Hardening techniques

There are many benefits to be reaped from contour spin hardening with the multifrequency method

The induction heating method used for small- and medium-sized gears is often referred to as spin hardening. This is because the gear is placed within an induction coil and spins as eddy currents are induced. Spin hardening is divided into two main methods: through hardening and contour hardening. The latter is a hardening method that hardens only the contoured edge of a work piece. This method is divided into single- and multifrequency processes (also known as the simultaneous dual-frequency method). With the former, a single generator feeds the inductor. Austenitizing is achieved either in a single heating, or by preheating the gear to 550-750°C before heating it to the hardening temperature.

This multifrequency process uses either separate or simultaneous frequencies. Using separate frequencies achieves hardening profiles similar to case hardening. The process applies two different frequencies one after the other to the gear. The teeth are preheated at a low frequency to 550-750°C. The frequency should be such that preheating occurs in the root circle area. After a short delay, use of a higher frequency and specific power achieves austenitizing. Accurate monitoring systems are essential, as heating times are measured in tenths of seconds during this final heating phase.

With the simultaneous multifrequency method, a lower and a higher frequency feed into the inductor at the same time. Hardening is achieved by heating the root circle with the lower frequency, and the tooth tips with the higher frequency (Figure 1). Unlike the separate, or stepped process, preheating is not always required when using the simultaneous multifrequency process. However, the short heating times used with simultaneous frequencies place high demands on the generator and machine engineering. Figures 2 and 3 show examples of hardening profiles achieved with this method.

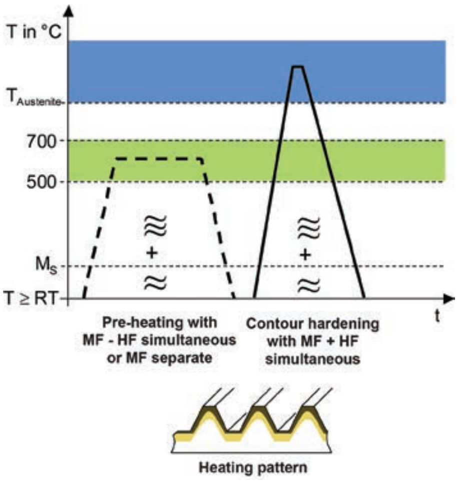

Figure 1: A schematic time-temperature graph for simultaneous dual-frequency contour hardening (MF = lower frequency; HF = higher frequency)

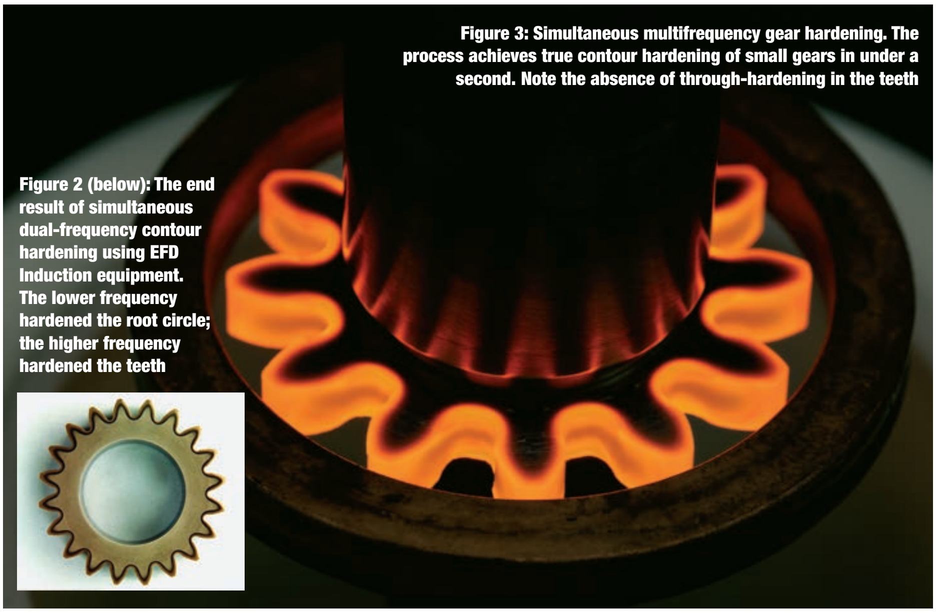

Figure 3: Simultaneous multifrequency gear hardening. The process achieves true contour hardening of small gears in under a second. Note the absence of through-hardening in the teeth

Figure 2 (below): The end result of simultaneous dual-frequency contour hardening using EFD Induction equipment. The lower frequency hardened the root circle; the higher frequency hardened the teeth

Correct quenching is critical for optimal spin hardening results, and should be performed as soon as possible after final heating. The time gap between heating and quenching can be minimized by using a fast CNC axle to position the spray head, or by integrating a quench circuit into the inductor. During the quenching phase, the rotational speed of the gear is decreased to below 50rpm to avoid a shadow effect on the flank opposing the direction of rotation.

Due to short austenitizing times, the initial steel structure must be close-grained (ASTM 7 and above). Non-homogeneous pearlite-ferrite initial structures are not suitable. Initial structure and carbon content increase in importance as module size decreases. If an increased quenching distortion is acceptable, inductive pre-quenching and tempering prior to contour hardening can greatly improve the gear's ability to harden.

Module size is another key factor in spin hardening. For the multifrequency method with simultaneous frequencies, the range is $2.2 < m \leq 5$mm. However, for cost reasons the gear diameter should be limited to $d \leq 250$mm. For modules of $m \leq 3$mm, the stepped multifrequency method is preferred. This is because a final hardening phase with only the higher frequency achieves better hardening at an irregular distance to the face. The single frequency method is almost exclusively used for internal ring gears with a module where $m \leq 1.25$mm, such as those frequently used in automotive automatic transmission systems.

Spin hardening is a versatile and reliable process that can harden spur-toothed, helical spur, and internal gears at an irregular distance to the face. However, different gear forms influence the hardening results. With helical gearing, an asymmetrical hardening of the tooth flank at a depth of up to 2-3mm from the gear face has to be accepted. This situation is however only pronounced with helix angles of $\beta \geq 28°$. Patented coils are available that limit this effect by enhancing power distribution. TTI