# Continuous generating grinding of asymmetric gears

Today, transmission developments aim at increasing power density, reducing gear noise, and improving energy efficiency.

The increase of 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 energy efficiency reduces the power loss in transmissions and converts directly into a $CO_2$ emission 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 forces in the direction of the applied torque, the tooth meshing can be optimised by 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.
- Crane transmission: the weight load always applies in the same direction.

Asymmetrical gears can be easily manufactured by the discontinuous profile grinding method. This method, however, is slow, and economically speaking, makes only sense for low volume production of high-value components such as wind generation gears. Nevertheless, today, automotive gears can also benefit from an asymmetrical design. Automotive gears are subject to enormous economic constraints. They must be manufactured both in high volume and at low costs, for which discontinuous profile grinding is not a viable option.

Reishauer's continuous generating grinding process represents the industry standard for the manufacture of symmetrical automotive gears at high volume, high quality, and at low unit costs.


**Reishauer RZ 260 twin-spindle generating gear grinder**

Based on a dressable threaded grinding wheel, and a twin-spindle concept, this process has proven itself, both in terms of flexibility and high productivity.

In principle, the kinematics of this process is 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, of course, also an asymmetrical profile, as shown in Illustration 3.

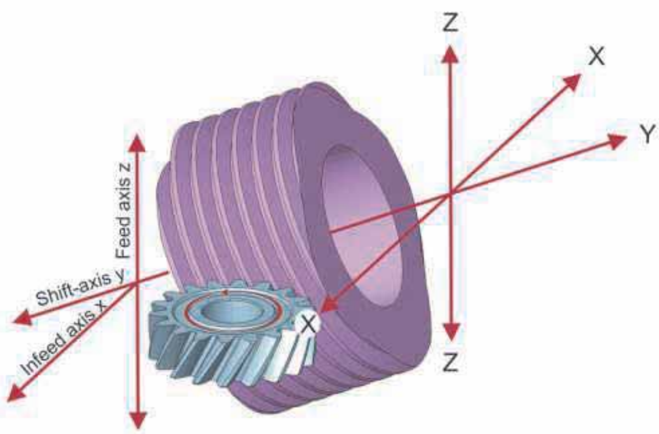


**Illustration 2: Kinematics of the continuous generating process**

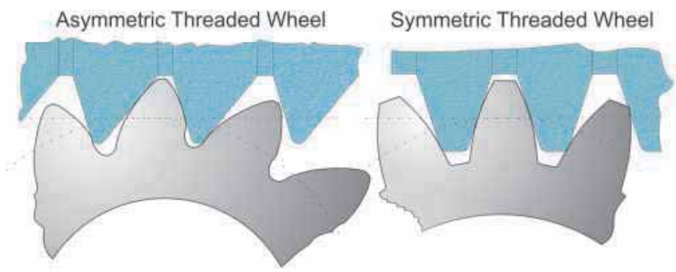


**Illustration 3: Asymmetrical and symmetrical grinding wheel profiles**

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 Reishauer continuous process allows a subsequent polish grinding stroke in the same clamping operation if a two-zone grinding and polishing threaded wheel is used. Dedicated diamond dressing rolls with asymmetrical profiles achieve the same efficiency and economy as known for symmetrical gear grinding. Illustration 4 shows the appropriate dressing tool for dressing vitrified threaded grinding wheels. Furthermore, the diamond rolls can dress the grinding and polishing section of the threaded wheel in the same dressing operation.

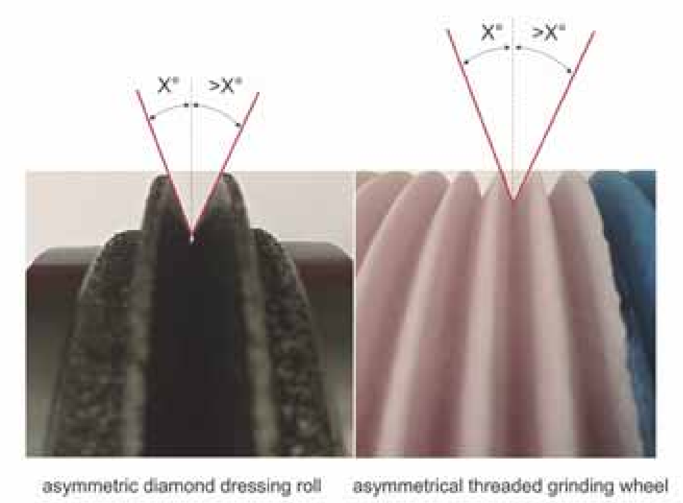


**Illustration 4: Diamond dressing roll and threaded grinding and polishing wheel**

Additionally, the automatic gear meshing, which aligns gears into the correct grinding position, required additional development work to ensure fast and reliable workpiece meshing and changing cycles. In asymmetric gears, the left and right pressure angles of the individual gear tooth are different. For this reason, the depths of grinding cuts are different for both flanks at an equal radial infeed. Hence, a continuous adjustment of the axes synchronisation via the machine's CNC control is necessary to maintain an equal grinding depth on both flanks.

