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Tips for Selecting Induction Heating Equipment

Induction heating equipment is one of those areas that many of us need to know more about. We need to know when and how to apply this technology, if it is the right one for the job and how to purchase it if we need to do so. Let's learn more.

The following factors typically influence equipment design:

- Material
- Prior microstructure
- Part geometry
- Austenitizing temperature
- Production rate
- Power requirements, kW*
- Frequency selection, kHz*
- Pattern/profile (shape of heating area)
- Coil design*
- Process-development requirements
- Application-specific criteria (e.g., water versus polymer)
- Method of loading and unloading the workpiece (e.g., manual or robotic)
- Stock removal after heat treatment
- Type of tempering (furnace/oven versus induction)

* Typically selected by vendor based on information provided.

Key process parameters for induction heating include:

- Type (single-shot or scanning)
- Power level
- Frequency
- Part position (rotation)
- Quench flow and pressure
- Quench temperature
- Quench time
- Quench concentration (if polymer)

Questions to Ask

The following questions (and their answers) will help educate the buyer:

- How many kilowatts do we need to do the job?
- What frequency is needed for the case depth required?
- How does the part get placed into and removed out of the machine?
- How many different coil sizes (and types) will we need to cover our range of parts?
- How does the control system work? Are the computer screens user-friendly, and do they have the type of information you need?
- Do we need an optical pyrometer as part of the control system? What are the effects of overheating and underheating, and how can we reject parts based on temperature criteria?
- What, if any, temperature differential will there be, from one end of the part to the other, from center to surface?
- What input voltage do we have in the plant?
- What type of plant cooling system is needed? If existing, is there unused capacity?
- How much will the machine cost to operate per unit of time? Are there demand charges for electricity (on-peak or off-peak)?
- How much will it cost to install?
- What maintenance needs to be done on the equipment? How frequently does maintenance need to be performed?
- How much (floor) space and headroom is needed and in what configuration?
- Do we need ventilation or an air exhaust system?
- Should we wash the parts prior to induction heat treating?

In addition, here are some specific items to focus on.

Power Supply

Power, expressed in kilowatts (kW), refers to the induction power-supply size. A power supply must be sized to heat a given mass or given surface area to a specific temperature within a specified time. A general rule of thumb is that the surface area (exposed to the coil) used to determine the power level is 6-12 kW/inch^2. The prior part microstructure (annealed, normalized, quenched

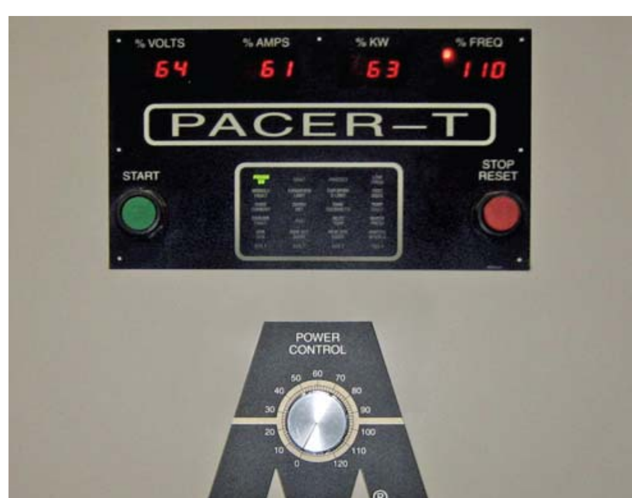

Fig. 1. Near-perfect tuning match

and tempered) will influence the power density (kW/inch^2) required. For example, a quench-and-tempered microstructure is optimum for most induction applications.

More power is not necessarily better. Matching the power and frequency is the key. While more power lets you heat faster, it may also melt the surface or produce a deeper pattern (there is also more danger of through hardening), and it is harder to control grain growth.

Frequency

High frequency in the form of alternating current is passed through the coil to create a magnetic field producing eddy currents. These are generated within the metal under the surface, and the resistance to this current flow is the principal source for heating of the metal.

The following guideline for "relative" depth of penetration (depth of hardening or case depth) as a function of frequency might be useful. This information is application-specific and dependent on both power density and heat time but is considered typical of what is found in the industry:

- @ 450 kHz the case depth developed is (approximately): 0.030-0.040 inch
- @ 100 kHz the case depth developed is (approximately): 0.050-0.080 inch
- @ 30 kHz the case depth developed is (approximately): 0.080-0.120 inch
- @ 10 kHz the case depth developed is (approximately): 0.090–0.200 inch

The depth of current penetration (hardened depth) is a function of part diameter and the resistivity of the material. There is an optimum depth of current penetration range, which is what each manufacturer strives to provide.

