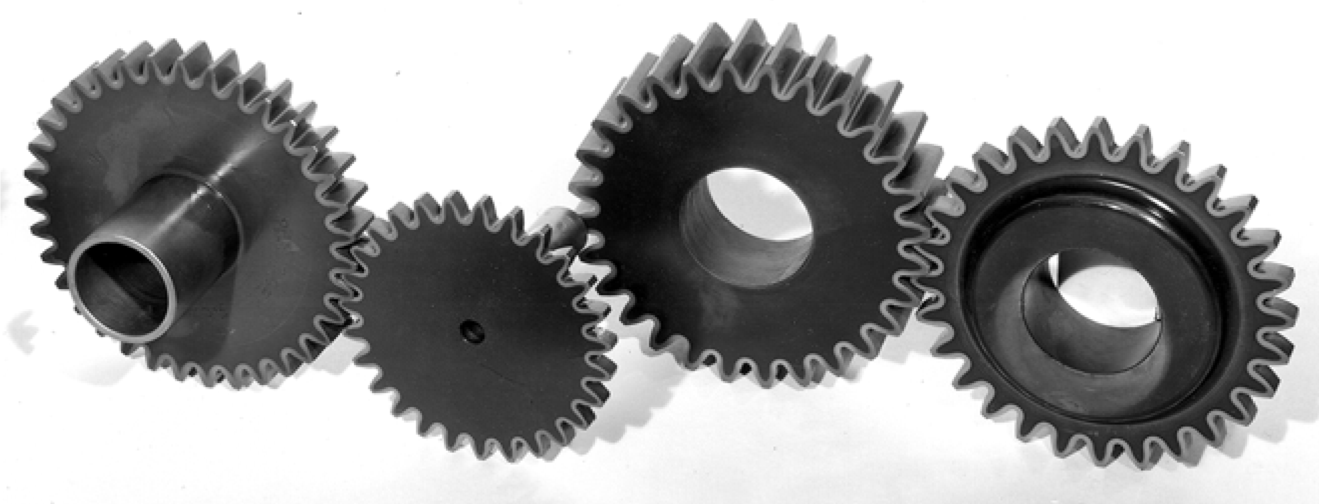
Induction hardening gear

In recent years, gear manufacturers have gained additional knowledge about how technology can be used to produce quality parts. The application of this knowledge has resulted in gears that are quieter, lighter, and lower cost, and have an increased load-carrying capacity to handle higher speeds and torques while generating a minimum amount of heat.

Gear performance characteristics (including load condition and operating environment) dictate the required surface hardness, core hardness, hardness profile, residual stress distribution,grade of steel, and the prior microstructure of the steel [1].

In contrast to carburizing and nitriding, induction hardening does not require heating the whole gear



(Figure 5 Induction hardened gears).

A major goal of induction gear hardening is to provide a fine-grain martensitic layer on specific areas of the part. The remainder of the part is unaffected by the induction process.Hardness, wear resistance, and contact fatigue strength increase.

Another goal of induction gear hardening is to produce significant compressive residual stresses at the surface and in a subsurface region[1]. Compressive stresses help inhibit crack development and resist tensile bending fatigue. Depending upon the required hardness pattern and tooth geometry, gears are induction hardened by encircling the part with a coil (so-called “spin hardening”) or, for larger gears, heating them “tooth-by-tooth” (“tip-by-tip” or “gap-by-gap”).

“Gap-by-Gap” induction hardening of gears

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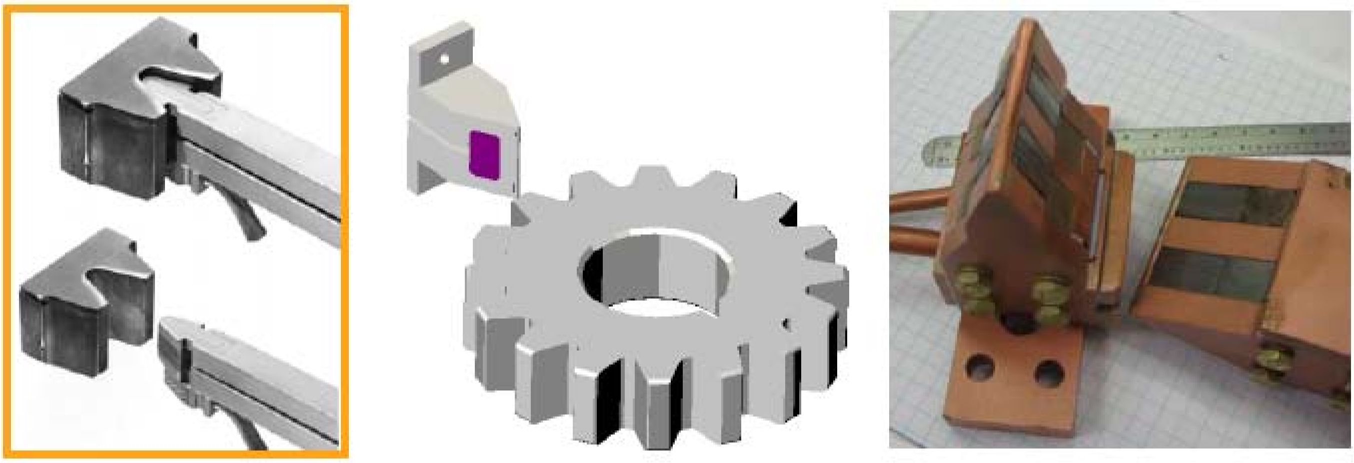
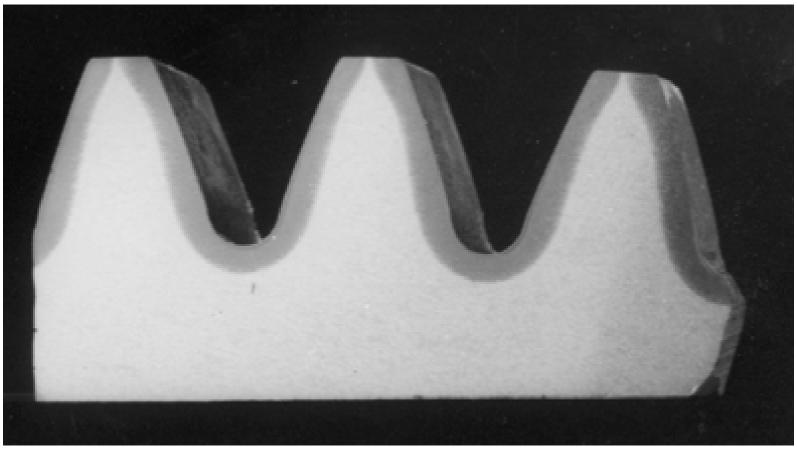


