Backlash in Bevel and Hypoid Gears

Email your question — along with your name, job title and company name (if you wish to remain anonymous, no problem) to: *jmcguinn@geartechnology.com*; or submit your question by visiting *geartechnology.com*.

QUESTION

Reader question from Zhao Shenghui, Siemens Mechanical Drive Systems (Tianjin) Co., Ltd.

"I am a research engineer in the R&D department focusing on gear technology. I like the 'Ask the Expert' part of your magazine very much and hope you can help me solve the following question:

"What is the relationship between angular backlash or mean normal backlash change and the axial movement of the ring gear in bevel and hypoid gears?"

Expert response provided by Dr. Hermann J. Stadtfeld. The normal backlash is determined by clamping pinion and gear in a roll tester. First it must be ensured that pinion and gear are rotated to the so called "tight spot." Because of pinion and gear runout, the difference between tight spot and loose spot may be significant. It is important to determine the minimal backlash, because this is the value that must be properly defined for the operation of the gearset. The tight spot can be found on a manual roll tester by setting the pinion cone to the exact mounting distance and rotating the gear by hand until the first metal to metal contact occurs. Further rotation will show if the gear cone has to be increased or reduced in order to maintain a slight metal to metal contact. The angular ring gear position with the largest gear cone adjustment represents the tight spot. Now, the ring gear cone is adjusted to the correct mounting distance and a dial indicator is positioned at the outside in the middle of the profile of a convex ring gear tooth.

Figure 1 displays the setup and indicator position in a 90° roll testing machine. The indicator shaft direction includes a 90° angle to the radius connection between probe contacting point at the flank, and at the center of the ring gear. The probe shaft is also in the plane of the ring gear rotation.

When possible, the pinion rotation should be locked before the indicator is positioned. After completing these preparations the ring gear is rotated in a clockwise direction until the coast side flanks are in firm contact and the indicator is set to zero (pinion convex and ring gear concave = coast side). A slight rotation is then made in counterclockwise direction until a firm contact of the drive side flanks is achieved (pinion concave & ring gear convex = drive side). The indicator reading after this procedure is defined as the "minimal backlash in the plane of rotation" Δt. The relevant value that relates to the normal backlash values in the dimension sheet Δs must be calculated as shown in Figure 2.

Figure 1 Measurement of normal backlash.

where:

Δs = Normal backlash
Δt = Backlash in the plane of rotation
ß,,, = Spiral angle
ß*,,, = Spiral angle projected into plane of rotation
Δts = Backlash normal to projected spiral angle
γ = Pitch angle
α = Pressure angle
h = Backlash perpendicular to pitch cone

Backlash adjustment is done with an axial change of the ring gear position (gear cone). The axial gear cone change between

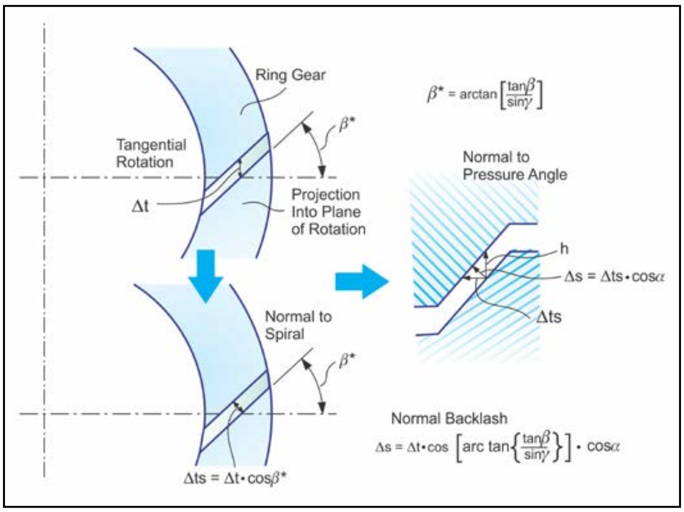

Figure 2 Calculation of normal backlash Δs.

