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Recent Inventions and Innovations in Induction Hardening of Gears and Gear-like Components

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Presentation focuses on recent inventions and innovations (last 4–6 years) in induction hardening of gears and gear-like components, including but not limited to:

- “Know-how” in controlling distortion of induction hardened gears.
- Simultaneous dual-frequency induction hardening.
- Advanced induction hardening process recipes when hardening small and medium size gears.
- Novel inductor designs to minimize a distortion when induction hardening of hypoid and spiral bevel gears.
- IFP technology for induction gear hardening.
- Induction tempering and stress relieving of gear-like components with improved temperature uniformity.

Presentation also provides a review of basic principles and applications devoted to induction hardening small, medium and large size gears using tooth-by-tooth techniques and encircling method.

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Depending upon the gear size, required hardness pattern and tooth geometry, gears are induction hardened by encircling the whole gear with a coil (so-called “spin hardening of gears”), or for larger gears, heating them “tooth-by-tooth” [1–6].

“Tooth-by-tooth” hardening

Tooth-by-tooth method comprises two alternative techniques: “tip-by-tip” or “gap-by-gap” hardening [1–4]. “Tip-by-tip” method can apply a single-shot heating mode or scanning mode. While “gap-by-gap” techniques exclusively applies the scanning mode. Inductor scanning rates are typically within 6 mm/sec to 9 mm/sec. Both “tip-by-tip” and “gap-by-gap” techniques are typically not very suitable for small and fine pitch gears (modules smaller than 6) [1,2].

According to the “tip-by-tip” hardening, an inductor encircles a body of single tooth. Presently, this technique is not used, because the hardening patterns typically do not provide required fatigue and impact strength. “Gap-by-Gap” hardening is much more popular technique compared to “tip-by-tip” method. This is the reason why the term “tooth-by-tooth” hardening is often associated with the “gap-by-gap hardening method. “Gap-by-Gap” hardening requires the inductor to be symmetrically located between two flanks of adjacent teeth. Inductor geometry depends upon the shape of the teeth and the required hardness pattern. Special locators (probes) or electronic tracing systems are often used to ensure proper inductor positioning in the tooth space.

Two scanning techniques used include one where the inductor is stationary and the gear is moveable, and the other where the gear is stationary and the inductor is moveable. Later technique is more popular when hardening large-size gears. Inductors can be designed to heat only the root and/or flank of the tooth, leaving the tip and tooth core soft, tough and ductile (Figure 1). Though this is one of the oldest hardening techniques, recent innovations continue improving quality of gears heat-treated using this method.

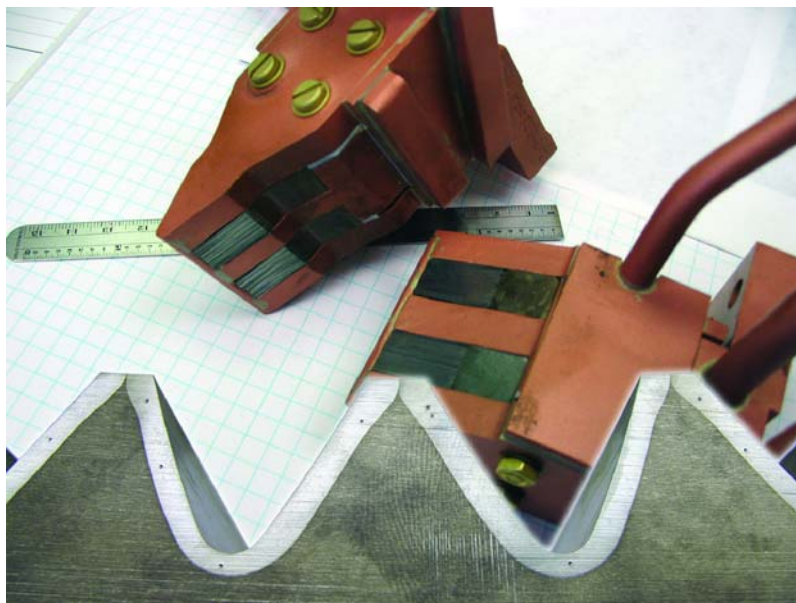


Figure 1. In tooth-by-tooth hardening, inductors can be designed to selectively harden specific areas of gear teeth where metallurgical changes are required [2]