“Gap-by-Gap” gear hardening principle and typical inductor designs

“*Gap-by-Gap*” technique requires the coil to be symmetrically located between two flanks of two adjacent teeth (Figure 6). Hardening inductor can be designed to heat only the root and/or flange of the tooth, leaving the tip and tooth core soft, tough and ductile (Figure 7).



“Gap-by-Gap” pattern profile

There are many variations of coil designs applying these principles. Probably two of the most popular inductor designs are shown on Figure 6. Applying a single-shot or scanning heating mode can realize “gap-by-gap” gear hardening technique. Scanning rates can be quite high, reaching 15” per minute and even higher. Coil geometry depends upon the shape of the teeth and the required hardness pattern. Both “tooth-by-tooth” and “gap-by-gap” techniques are typically not very suitable for small and fine pitch gears (modules smaller than 6).

Gear spin hardening

Spin hardening: Spin hardening is particularly appropriate for gears having fine- and medium-size teeth (Figure 8). Gears are rotated during heating to ensure an even distribution of energy and quenchant. When applying encircling coils, there are five parameters that play important roles in obtaining the required hardness pattern: frequency, power, cycle time, coil geometry, and quenching conditions.

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Figure 8. Examples of gears that use induction spin hardening techniques

Different patterns can be produced by properly controlling these parameters. Figure 9 shows a variety of induction-hardened patterns. They were produced by varying heating time,frequency, and power.

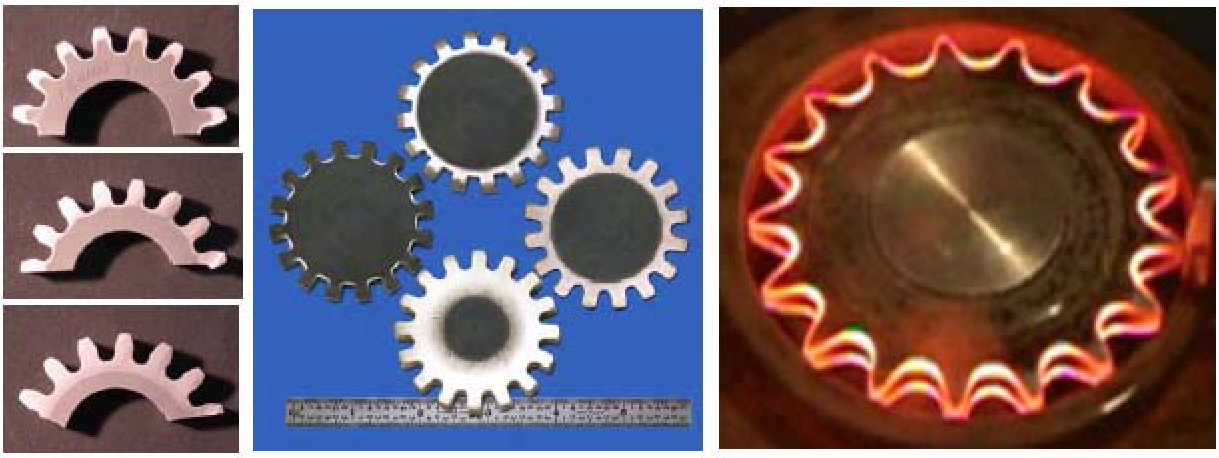

Figure 9. Diversity of hardness patterns obtain with induction spin hardening

As a rule, when it is necessary to harden only the tooth tips, a higher frequency and high power density should be applied. To harden only the tooth roots, use a lower frequency. A high power density generally gives a shallow pattern, while a low power density will produce a deep pattern with wide transition zones. Hardness pattern uniformity and repeatability depend strongly on the relative positions of gear and induction coil, and the ability to maintain the gear concentric to the coil.

There are four popular heating modes used for the induction spin hardening of gears that employ encircling-type coils: the conventional single-frequency, pulsing single-frequency, pulsing dual-frequency concepts and simultaneous dual-frequency. All four can be applied in either a single-shot or scanning heat treating approach [1,2]. The choice of heating mode depends upon the application and equipment cost. As an example, Figure 10 sows induction hardening of automotive7 transmission component. There is a helical gear on the inside diameter and large teeth on the outside diameter for parking brake. Both I.D. and O.D. require hardening. Frequency of 200kHz was used for hardening fine teeth and 10kHz was used for hardening large teeth.

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