the correct mounting distance setup to the metal to metal condition can therefore be used to determine the normal backlash. Pinion and gear are clamped in a roll tester. First it must to be assured that pinion and gear are rotated to the so called "tight spot." Therefore, pinion and gear cone are set to the exact mounting distance. Then the gear is rotated by hand until the first metal to metal contact occurs. Further rotation will show if the gear cone has to be increased or reduced in order to maintain a slight metal to metal contact. The angular ring gear position with the largest gear cone adjustment represents the tight spot. Ensure firm double flank contact at the tight spot and read the gear cone position on the electronic read out or on the Vernier scale. Now, the ring gear cone is adjusted to the correct mounting distance. The difference in the values of the gear cone at the tight spot metal to metal position to the correct ring gear mounting distance is recorded as "Δz." The schematics and formulae in Figure 3 show the relationship between axial gear movement and normal backlash.

where:

Δz = Axial ring gear move from nominal to metal to metal
z_1 = Number of pinion teeth
z_2 = Number of ring gear teeth
α_1 = Pressure angle convex gear flank
α_2 = Pressure angle concave gear flank

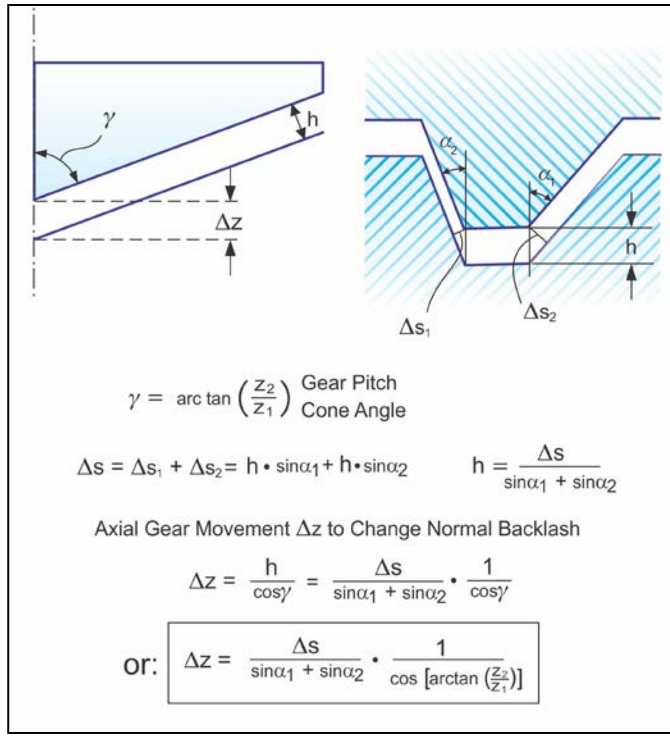

Figure 3 Relationship between withdraw and backlash.

The calculation of angular backlash can be done by dividing Δt by the mean gear radius. The result is in radians and has to be converted to degrees if required. With the relationship between Δs and Δt given in Figure 2, the conversion between angular backlash and the different linear backlash definitions can be quickly be determined. (In addition, see Dr. Stadtfeld's technical paper — "MicroPulse and MicroShift for Ground Bevel Gearsets" — pg. 60.)

Dr. Hermann J. Stadtfeld received in 1978 his B.S. and in 1982 his M.S. in mechanical engineering at the Technical University in Aachen, Germany; upon receiving his Doctorate, he remained as a research scientist at the University's Machine Tool Laboratory. In 1987, he accepted the position of head of engineering and R&D of the Bevel Gear Machine Tool Division of Oerlikon Buehrle AG in Zurich and, in 1992, returned to academia as visiting professor at the Rochester Institute of Technology. Dr. Stadtfeld returned to the commercial workplace in 1994 — joining The Gleason Works — also in Rochester — first as director of R&D, and, in 1996, as vice president R&D. During a three-year hiatus (2002-2005) from Gleason, he established a gear research company in Germany while simultaneously accepting a professorship to teach gear technology courses at the University of Ilmenau. Stadtfeld subsequently returned to the Gleason Corporation in 2005, where he currently holds the position of vice president, bevel gear technology and R&D. A prolific author (and frequent contributor to Gear Technology), Dr. Stadtfeld has published more than 200 technical papers and 10 books on bevel gear technology; he also controls more than 50 international patents on gear design, gear process, tools and machinery.