The Benefits of Asymmetric Gears

By Andreas Mehr

A newly developed asymmetric gear tooth generating-grinding method combines maximum productivity with superior quality.

GEAR WHEELS OFTEN ROTATE IN ONLY ONE direction throughout their entire service lives. This applies particularly in the case of cars, commercial vehicles, ships, lifting gear, or generators. In the case of these gear drives, the tooth load on one flank is considerably higher than on the opposite one. This means that little or no load is applied to opposite-coast flanks during a relatively short work cycle. An asymmetric tooth shape reflects this functional difference.

“One of the design objectives of asymmetric gear teeth is to improve the performance of primary drive profiles at the expense of opposite-coast profile performance,” said Dr. Alexander Kapelevich, president of AKGears and an expert in the mathematics of tool profiles and other parameters for asymmetric gear teeth. “Asymmetric tooth profiles make it possible to simultaneously increase the contact ratio and operating pressure angle beyond those limits achievable with conventional symmetric gears.”

Gear tooth stiffness can be significantly improved by means of latitudinal and frontal load sharing as well as by altering dynamic contact. Tooth-flank load capacity also benefits from an increased pressure angle on the stressed tooth flanks. Tooth-root load capacity is also improved.

The main advantage of asymmetric gears is contact stress reduction on the drive flanks. That results in higher torque density, i.e., ratio of load capacity to gear size. Another key advantage is the opportunity afforded of designing opposite-coast tooth flanks differently to drive tooth flanks. This effectively manages tooth stiffness while retaining the desired pressure angle and contact ratio of the drive flanks. This allows for increased tooth tip deflection, thus damping tooth mesh impact and resulting in a reduction of gear noise and vibration.

DEDICATED TOOLS REQUIRED

Kapelevich defines asymmetric tooth-root geometry irrespective of the model of gear rack that’s used, which distinguishes him from other gear technology researchers. Kapelevich’s Direct Gear Design® approach enables asymmetric gear tooth and tooth fillet geometry to be optimized to achieve maximized performance for specific gear applications. Such an approach, of course, requires special tools. Once tooth-root geometry has been optimized, Direct Gear Design also defines tool profiles and other parameters.

SMART CONTOURING

Roughing, tempering, and subsequent hard finishing (skiving or profile grinding) have been the industry standard method of producing asymmetric gear teeth for years. Skiving is effective, although it does not quite deliver maximum gear tooth quality (DIN 6 to DIN 7). Profile grinding delivers a significantly higher standard of quality, but it takes longer than a continuous generating method. Liebherr-Verzahntechnik GmbH developed its asymmetric gear tooth generating-grinding method upon customer requests. The method combines maximum productivity with superior quality.

Asymmetric gear teeth, however, represent more of a challenge in terms of the generating-grinding method as well as of grinding and dressing tools rather than the grinding process itself. Developing this innovative grinding method simultaneously raised a number of issues.

Liebherr-Verzahntechnik’s grinding and shaping technology development and consultancy team were faced by twin challenges. On one hand, they required dress-
Modified centering:
• Shifted tool/workpiece center \( X \) via radial feed \( X \)
• Compensation of different allowances \( d_s \) on left and right flanks
• Can be adjusted during setup process

Benefits of asymmetric gear teeth in a gearbox:
• Reduced tooth-root stress and contact stress
• Improved specific sliding
• Increased pitting and tooth-root bending strength
• Increased torque density (ratio of load capacity to gear size)
• Longer life
• Increased efficiency
• Reduced noise and vibration
• Increased operating reliability

Figure 2: Modified centering and the benefits of asymmetric gear teeth in a gearbox

PROFILE ANGLE ADJUSTMENT DURING DRESSING

For dressing purposes, the experts developed a software package that can work with both asymmetric and symmetric dressing units. An asymmetric dressing unit is ideal for serial production purposes. A symmetric dressing unit can also be pivoted as appropriate for prototype construction purposes. The machine features a pivot range of up to 7.5 degrees. A major challenge, as far as dressing was concerned, was the complex mathematical calculations of the degree of pivot travel required by the dressing unit. During the dressing process, the diameter of the grinding worm is reduced, which, in turn, necessitates a profile-angle correction — after each dressing sequence.

A quite different dynamic in respect to tooth-flank contact between the grinding worm and workpiece occurs during the grinding process itself, compared with conventional, symmetrical grinding processes. Because left and right tooth flank offsets change during the asymmetric gear wheel grinding process, given differing pressure angles, this requires electronic correction. This degree of correction is determined by means of modified centering during the setup procedure. In the case of asymmetric gear teeth, this centering procedure, i.e., centered meshing of the grinding worm with the tooth fillet, has to be slightly shifted and maintained during the grinding process using precision monitoring and control technology.

CONCLUSION

With the benefits of this new grinding process, asymmetric gear wheels will be used more frequently. Kapelevich’s calculations have facilitated a simple interpretation of the macro-geometry involved. The generating-grinding process can now be reliably managed as well. At the same time, Liebherr’s customers can use the generating-grinding process for initial prototyping purposes using the software package. Customers need to invest in an asymmetric dressing unit once they get to the serial production stage.

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