Hard-Finishing Spiral Bevel Gears

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QUESTION

Could you explain to me the difference between spiral bevel gear process face hobbing-lapping, face milling-grinding and Klingelnberg HPG? Which one is better for noise, load capacity and quality?

Expert response provided by Dr. Hermann J. Stadtfeld.

Face hobbing lapping. Spiral bevel gears have no length sliding between the flank surfaces while they mesh. If they are lapped, the lapping action fully depends on the profile sliding. However, at the pitch line, the profile sliding is zero and the lapping removal as well. It is therefore very difficult to lap spiral bevel gears (in contrast to hypoid gears which lap very well). The material removal principles, of the three discussed hard-finishing methods, are shown in the graphics for Figure 1.

Face milled spiral bevel gearsets have generating flats on their surfaces which are parallel to the contacting lines between them during meshing. The lapping process will follow the generating flats and magnify the ripple they cause if the lapping takes too long. In other words, spiral bevel gears are difficult to lap due to the missing length sliding. If spiral bevel gears are face milled, then they present a combination of obstacles which makes them rather "unlappable."

Face hobbed spiral bevel gearsets have generating flats which cross under 10 degrees to 20 degrees the contacting lines between the flanks. The lapping motion moves the lapping compound across the ripples which reduces them and makes the lapping efficient. However, there is still the obstacle with the missing sliding velocity along the pitch line. It is only possible to lap face hobbed spiral bevel gearsets for a very short time (e.g. 30 sec.) with low torque (e.g. 5 Nm). The contact before lapping must be positioned to the top-toe at the drive side and towards the top-heel on the coast side. Also, the pitch line needs to be very high (towards the topland) on the gear member.

Although the gear quality of face hobbed/lapped gears is often rated only in the AGMA 10 to 11 range, roll behavior, break-in properties and strength are very good. One of the great advantages of face hobbed/lapped bevel gearsets is the insensitivity to housing deflection and building tolerances.

Face milling grinding. The obstacles with lapped spiral bevel gearsets previously described make the face milling/grinding combination process the choice for spiral bevel gears. While face hobbed gears cannot be ground because of their epicyclical lead function, face milled sets are ideal for grinding. The grinding wheel just emulates the silhouette of the cutting blades in the soft cutting process. The direction of the generating flats has no influence to the process and the final results. It is recommended for strength reasons to avoid root grinding; however, the fillet region should show a soft blend between the ground flank surfaces and the root. Root grinding will form a slightly different fillet surface than the previous soft cutting operation with separate inside and outside blades. The grinding wheel will remove steps and fins and therefore cause "invisible notches" in the material structure. To "design around" root grinding, it is recommend-

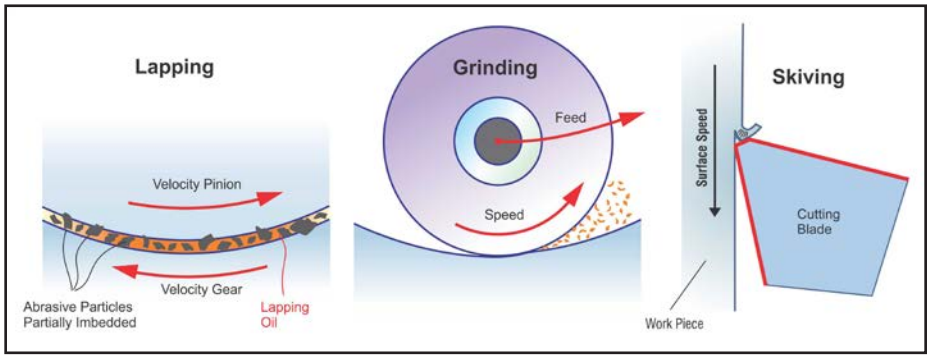

Figure 1 Hard-finishing material removal mechanisms.

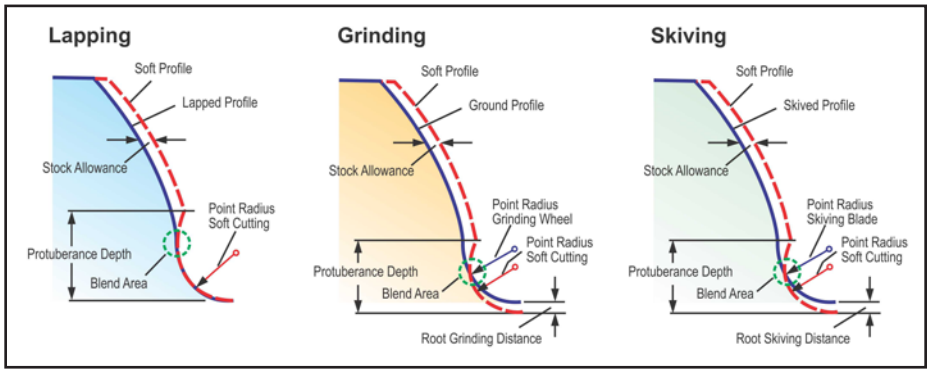

Figure 2 Semi-finish strategy.

