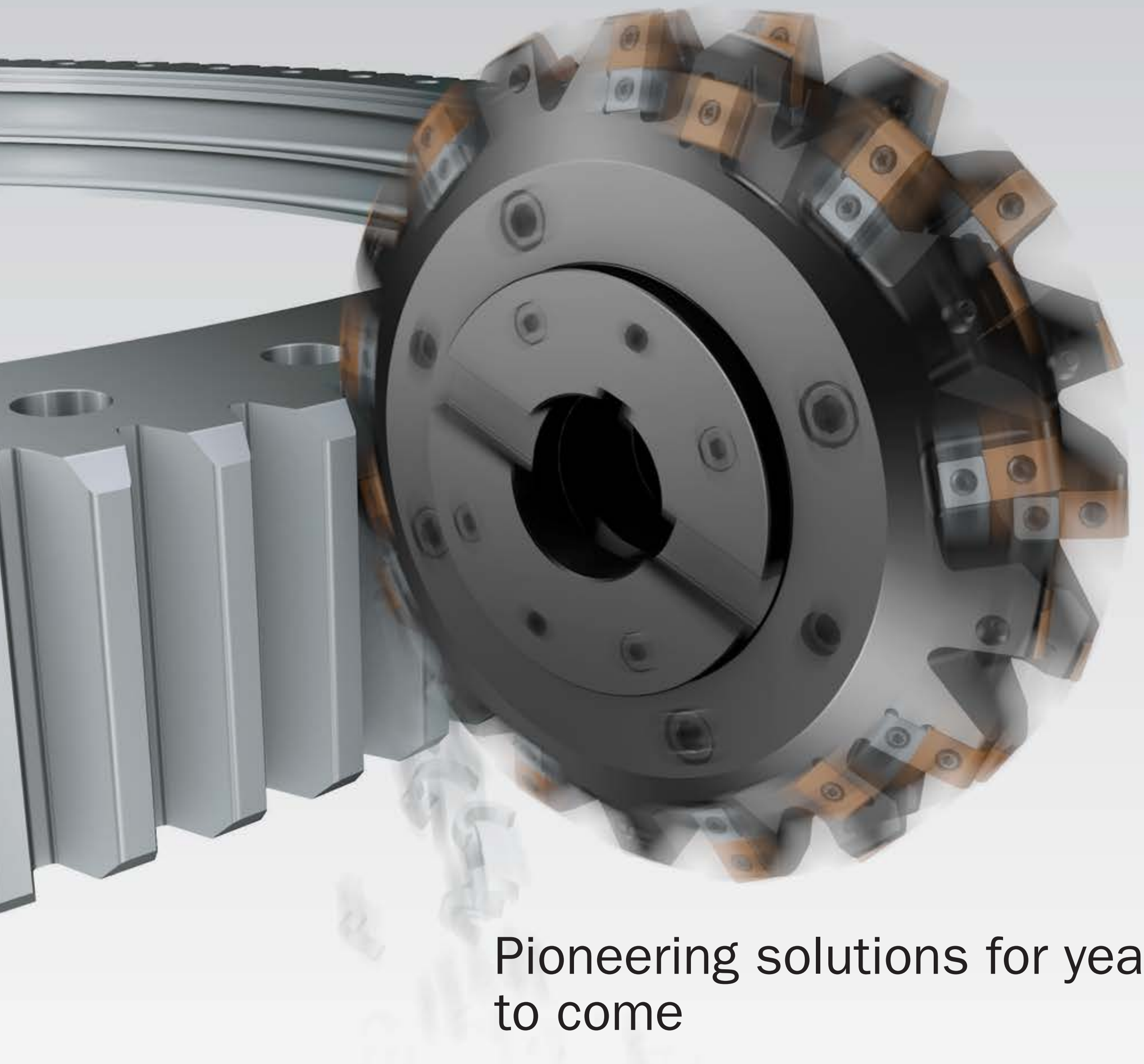

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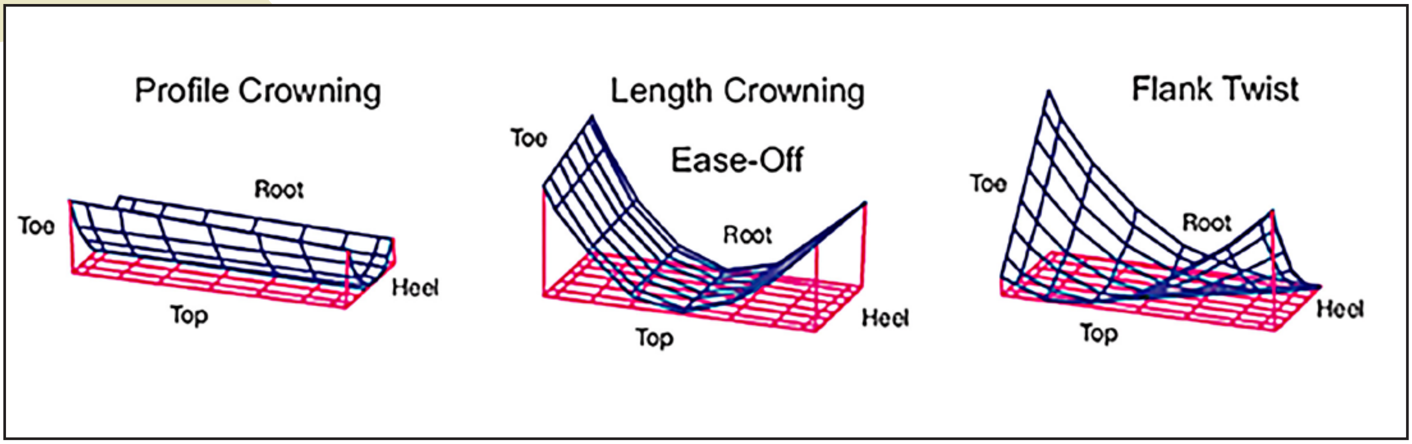


Figure 2 Flank surface modification elements (crowning) used for bevel gears.

shaping) in order to prevent the concentration of load at the tooth ends. More sophisticated is a circular length crowning in connection with a protuberance in the tool profile. A protuberance tool creates a profile relief like that shown in Figure 3 (right). Many helical gears that are ground have this advanced crowning applied. Crowning in face width direction and protuberance are also applied in cases in which the soft manufacturing is the final operation of a cylindrical gear.

Because the cylindrical gear shafts are parallel in the stage of building a gearbox, the gearbox tolerances will basically influence the center distance. Tolerances in milling the bearing journal seats can normally be ignored because they cause only a negligible