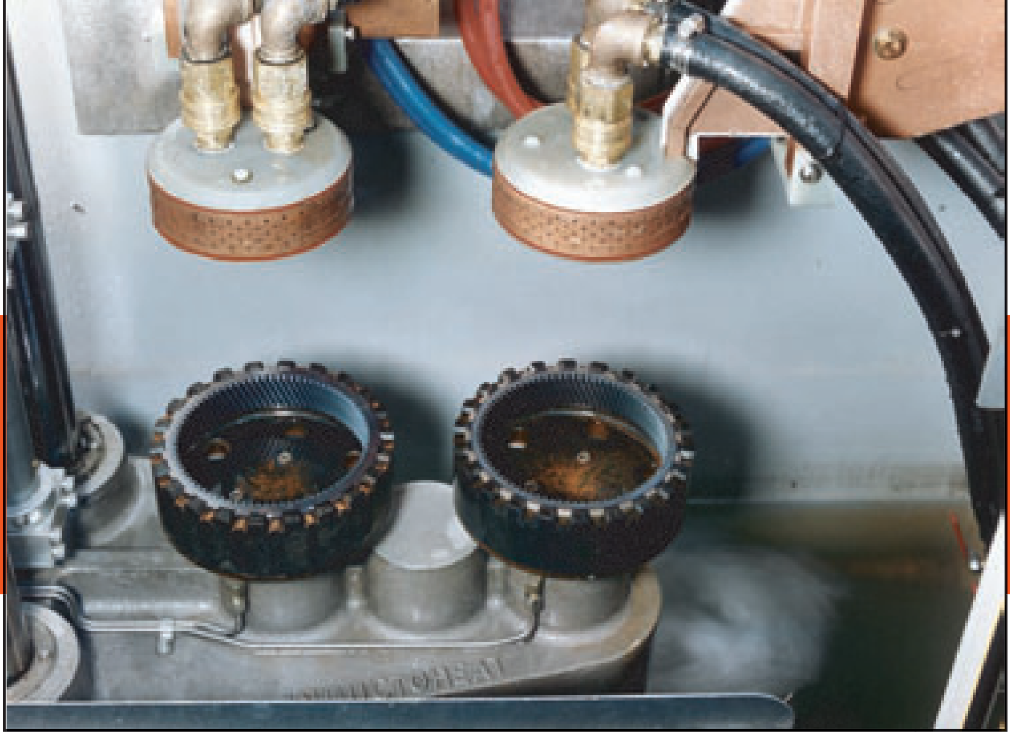

THE

Ring gears from Inductoheat.

Gear Up for Induction Hardening

— Daniel J. Williams

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Management Summary

Part one of this series on induction hardening of gears, originally printed in the March/April 1998 issue of *Gear Technology*, provided a step-by-step guide to assist readers in specifying induction hardening equipment. Part two covers machine preventative maintenance and modification of machinery to induction harden different gears.

So, you have purchased your induction heat treating system. This machinery is an integral part of your production line and needs to run consistently around the clock. What can you do to assure that your induction hardener is able to run three shifts a day, seven days a week?

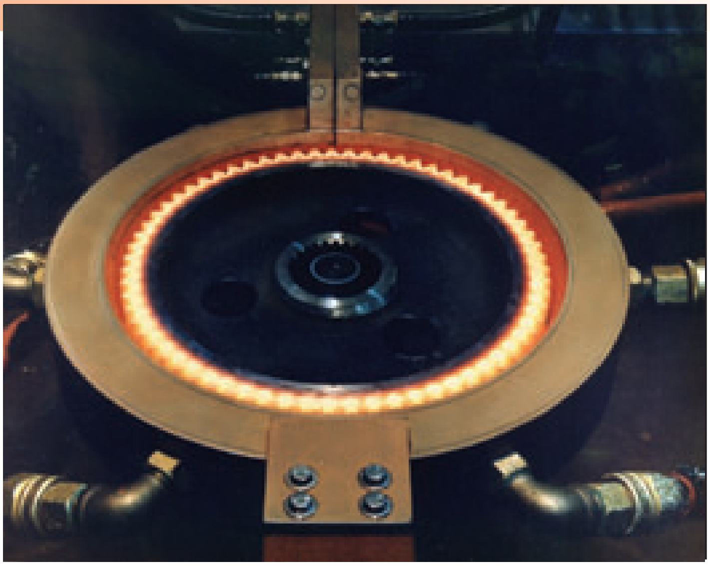
Along with preventative maintenance, which should be performed by your induction equipment supplier annually, the checklist below should be followed. Routine maintenance is the best way to assure that the machine produces quality parts and remains in good working order. These procedures should be performed daily:

