Generating gear grinding

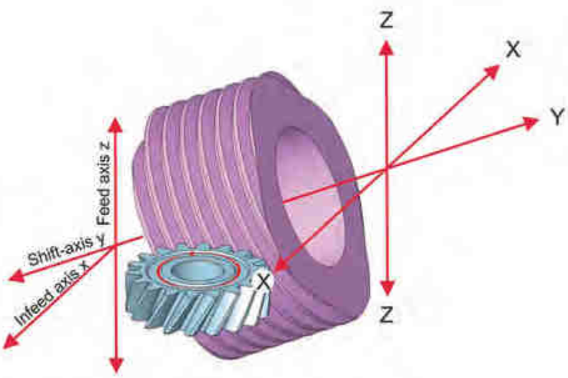
A generating gear grinding process for asymmetrical design enables greater load capacity on the flank and root, while maintaining high volume and low costs

Transmission developments now aim at increasing power density, reducing gear noise and improving energy efficiency levels. The increase in power density translates into a boost of the power transfer while maintaining or even decreasing the available installation space. This economy of space makes weight reduction possible. Improving the energy efficiency of a vehicle reduces the power loss in transmissions and converts directly to a CO_2 emissions reduction.

In the real world, gear teeth are rarely subjected to equal loads on both the drive and the coast flanks. If one of the tooth flanks is subjected to higher force in the direction of the applied torque, the tooth meshing can be optimized using an asymmetrical tooth flank geometry. Typical examples of a preferred direction of applied torque are tractors (the maximum torque load works in one direction only), wind turbine gearboxes (the wind load and breaking torque apply on the same gear flanks) and crane transmissions (the weight load always applies in the same direction).

Asymmetrical gears for the applications mentioned above can easily be manufactured through discontinuous profile grinding. This method, however, is very slow and, economically speaking, only makes sense for low-volume production of high-value components such as wind-turbine gears. Nevertheless automotive gears can now also benefit from an asymmetric design. Automotive gears are subject to enormous economic constraints and must be manufactured both in high volume and at low cost, for which discontinuous profile grinding is not a viable option for auto makers.

The RZ 260 twin-spindle generating gear grinder developed by Reishauer aids OEMs' quest for lower emissions



A kinematic diagram of the forces involved in the continuous generating process

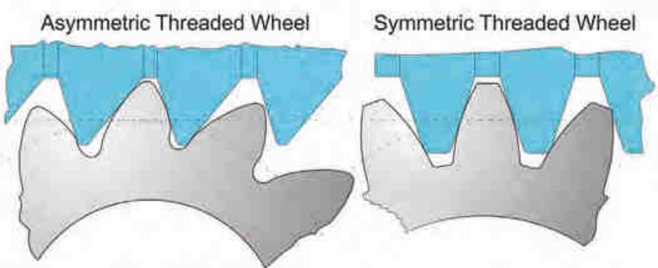


Figure 1: A depiction of both asymmetrical and symmetrical grinding wheel profiles

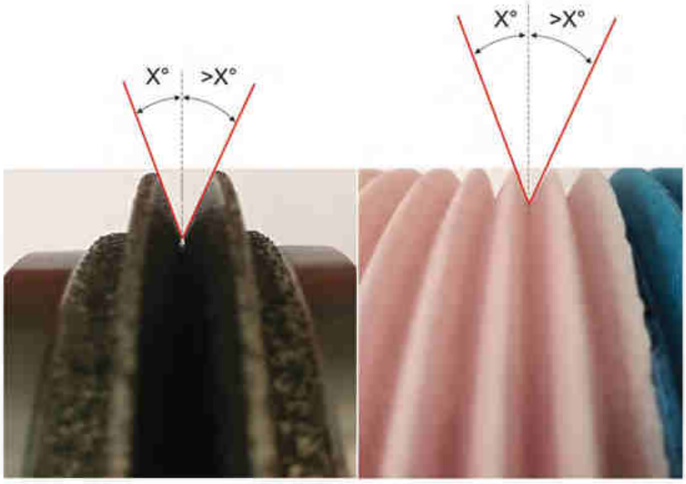
Reishauer's continuous generating grinding process represents the industry standard for the manufacture of symmetrical automotive gears at high volume, high quality and low unit cost. Based on a dressable grinding worm and a twin spindle concept, this process has proved itself in terms of flexibility and productivity.

In principle the kinematics of this process are comparable to a worm drive, with additional abrasive machining movements consisting of an infeed X, a vertical feed-rate Z, and a lateral shifting motion Y.

This principle applies equally to symmetrical and asymmetrical gears. The difference is the profile of the threaded wheel, which requires an asymmetrical profile (Figure 1).

Today, the continuous generating grinding principle also applies to the grinding of asymmetrical gear flanks, with the process now being as efficient and economical as the grinding of symmetrical gears. Furthermore, the company's continuous process allows a subsequent polish grinding stroke in the same clamping operation if a two-zone grinding and polishing threaded wheel is used.

