Simple solution for a typical induction scan hardening problem

PROFESSOR INDUCTION

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When purchasing an induction hardening machine, it is not unusual to choose a system with an extra margin of available power (10 to 20%) to accommodate a potential future growth in production. It seems to make good sense: the required increase in scanning speed can be simply compensated for by a corresponding increase in applied coil power. However, once the scanner starts to produce parts at a higher rate using a higher scan speed, it might suddenly be observed that hardness specs aren't being met and / or hardness readings are inconsistent (scattered soft and hard spots). This month's column examines the causes of these not unusual problems, and explains how to fix them.

Scan hardening basics

Scan hardening of steel is one of the most popular applications of induction heating. It is done to enhance specific properties of the material that include but are not limited to strength, fatigue resistance, and wear resistance.[1] In scan hardening, the part to be heated is typically held between centers. Heat is then applied while either the part or the inductor is moving. This type of system is flexible with respect to part length and, to some extent, outside diameter. Scanners can vary scanning speed and power, which control the amount of heat applied to different areas of the part. Depending on the workflow of parts, an induction scan hardening system can be vertical, horizontal, or even at an angle. Vertical scanners are the most popular (Fig. 1).

Inductors: Scan inductors may be of single-turn or multiturn design. The number of turns required is determined by the ability to load match (load tune) the coil to the power supply or by specific process requirements.[1] The longer the inductor, the faster the possible scan rate — a longer inductor can heat the part for a longer time.

Fig. 1 — A dual-shaft vertical induction scan hardening machine in action. Quenching is taking place below the single-turn MIQ (machined integral quench) inductors.

Single-turn inductors, with a narrow heating face, are used when a sharp hardness pattern run-out or a short longitudinal transition zone is required. An example of this is where a pattern must end near a snap-ring groove.[1] Single-turn inductors are typically machined from a solid copper bar, which makes them very rigid, durable, and repeatable. Multiturn coils often are fabricated from copper tubing.

When scanning vertically, quenching is done below the inductor. This lets gravity pull the quenchant down. The quench barrel and quench holes can be integrated into a single-turn scan inductor. This type of inductor is sometimes called an MIQ (machined integral quench) inductor (Fig. 2).

Parts that have a continuous pattern around their perimeter are usually rotated during scan hardening. The rotation ensures consistent heating and quenching along the perimeter. Part rotation should be smooth and wobble-free.

First potential problem

A common problem that can occur when trying to increase scan speed with a corresponding increase in applied power involves inconsistent hardness readings (scattered soft and hard spots). This typically is the result of incomplete austenitization. It is important to remember that raising the heating rate affects the kinetics of austenite formation by increasing all critical temperatures.[1, 2]

Depending upon the initial microstructure of the part — annealed, normalized, or quenched and tempered — it might not be enough to just increase the power. Steels with large stable carbides (annealed and spheroidized microstructures) naturally have a poor response to induction hardening, and thus require prolonged heating and higher temperatures for austenitization. And microstructures having coarse ferrites would also require a certain minimum amount of time to allow carbon to diffuse into the carbon-lean ferrite.[1]

Solution: If metallographic examination reveals "ghost pearlite" or "an excessive amount of free ferrite," then an appropriate increase in coil length must accompany the increase in applied power to properly compensate for the faster scan speed. Bear in mind, however, that an increase in coil length also results in a longer transition zone.

Second potential problem

Lower-than-expected hardness readings is another problem that can occur when scan speed is increased with an appropriate increase in the power applied to the coil. In these cases, adjusting only the power level and / or coil length might not help.

To ascertain the cause of the problem, remember that hardening is a two-part process: heating and quenching. If scanning speed is increased, both heating time and quenching time will be shortened. As already mentioned, a reduced heating time often can be compensated for by an appropriate increase in applied power (to keep the induced energy level approximately the same) and / or by adjusting coil length. However, compensating for a quench time reduction requires a different approach. The objective is to ensure a martensitic case, avoiding the formation of upper transformation products, such as upper and lower bainite and pearlite, which can result when quench severity is less than that required for martensite and the cooling curve "enters" the upper transformation region of the steel's CCT (continuous cooling transformation) diagram.[1] In addition, insufficient cooling might lead to an undesirable "tempering back," which results in reduced hardness of the as-quenched part.

Solution: If lower hardness is observed, the first step is to conduct a metallographic analysis of the as-quenched part. If the microstructure contains tempered martensite or upper transformation products, then a too-short quench is probably the cause. To ensure proper hardening, increase the quenchant flow rate and / or add or enlarge the quench follower (Fig. 2, at right). **HTP**

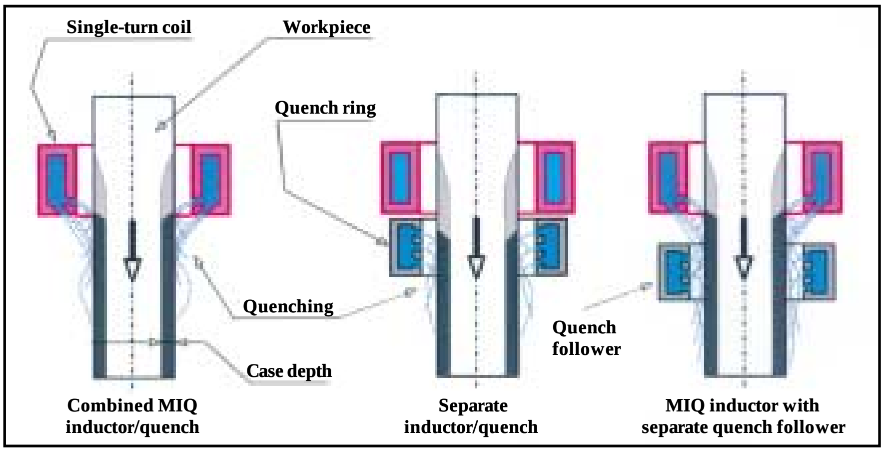

Fig. 2 — Combined and separate inductor/quench designs for vertical scan hardening systems using single-turn coils. The designs at left and right use MIQ inductors. The design at right has a quench follower below the MIQ inductor. Ref. 1.

References

1. *Handbook of Induction Heating*, by V. Rudnev, D. Loveless, R. Cook, and M. Black: Marcel Dekker Inc., New York, 2003, 800 p.
2. "Can the Fe-Fe3C Phase Transformation Diagram Be Directly Applied in Induction Hardening of Steel?," by V. Rudnev: *Heat Treating Progress*, Vol. 3, No. 4, June / July 2003, p. 27.