HOTSEAT

jackTITUS
Director of process and developmental engineering, AFC-Holcroft

ALL GEARS BEGIN THEIR LIVES AS A FORGING, casting, hot-rolled bar, billet, powder metal, and, most recently, directly from 3D printing (additive manufacturing). Depending on the application, there then may be subsequent operations such as cold forming, instead of machining, to create the final shape.

Most gear applications require a strengthening process after final machining or forming, such as of carburizing and neutral hardening of steel, flame hardening, or austempering for cast iron and nitriding for steel (as well as cast iron). After the initial forming processes and before final machining still other heat treating is required to assure that all of the alloying elements especially carbon are in solid solution and uniformly distributed in austenite.

Forging (hot) from billets is a common practice that produces a blank in the basic shape of the gear or pinion. Billets are rectangular bars cut or extruded from hot rolled slabs or continuous cast steel to specific sizes, to accommodate the mass of an individual gear blank. During the forging process, flow lines that conform to the blank's cross section are created—these lines represent a segregation of the alloy. If hardened in this condition stringers of soft material (low-alloy regions) parallel to the flow lines of richer alloy will create excessive distortion when quenched and uneven wear in use.

Normalizing is the process that homogenizes the blank's microstructure thereby distributing the alloy more uniformly throughout the part's shape. Since much of the forged blank's surface will be machined away normalizing is usually performed in air or direct [gas] fired cast-link furnaces at plus or minus 1700°F [926°C] and allowed to slow or air cool outside of the furnace. Batch furnaces are also used with the load cooling in a separate cooling chamber like a top cool. This cooling process although not intentionally accelerated, in the continuous furnace, usually results in some small percentage of martensite which in combination with other NMTP [non martensitic transformation product] provides for an ideal machining capability; if cooling is too slow, [annealed] the microstructure will consist of pearlite, cementite and ferrite a very soft composition making automated machining difficult.

From smaller cold formed steel [pucks] gears can be cold pressed into the final shape and size, teeth and all. To allow the steel pucks to be forced, via steps into the gear's shape the steel must be as soft as possible; it must be annealed. The spherodize annealing process reheats the hot rolled bars [prior to cold forming into pucks] in a protective atmosphere to coalesce the carbon into small evenly distributed cementite [iron carbide, Fe3C] spheres creating the softest microstructure possible. Depending on the number and severity of the forming steps the part may be annealed between each step until the final shape is achieved. The need to anneal the cold formed gear between the forming steps can be better understood with the everyday steel wire clothes hanger. Try flexing the hanger back & forth until it becomes stiff and finally breaks. This phenomenon is called "cold working" or "work hardening". The same distortion of the lattice structure occurs in the gear as the steel is forced through the dies with extremely high force.

> From smaller cold formed steel, gears can be cold pressed into the final shape and size, teeth and all.

Again depending on the gear's size it may also be made simply by cutting pieces of hot rolled steel rounds that are directly fed into an automated gear cutting machine. Although bars can have banding segregation in the center of the longitudinal direction, the middle portion of the bar is machined away creating the gear's ID thus the segregation is removed.

In reality all gears regardless of size evolve from castings, large billets formed by the pour from the refining ladle. Once cooled the multi-ton bloom is further massaged into a large rectangular block that is sent into the rolling mill to be processed into square and flat bar, round bar, structural shapes, plates and finally sheet metal. Eliminating the primary rolling process, steel can also be continuously cast in one long bar from a single melt that emerges from the casting machine in a continuous stream going directly into the secondary forming processes.

Whichever process is used to produce the gear, the designer is becoming faced with fewer options due to the desire to reduce carburizing time. Micro-alloyed steels are being produced to reduce the potential grain growth while carburizing at higher temperatures and this creates the need for very precise steel chemistries forcing an increase demand for near neat shape processing to save material cost. A significant quantity of steel today is made from scrap where possible and that means melting a range of material compositions, not so easy for precise chemistry control so making steel from oxide pellets and more raw material is required combined with such things as vacuum re-melting among others.

ABOUT THE AUTHOR:

Jack Titus can be reached at (248) 668-4040 or jtitus@afc-holcroft.com. Go online to www.afc-holcroft.com or www.ald-holcroft.com.