1. Inspect a cross-section of a gear coming off the induction hardener by performing a destructive test followed by an acid etch. Examine for pattern location and hardness Once a week, a sample should be prepared, mounted and inspected for desirable microstructure. If parts are prone to cracking problems, magnetic particle inspection should be utilized until the root cause of the problem can be determined and eliminated. If the possibility of cracking persists, non-destructive eddy current inspection can be used for 100% inspection and automatic sorting of cracked parts. Inspection of the part assures its quality and is also used to confirm that machine motions are operating within specifications. Maintenance of the guide shafts and ways is confirmed with precise accurate motion.

2. Inspect all percent meters on the induction power supply inverter to assure consistency with expectations.

3. Inspect the quench water additive to assure desired ratio is consistent with expectations and recommendations. Polymer quenchant manufacturers should be consulted for each application to assure compatibility with other fluids that may be introduced.

HEAT GOES ON



Gears in the midst of one of Inductoheat's hardening processes.

4. Check the quench temperature. If it's too cold, the part will crack. With a quenchant that's too warm, the required level of hardness will not be obtained.
5. Assure that the number of kilowatt-seconds is consistent with expectations.
6. Inspect the quench filter and clean or replace as necessary. If the filter is plugged, quench flow will be restricted and proper hardening will not take place. On newer systems, pressure gauges across the filter should be checked. Older systems require that the canister be manually opened and visually inspected.
7. Observe several machine cycles to assure that the part is properly rotating.
8. Inspect the coil and bus connections for debris, and ensure the connections are tight. Field service technicians frequently are called to plants when arcing occurs, only to discover that the coil and bus connections are loose.
9. Assure that the isolation transformer connections are tight.
10. Check quench holes for obstruction and clean as needed. The quench ring often (unfortunately) acts as a quench filter and collects particles (scale), which eventually cause blockages in quench flow. This reduces the cooling effect of the quenchant, leading to inconsistent results.
11. Assure that the inductor coil is properly located with respect to the part. Check for concentricity between the coil and part in the known heat treat position.

Every six months, drain and clean the quench tank, then replace the fluid. Clean or replace all filters and check quench holes for obstructions. Then, inspect coil for cracking around quench holes.

Be sure to also check for loose hoses internal to the power supply.

Machine Modification to Handle Various Gears

As a follow-up to these points, this article will discuss ways to modify induction hardening machinery to handle additional gear applications.

Can I use my induction system to process a different gear?

Gear #123 is being successfully processed on your induction hardening system. However, your company has just received a large contract to manufacture gear #789. Part prints show that gear #789 will require induction hardening. Rather than immediately deciding that new equipment is the order of the day, it may be possible to retool an existing system. The following factors must be considered:

Capacity. Is there open capacity on current induction machinery? If your answer is yes, continue considering a retool. If not, purchasing an additional piece of equipment may be your only option.

Machine's frequency. Part prints will indicate the case depth required for gear #789. Frequency selection is very important to obtain specified results.

Too low of a frequency will leave the tooth tips unheated. On the other hand, heating with too high a frequency will not heat the root area and will overheat the tips (see Fig. 1).

