Direct Gear Design Drives Performance

By Alexander L. Kapelevich, Ph.D.

On custom jobs, consider Direct Gear Design — an application-driven gear development process with primary emphasis on performance maximization and cost efficiency.

Modern gear design based on the gear rack generating process was introduced in the 19th century and remains the only way to design gears today. It considers the gear rack profile as the cutting edge of the tool. In order to define the gear geometry, the designer must select the generating rack parameters such as pitch (or module), tool profile (or pressure) angle, proportional tooth addendum, and dedendum, etc. It makes gear design indirect, dependent on pre-selected (typically standard) tool parameters limiting the range of possible gear solutions and gear performance as a result.

There is a distinct difference between gear design and design of any other mechanical components. These components are designed directly based on desirable technical and market product performance for certain operating conditions. Tooling selection, in this case, is a secondary concern.

The gear generating process is not dominant in the gear industry anymore. There are high productive machining methods (gear milling, broaching, form grinding, etc.) and gear forming processes (powder metallurgy, plastic and metal injection molding, forging). Despite this, all of these processes do not use the gear rack as the tool profile; they are traditionally designed by the rack generation.

Customization is today's trend in gear transmission development. It is driven by market demand for competitive and high performance products. Modern gear design based on rack generation simply does not meet this demand.

AKGears, LLC, has developed a design methodology that is free from generating process limitations. With Direct Gear Design℠ the general idea of this methodology is "part design is primary, tool definition is secondary," and not vice versa. This is not new: almost all machinery parts are designed this way.

The rack generating-based design can be applied to a single gear. But in the same way that any gear drive must have at least two gears, Direct Gear Design is applicable to at least two gears. It defines the tooth profile by two involutes and angular distance between them. If the involutes are unwound from the same base circle, the gear has symmetric teeth (Figure 1). If the involutes are unwound from two different base circles, the gear has asymmetric teeth (gears with asymmetric teeth are used to significantly improve performance of gear drives with unidirectional load application such as propulsion gear transmissions, Figure 2). The outside circle provides the necessary top land to avoid pointed tooth tips. The bottom portion of the tooth or fillet is the area of the maximum bending stress that is initially described as a trajectory of the mating gear tooth tip. Later, the fillet is optimized to minimize the bending stress concentration. The direct designed gears can work together, if they have the same base pitch. This is a necessary and sufficient condition to define all gear mesh parameters such as the operating pressure angle, contact ratio, backlash, etc., without any of the tool parameters.

(hobbing, for example) is selected, the gear profile defines the cutting edge of the tool by reversed generation.

Direct Gear Design optimizes the gear tooth in the normal section that makes it equally applicable for any kind of involute gears such as spur, helical, bevel, worm, face, etc. It expands the current limits of the involute gear parameters:

- Minimum number of teeth is just three for spur symmetric gears and just one for helical and spur asymmetric gears. Maximum number of teeth is unlimited.
- Operating pressure range 5-85°.
- Face contact ratio range is 0-5 and higher. Range 0-1 is for helical gears with axial contact ratio > 1.0.
- One stage gear ratio from 1:1 to 50:1 and higher.
- One planetary stage (number of planets at least three) gear ratio from 1:1 to 300:1 and higher.

Fig. 1

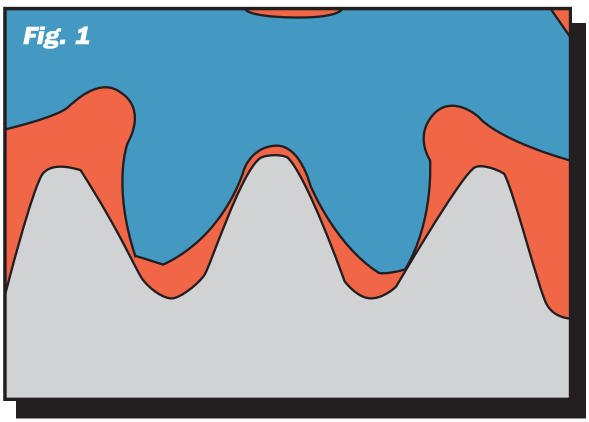
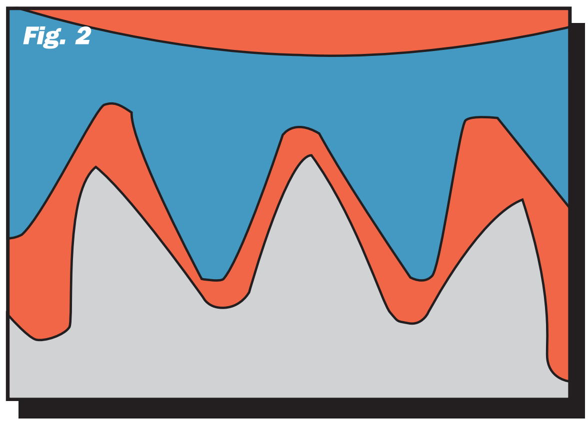


Fig. 2



Direct Gear Design can be defined as an application driven gear development process with primary emphasis on performance maximization and cost efficiency without concern for any predefined tooling parameters.

Direct Gear Design includes following stages:

- Gear mesh synthesis—initial gear geometry definition for the gear in the tight mesh (backlash is zero).
- Efficiency maximization—equalizing the specific sliding velocities for mating gears. Unlike in the rack generating method, it could be done without compromising tooth strength and stress (or safety factor) balance.
- Bending stress balance—achieving the equally strong gears by adjusting the tooth thicknesses at the operating pitch diameters. Iteration method combined with FEA is used.
- Fillet profile optimization—achieving minimum bending stress concentration along the fillet. Random search method combined with FEA is used. It provides 15 to 30 percent maximum stress reduction compared to the best rack generated gears.
- Tool design—tool parameters' definition for the selected manufacturing process. If the rack generating machining

The creativity, freedom, and flexibility of Direct Gear Design allows the user to optimize the custom gear drive for certain application and operating conditions, providing the following benefits:

- 15-30 percent increased load capacity.
- 3-5 times longer life.
- 10-20 percent reduced size and weight.
- Cost reduction.
- Increased reliability.
- Noise and vibration reduction.
- 1-2 percent increased gear efficiency per stage.
- Maintenance cost reduction.
- Other specific benefits for the particular application.

About the Author

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