To achieve the same efficiency and economy as in symmetrical gear grinding, dedicated diamond dressing rolls with asymmetrical profiles needed to be developed



The asymmetrical diamond dressing roll (left) and asymmetrical threaded grinding and polishing wheel (right) enable greater efficiency and economy in gear grinding

to appropriately dress the vitrified threaded grinding wheels. Furthermore, the diamond rolls can dress the grinding and polishing section of the threaded wheel in the same dressing operation.

In addition, the automatic gear meshing – which aligns gears into the correct grinding position – required additional development to ensure fast and reliable workpiece meshing and changing cycles. Given that the left and right pressure angles of the individual gear tooth are different, and therefore the depths of the grinding cuts are different for both flanks at an equal radial infeed, continuous adjustment of the synchronization of the axes via the machine's CNC is necessary to maintain the equal grinding depth on both flanks.

The asymmetric design of gear flanks serves to increase the load capacity of the gear flank and the gear root. As shown in Figure 2, an increase in the pressure angle leads to a rise of the curvature radii

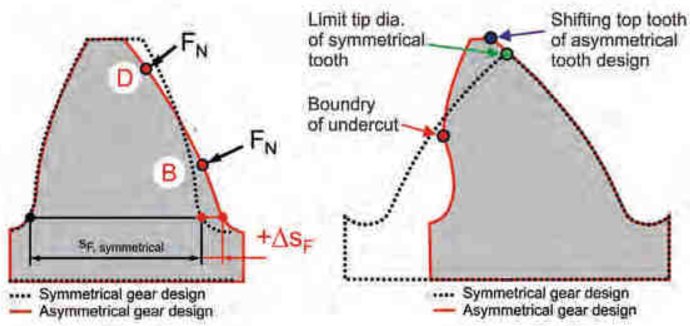
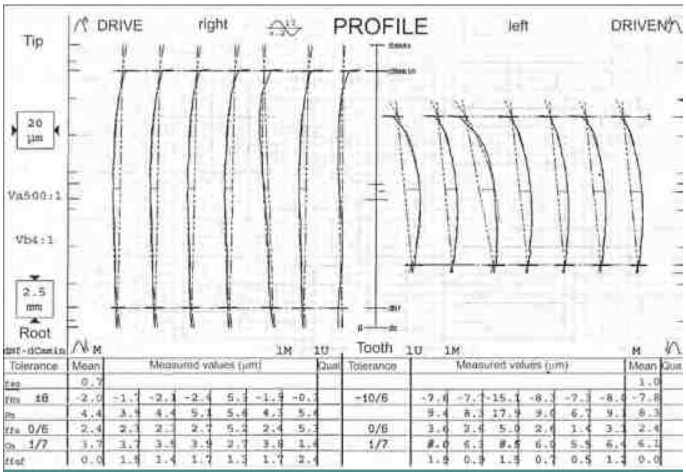
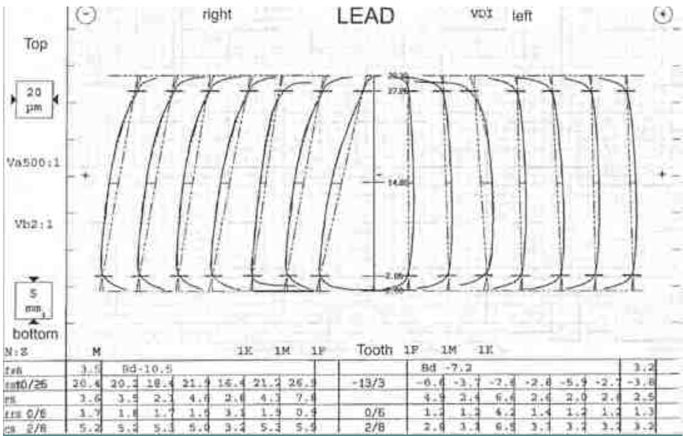


Figure 2: Features of asymmetrical tooth shape. F_N: normal force acting on the tooth. B: inner singular contact point relevant to contact stress and flank load capacity. D: Outer singular contact point. S_F: Critical cross-section of gear tooth root



The results demonstrated from an asymmetrical ring gear, polish ground with gear data of 60 teeth, a module of 2.8 as well as a pressure angle of 30.5°/16.5°



Ring gear profile chart. Reishauer works alongside OEMs in the push for efficiency

on the gear flank as the base cylinder is decreased (point B moves toward the outside). Increasing the pressure angle also leads to a strengthening of the root load capacity and lowers the bending load as the bending moment is reduced (point D moves downward). Moreover, increasing the pressure angle enlarges the tooth root cross-section sF, which increases its robustness.

There are benefits to increasing the pressure angle, with the only limitation being that the boundary line of the undercut shifts toward the tip of the tooth. But shifting the tooth top limit of an asymmetrical design, enables increased tooth-bearing load capacity, increased contact ratio, reduced contact stress, reduced noise excitations, enlarged tooth thickness at the tip and reduced danger of tooth top breakage caused by through-hardened tooth tips.

The Reishauer machines are ready for the grinding of automotive asymmetrical gears and are actively engaged in projects with OEMs. The whole machine concept has been designed to be user friendly in regard to data input as well as the operation of asymmetrical gear grinding for standard symmetrical automotive gears.