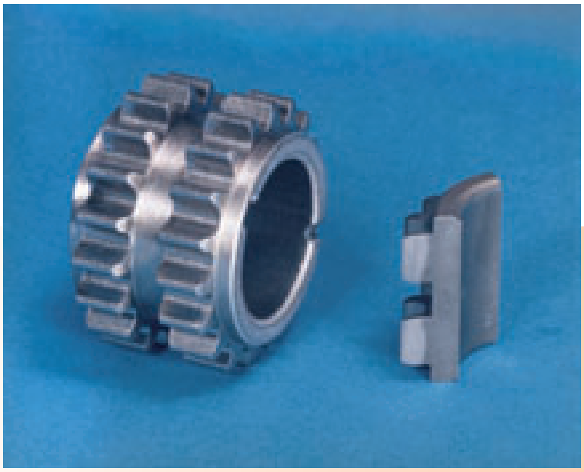
Even if the frequency does not match that used on the current equipment, it may still be functional by adding 25–50% to the "heat on" interval. If the frequency is far out of range, you may consider purchasing a more appropriate power supply and having it installed in the existing machine platform.

Table 1—Examination of Power Supply (Frequency and Power).

	Analysis Available vs. Required	Action
Frequency	The available frequency is greater than or equal to the required power supply	Use existing power supply
Frequency	The available frequency is too low	Buy new power supply
Power	The available power supply is greater than or equal to the required power supply	Use existing power supply
Power	The available power is too low	Buy new power supply

Power. Power determination is calculated based on five major factors: prior microstructure of the part; material; case depth required; diametral pitch; and surface area to be hardened. Further experiments establish power levels for a thermally hardenable material with three different microstructures (annealed, normalized, and quenched and drawn). If the required power is equal to or less than that currently owned, move ahead. If not, consider buying a new, larger power supply to be installed in the current machine platform.

Part size. Will gear #789 fit into the machine? The existing induction equipment does have certain space limitations. The maximum diameter of gear #789 (or any gear) cannot exceed center-to-center machine constraints (approximately 10" in this example).



Sprocket gears are among those most suitable for induction hardening.

Both single- and dual-spindle machines offer options. If the major diameter of gear #789 exceeds 10" on a dual-spindle machine, a simple solution is to utilize only one spindle to allow for more space. In other words, a dual-spindle machine is modified to become a single-spindle. If gear #789 does not exceed the 10" maximum, a dual-spindle machine can continue to operate as a dual-spindle.

Tooling. If your examination determines that this job can be processed on existing equipment (i.e., open capacity exists and the power and frequency are acceptable), then retooling the machine is the next step. An important tip: Locator tooling is best purchased from the same company designing and building the inductor coil. Proper locator tooling is essential to minimizing or eliminating part distortion.

Perishable tooling includes locator tooling. Part touch tooling, as the name implies, touches the part. It is designed by looking for datum surfaces that are repeatable within 1/10 the tolerance of the heat treat specifications. The lateral position and height must also be established in the case of vertical machines. Concentricity of the gear within the coil must also be examined.

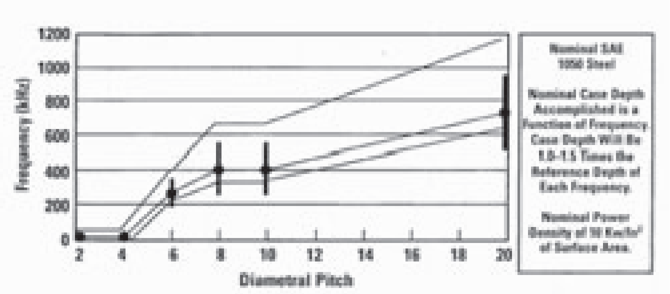


Figure 1—Proper frequency selection is needed to accomplish even heating across the part. It may be possible to have a new power supply installed in the current platform.

Ideally, tooling will be non-ferrous to avoid corrosion or inadvertent heating by the magnetic field of the inductors. Mild steel can be used in cases where the locator tooling is sufficiently spaced from the inductor coil. Zinc dichromate or electroless nickel coating will enable mild steel to weather the quenchant.