Higher frequency has a distinct advantage when you have marginal prior part microstructures (annealed or normalized). Higher frequency allows the concentration of more energy near the surface of the part, avoiding long heating times or requirements for higher power density (more costly in terms of \$/kW).

Tuning

Tuning (power-supply load matching) is a very important consideration to achieve the desired case-depth profiles and for overall power-system efficiency. This is done by adjusting the tap of a variable-ratio transformer or by adding/subtracting a portion of a capacitor to achieve the desired frequency and a balanced load match between amperes, volts and kW. These are typically viewed on a meter panel on the power supply.

The goal is to have a system that requires a minimal amount of tuning, which becomes more important as power levels approach the maximum nameplate rating of the power supply. For consistency of heating, the power supply should be tuned so that it is not running to its limit.

Computer-controlled and recipe-selected automatic capacitor contactors can be used to load match when many different workpiece sizes are heat treated on the same piece of equipment. Many power-supply manufacturers design a tuning window that allows you to make some changes to the part size being run. When only one part is dedicated to a system, no tuning is required after initial setup and testing.

Coils

All workpieces have their own function, shape and properties. Coils (inductors) are water-cooled copper tubing or machined from solid copper blocks. They are designed and built specifically to meet the metallurgical requirements and production rates of the workpiece. Coils require periodic maintenance (repair) and must be suitable for the applications whether it be scanning, static heating or single-shot heating.

Scanning inductors (Fig. 2) may be single-turn or multi-turn design. The required number of turns is determined by the ability to load match (tune) the coil to the output transformer in the power supply or to match specific process requirements. Too wide a heating zone affects the end of the pattern's transition zone. Scanning allows use of a smaller kW power supply and is easily adapted for a manual or an automated process for running a variety of different part diameters or lengths.

Single-shot inductors (also known as

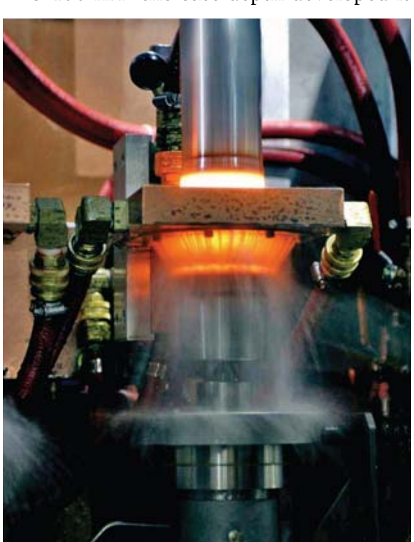

Fig. 2. Steering component heated with a machined single-turn coil

Fig. 3. Single-shot coil

static inductors) are designed for a specific heat-treatment pattern on a specific workpiece and are commonly used in high-production applications (Fig. 3). They usually have very short heat times and have a fixture to position the part and rotate while heating. Quenching can occur in the coil, or the part can be indexed to a separate quench ring or a submerged tank with agitation.

Induction systems that need different coils to heat treat various workpieces use quick-disconnects so that no hand tools are required to change the coil. Systems heat treating just one part size with one coil can utilize bolt-on connections and hose clamps (requiring tools to change).

Controls

Control packages should be based on functionality, need and budget constraints. Factors such as how often one changes inductors, the number of shifts of operation, the skill level of the operator, the complexity of the workpiece (or pattern) and product end-use application all play a part when selecting what types of controls are best. Controls can be as simple as the power-supply kW output rotary pot with a timer. An ideal control package would utilize a Windows-based-software operator computer with a color screen that has recipe storage and can hold hundreds of workpiece process requirements.

A computer-based control system can store data such as dwell times, quench pressure, flow and temperature levels for a particular workpiece, kW at the coil and scan speed. Maintenance checklists and drawings or even a video of how to change the coil can be stored on hard drives.

Future Needs

A key ingredient of any successful purchase is flexibility and adaptability to new innovations. The following list will help you determine if you need this feature now or decide if it will be incorporated on the machine in the future. It will also help you figure out how much will it cost?

- Automatic adjustment of the power-supply frequency
- Automatic inductor-changing carousels
- Automatic recipe development
- Computer calculation of the power levels, scan speeds and dwell times necessary to process the first sample for subsequent metallurgical evaluation based on user inputs (diameter of the part to be processed, required case depth, type of material, face and I.D. dimensions of inductor)
- Automatic depth and hardness testing in the heat-treat machine
- Faster real-time processing recipe data
- Simpler and less-expensive controls
- One coil fits all size parts. **IH**

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