The Case for Cold Rolling

By Steven Van Dyck
For many gear and spline applications requiring high strength and a smooth surface finish, cold roll forming may be the preferred process.

Powdered metal, extruded, hobbed, rack rolled, or cold roll formed... which manufacturing method produces the best gears and splines? That largely depends on evaluation and selection methods. However, for gear and spline applications with some or all of the following requirements, cold roll forming may be the preferred process:

- Optimum tooth strength;
- Severe duty applications;
- Tolerances ranging from .002” on fine gears (20 to 48 pitch) and from .003 to .005 on coarse gears (6 to 16 pitch);
- “As produced” surface finishes as good as 4 Ra;
- The desire to eliminate secondary operations, such as heat treating;
- Unique shapes and tooling flexibility;
- Standard runs from 12 feet to thousands of feet;
- Outside diameters from 3/16” to 6”;
- Steels grades ranging from low carbon (1117, 2115), medium carbon (4140, 8620) and high carbon (4130, 4150); stainless steel (316 and 416 series) and aluminum (2024 and 6061 series).

UNDERSTANDING THE PROCESS

Achieving desired characteristics in the finished product requires control throughout every step of the process. Cold roll forming starts with bar stock, typically 12’ long, that is free of flaws and uniform in ductility. Materials with a 20 Rockwell C hardness or less work well. As noted above, carbon and alloy steels can be used, but in some cases:

![Fig. 1: The cold roll forming process strikes the raw bar stock simultaneously from its top and bottom.](image-url)
cases require annealing. In all cases, keeping accurate lot and heat treatment records is critical for ensuring repeatability.

The raw bar stock is rough turned to strip away surface imperfections and to control the shape to within .015 or .0020” of its final size. The turned stock is then passed through a two-roll bar straightener or punch straightener and then run through a centerless grinder that grinds it to an exact predetermined stock size, which is between the root diameter and outside diameter of the finished gear.

Once in the rolling machine, the leading edge of the drilled and tapped bar is pulled through the forming rolls and indexed for precise spacing of the teeth. A bushing supports the trailing end of the stock by its outside diameter.

**METAL DISPLACEMENT**

To shape the round bar, two forming rollers positioned at the top and bottom of the bar (see fig. 1) simultaneously strike the bar. These rollers displace the exact negative

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**Fig. 2:** The cold roll tooling displaces, not cuts, metal in an exact negative of the desired shape.
shape of form into the bar (fig. 2). The rollers then leave the rolling area, at which time the bar stock indexes. The rollers again make contact, forming the next tooth and space. While indexing in this manner, the bar stock also continuously advances on its longitudinal axis. Feed rates vary from a fraction of an inch to several inches per minute depending on bar diameter, material hardness, and pitch.

With cold roll forming, the tooling actually displaces material from the dedendum, or the area from root to the pitch circle, and pushes it up to form the addendum, or tooth tip area. With no elongation in the bar stock the area of raw material displaced is exactly the same as the area from which it was displaced. The process can roll an even or uneven number of teeth, but only with symmetrical patterns.

The process of displacing metal rearranges the grain structure of the material over the entire tooth profile (fig. 3). It increases yield and tensile strength over the entire area, but especially at the root area, where strength is most crucial. In applications requiring durability, or when other gear forming methods have produced a less than desired lifecycle, increased tooth strength is the number-one reason to examine the cold roll forming process.

The surface of a cold roll formed product is work hardened, with the amount depending on material composition, hardness before rolling, depth of tooth form, and feed rate of rolling. Not all material works well for the same shape. For example, some aluminum and stainless grades may be formed to produce a shallow gear or spline tooth, but cannot be used to produce a deep tooth because the material work hardens too quickly and will not flow up to fill in the tooth form.

The roll forming process also produces a very high surface finish. Ra 4—“mirror” or ASTM #8—readings have been produced. In some applications, notably load-bearing ones, smooth surfaces better support the lubrication film and extend component life, where
rough surfaces break up the film and may lead to premature component wear.

As one example of the benefits of cold roll forming, a power tool manufacturer had been hobbing and heat treating their gears to get added life. By switching to a cold roll formed gear, the manufacturer found that they could use the part without heat treating. In fact, after four life cycle tests produced the same outstanding results, they stopped lifecycle testing.

Fig. 4: The Grob standard spline formula is extremely simple and flexible. Also, note that design is parallel over two or more teeth.
A UNIQUE SPLINE

One unique spline design combines the strengths of both parallel-sided standard spline and the higher tooth count and self centering of standard involute splines. The “Grob standard spline” (fig. 4), with the same tooth depth as a parallel-sided spline, has three times the working surface.

The matching parts are broached with close tolerances in the chord area, allowing more clearance in the major and minor diameters. A cold rolled spline, in conjunction with a cut sleeve or flanged bushing (fig. 5), creates a smooth sliding fit, even under load. Several NASCAR teams use the Grob design to create a collapsible steering column, as does major international truck company because it has proven more durable than the previous spline. For similar reasons, several well-known off highway and agricultural OEMs use the Grob spline design for their PTO drive shafts.

Fig. 5: The unique design of these cold roll formed splines and cut broaches offers three times the contact area as a standard parallel-sided spline.
FLEXIBILITY
While as little as 1’ of bar stock can be rolled, most cold roll formed gears and splines begin as 12’ lengths of stock that are then cut to exact length desired and finished as required. Note that material does not need to be rolled end-to-end. It can be rolled just on one or both end of an otherwise smooth bar to create a shaft of any length. Forms can also be rolled on tubing and sheet meal as well (fig. 6).

Grob has tooling on hand for thousands of shapes. However, because the actual forming tool itself is quite small, creating unique shapes or adjusting existing designs—such as for adjusting backlash, noise, or force per tooth—can be achieved quickly and new tooling machined in a matter of hours, and at the lowest cost possible compared to other gear manufacturing methods. Coupled with tight tolerances, high strength, and a smooth surface finish, cold roll formed gears continue to fill an important need in many gear and spline applications.

Fig. 6: While solid bar stock is the norm, tubing and sheet metal can also be formed by cold rolling.

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