Inductor. Inductor coils are application-specific and, therefore, gear #789—and most others—will require a new coil. An inductor coil will be designed nominally with an air gap that is no greater than 1.50 times the reference depth of heating for the given frequency. Quench holes will be selected to obtain 5–10% coverage on the coil heating face. Locator tooling and inductor coils are best developed by your induction equipment supplier before committing to a rebuild, a new power supply or even a new machine. Advance process development is completed to assure that metallurgical results obtained are satisfactory and acceptable. Quite often, results are not as hoped and part material, heat treat specifications and even product design may require modification. Locator tooling, inductors and process development are completed to establish satisfactory metallurgical results.

Buying Locator Tooling and Inductors

Although development of new part locator tooling may seem an easy task to a team of experienced engineers, it is actually best designed and built by an induction equipment supplier. Locator tooling is imperative to a successful induction process, as it establishes the correct relative location between the part and tool.

Locator tooling can also affect distortion of the part and should be designed in a way that minimizes distortion of the gear itself (i.e. taper and runout). Proper or improper design can prevent or add to distortion. Furthermore, locator tooling must be validated to assure that the part is not being distorted.

Choosing a material able to survive the induction environment is an important part of the design process. The selected material must be:

a) Able to withstand the proximity to the magnetic field and not intersect lines of flux;
b) Impervious and not affected by repeat exposure to quench; and
c) Self-cleaning.

Unless the gear in question is already in production and a suitable coil has been designed and built, a metallurgical laboratory is needed to test the coil and prove the process.

Inductor coil designs are difficult to predict. A design-build-develop (DBD) program, completed by an induction equipment supplier with an in-house metallurgical laboratory and a full-time metallurgist, is the best source for obtaining the proper coil. Repeated lab testing may reveal that the coil requires several slight modifications (e.g., air gaps and size specifications).

A quench barrel may be required in some cases. For instance, when the outer diameter of the gear requires quenching while the inner diameter is heated. Process development is required to assess whether a quench barrel is required.

Likewise, use of magnetic flux concentrators can only be confirmed via prior development.

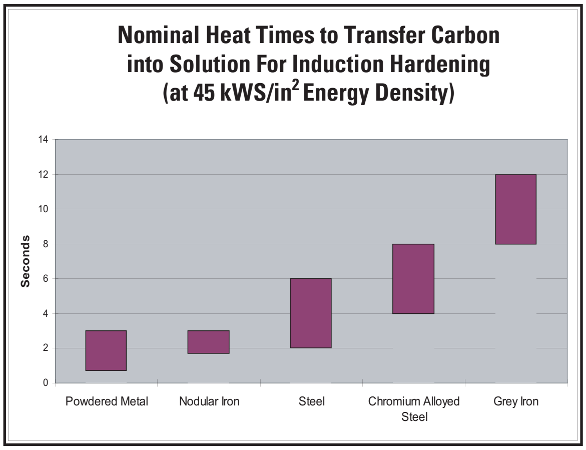


Figure 2—Typical power-on times for single-shot heating generally range between 2–20 seconds. (For scan heating, assume 0.25–2.0" per second.)

The equipment supplier's lab source will need guidance with respect to accomplishing desired results within the power supply size and power supply frequency constraints of the existing machine. For example, avoid allowing your induction equipment supplier's met lab to develop a gear hardening process at 200 kHz, if you have 30 kHz available. (Or until they prove that the 30 kHz just won't do the job.)

Quench barrel. A quench barrel may be needed for quenching out of position.

Finally, after obtaining satisfactory metallurgical results, the supplier's lab documentation is needed to confirm plans for implementation at your existing facilities. Get a quotation from your supplier for production-worthy tooling and implementation. This would include inductor coils, quench rings, locator tooling and any necessary machine modifications for adapters for the existing equipment to accept the new tooling and process. This would be an ideal time to consider replacement of the induction power unit with a variable frequency induction heating power supply, which enables future flexibility of the existing equipment. Field service may also be specified to assist with initial setup and debugging of the gear heat treat process.

Competitive pressure forces management to consider how to make more gears, of the same and of different types, on the same or lesser equipment, with no or minimal capital outlay. Careful consideration needs to be given to existing equipment's capability and flexibility before investing more cash into production equipment.