## Why use asymmetrical pressure angles?

The asymmetric design of gear flanks serves to increase the load capacity of the gear flank and the gear root. As shown in Illustration 5, an increase of the pressure angle leads to a rise of the curvature radii on the gear flank as the base cylinder is decreased (point B moves towards the outside). Increasing the pressure angle also leads to a strengthening of the root load capacity. This lowers the bending load as it reduces the bending moment lever arm (point D moves downwards). Moreover, increasing the pressure angle enlarges the tooth root cross-section SF, which renders the gear tooth root more "robust."

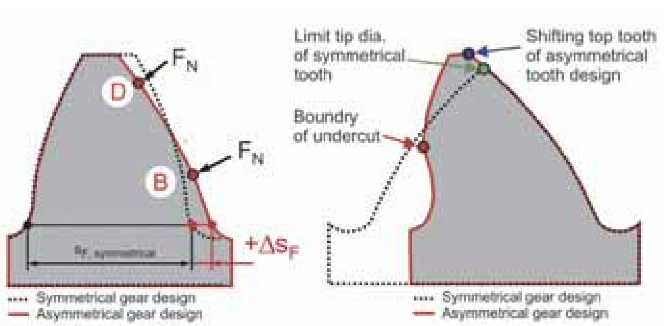


**Illustration 5: Features of asymmetrical tooth shapes**

$F_N$ Normal force on the tooth
B Inner singular contact point (relevant for the contact stress/flank load carrying capacity according to ISO 6336)
D Outer singular contact point (relevant for root bending stress acc. to ISO 6336)
$S_F$ Critical cross-section of gear tooth root acc. to ISO 6336

There are many benefits for increasing the pressure angle, with the only limitation being that the boundary line of the undercut shifts towards the tip of the tooth. By shifting the tooth top limit of an asymmetrical tooth design, the following options become available:

- Increasing the tooth-bearing load capacity
- Increasing the contact ratio
- Reducing contact stress
- Reducing noise excitations (NVH)
- Enlarging the tooth thickness at the tip diameter
- Reducing the danger of tooth top breakage caused by through-hardened tooth tips

The following gear chart, Illustration 6, shows the results of an asymmetrical automotive ring gear, polish ground with the following gear data: ≈ 60 teeth, module ≈ 2.8, pressure angle ≈ 30.5°/16.5°.

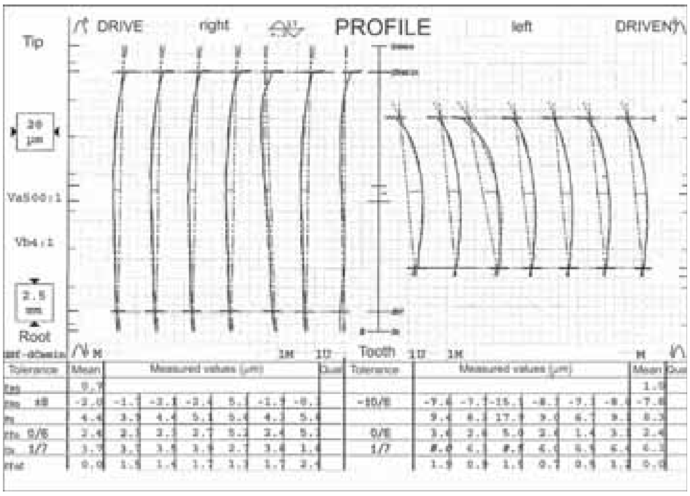


**Illustration 6: Gear chart of ring gear profile**

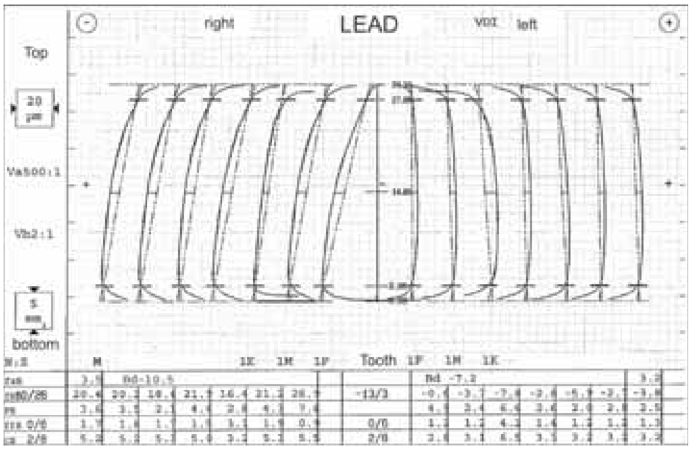


**Illustration 7: Gear chart ring gear profile**

## Conclusion

The new Reishauer machines are ready for the grinding of automotive asymmetrical gears and are used actively for projects of OEMs. The whole machine concept is very user-friendly as data input, and the operation of asymmetrical gear grinding are as easy to use as for standard symmetrical gears.

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