shaft inclination and generally only result in a center distance variation. Involute gearing is impervious to center distance changes, so the emphasis is on verifying the assembly result in order to maintain the backlash within the required limits. Checking the tooth contact is often not required because there are no significant influences that could greatly influence the contact conditions. Depending on the kind of transmission, the final inspection could still be a backlash and contact pattern check of every gear mesh, or a structure-borne noise analysis of the complete gearbox on a test rig.

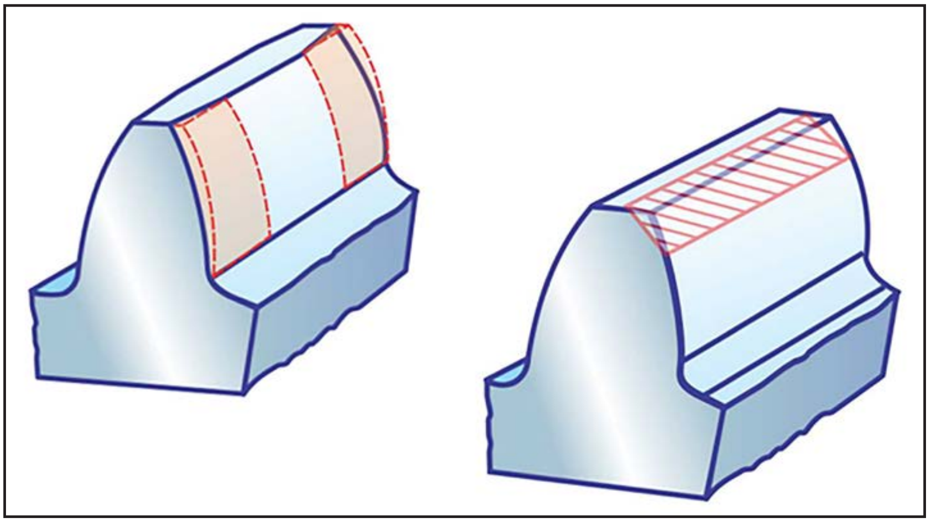
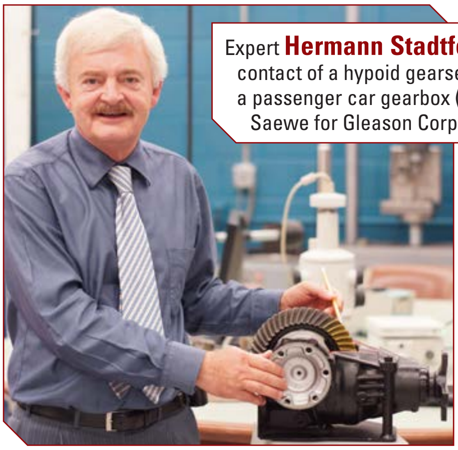


Figure 3 End relief—(left side) and top relief (right side).



Expert **Hermann Stadtfeld** checking tooth contact of a hypoid gearset after assembly in a passenger car gearbox (photo by Jasmin K. Saewe for Gleason Corp).

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