Dr. Hermann J. Stadtfeld is vice president/ Bevel Gear Technology -R&D, and longtime contributor to ***Gear Technology*** magazine.

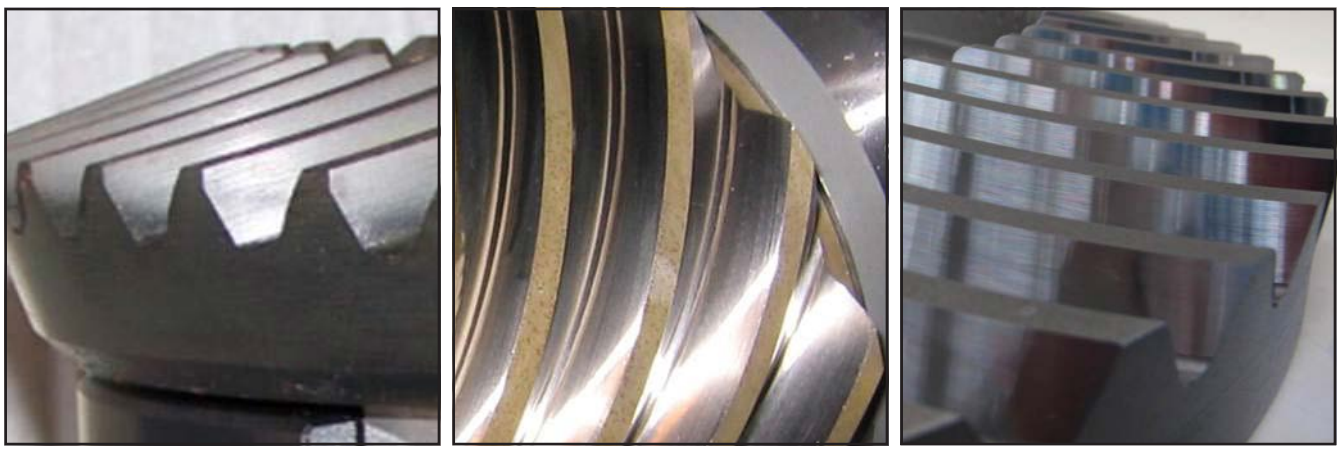

Figure 3 Surface appearance of lapped (left), ground (center) and skived (right) bevel gears.

ed to apply the semi-finishing geometry as shown in the center of Figure 2.

The gear quality of ground sets is AGMA 12 and 13 without extra effort. However, the surface roughness is higher than in lapping, which requires special oil properties and/or phosphate coating of the ring gear member in order to assure a good break-in result. The strength of ground gearsets with conventional geometry is equal to comparably lapped pairs. Grinding presents the advantage that higher order motions, such as *UMC* (*Universal Motion Concept*) with three pinion flank sections and additional gear end relief can be applied. *UMC*-optimized bevel gearsets have the same favorable displacement characteristic as face hobbed/ lapped gearsets, with a similar low-noise emission. Root bending strength and surface strength of *UMC*-optimized ground bevel gears is higher than the strength of their lapped or skived counterparts.

Hard skiving. Hard skiving of spiral bevel gears with Gleason Cyclocut or Klingelnberg Cyclo-Palloid HPGs is a viable process for the hard finishing of face hobbed bevel gearsets. In hard skiving, either coated carbide blades with a negative T-land (Gleason) or brazed on CBN cutting strips (Klingelnberg) are used to skim off a stock allowance of 0.10 mm to 0.15 mm, similar to grinding. The hard skiving blades should not have any cutting contact with the workpiece at their tip region. The depth of the soft cut slots therefore is 0.1 mm deeper than the depth of the hard finish cut. Just like the recommendation for grinding, the upper section of the root fillet radius should blend with the lower section from the previous soft cutting — preferably below the 30° tangent point.

The gear quality of hard skived bevel gears is in the range of AGMA 12 to 13. The flank surfaces have a mirror finish. A surface comparison between the three discussed hard finishing methods is shown in Figure 3.

While the strength is often expected to be higher than the strength of lapped gears, this is not correct. The root bending strength is comparable to lapped and ground gearsets with conventional design. Depending on operating speed and lubrication, micropitting has been found to exist along the crest of consecutive generating flats. In order to prevent surface problems during the break-in period, it is recommended to either coat the ring gear with phosphate and/or use a synthetic oil filling.