Induction Heat Treating: Things Remembered, Things Forgotten

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Many potential problems are not apparent when using new induction heat treating systems. The operator has been trained properly, and setup parameters are already developed. Everything is fresh in one's mind. But as the equipment ages, personnel changes or new parts are required to be processed on the old equipment, important information can get lost in the shuffle.

Now it's time to develop a new and updated checklist for the heat treating operation. In this article, we will discuss items to be included in a guideline for setups and a checklist for installation and operation of the induction system. We will also discuss the importance of the coil design, quenching, part rotation and induction temper, as well as what can be done about distortion of parts and shortcuts for nondestructive testing.

Ten Steps to Easy System Maintenance

Successful moneymaking induction systems should require few, if any, tools to change from one part to another. Great success can be achieved if you follow a few simple rules.

1. Read your OEM supplier manual.

2. Every day check the tightness of the bolts on the coil, bus work and quick disconnects.

3. Wear rubber gloves and a rubber apron when operating the equipment; wear hearing protection if needed.

4. Clean the inductor weekly or when a coil changeover is made to remove quench polymer and scale before it dries hard as a rock.

5. Before installing the coil, use a plastic scouring pad on the bus mating surface to remove foreign material from the electrical surface. Do not use sandpaper!

6. Do not use your induction system as a parts washer. Heavy oil will contaminate the quench. Chips will cause arcing and damage the coil. They will also clog the quench holes.

7. When installing the plumbing for a power supply, use only nonferrous material. Do not use aluminum, iron or steel. One single piece of iron in the cooling system will cause rust in the water recirculating system. Use copper, brass, 300-series stainless or Schedule 80 PVC pipe.

8. Clean the water cooling system at least once a year or as instructed in your OEM manual. Check the conductivity of the water system used to cool the power supply every three months. If you ignore rules seven and eight, your induction system will not last ten years and will give you problems constantly.

9. Never disconnect or jumper the ground detector circuit. Never operate the power supply or heat station with the doors open; replace door gaskets as needed. Keep the dirt out!

10. If you see sparks, overheating or smell anything funny, shut off the equipment immediately and find the problem before further damage is done.

The Setup

Change the coil via quick disconnects. Quench hoses should use "Hansen" quick couplings as shown in Fig. 1. Use one size coupling for quenching and another for coil cooling water. This eliminates the possibility of getting the hoses confused. Avoid using "O" rings. They are high-maintenance.

Tooling cups and centers for part support should not require any tools, yet they should be rugged enough to support the part without wobbling. The machine operator should use a setup sheet with all data pertinent to the job. Don't rely solely on his or her memory to adjust the machine to get a good pattern. The setup sheet or control memory should yield a good part. Only qualified personnel should be allowed access to change the program.

Fig. 1 — Machined integral quench coil with quick disconnect for power, water and quench.

A minimum of 5–10kW per square inch of coil face is required to get good results.

The Coil

The distance between the coil turn or winding and the part (coupling) should be kept to a minimum to reduce power consumption and time cycles.

If the part wobbles during rotation and touches the coil, do not make the coil coupling larger. Fix the rotation bearings!

If the copper coil is discolored, especially down the center leg, it is from overheating. More water cooling or less kW per square inch is required. By adding a booster pump in the coil water circuit, more heat can be removed from the coil. Remember, heat in the coil or tooling is your enemy. You want the heat in the part.

Every six months, flush the inside water cooling path of the coil with a "Lime-Away" type solution. This prevents buildup of salts that precipitate out of the water at 135°F. These salts look like a white powder adhering to the inside of the coil tube. This powder insulates the copper from the water, and the coil fails prematurely.

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This happens often on high kW density applications, especially on pancake-type coils, when heating the inside of a hole (I.D.), and on tooth-by-tooth coils. On I.D. heat treating applications, the failure of the coil occurs on the inside (down the center) leg. This is where the water temperature is the greatest. Make sure that on I.D. coils, the coolant water enters down the center leg first.

Machined coils shown in Fig. 1 are the most expensive type, yet they last the longest. Tubing type is the least expensive, but it can be bent with the bare hand. Precision work should always use machined coils, or setup time will increase and slight variations in the pattern from one setup to the next will develop.

Never change the wall thickness of a coil. The original OEM designed the coil wall thickness for a maximum kW density, current density, heat dissipation and frequency. The result of too thin or too thick of a wall is coil meltdown.

Quench is Everything!

Check polymer percentage every morning with a refractometer after the quench has been on and recirculating for a few minutes, but before any heat treating takes place. Recirculating will stir up the quench and give an accurate reading. It will also remove any air trapped in the quench lines. Use a timed quench temperature heater set up like a house thermostat. This turns on the heater for an hour or so before production starts, ensuring that every part sees the same quench temperature.

Quench temperature should be automatically controlled with a heat exchanger and solenoid valve. More than a 10°F window of operation can result in more distortion or a better chance of cracking the workpiece.

The volume or flow rate of quench can never be too great in most cases. The more quench, the faster the part can be processed. Spray shields, doors and enclosures should prevent the operator and floor from getting wet. Never place rag-type shields in the quench. As the polymer attacks them, they dissolve into the quench and plug the small holes in the quench barrel.

Quench barrels and integral quench coils should have at least four quench water inputs for even distribution. If in doubt, with the power supply turned off, the workpiece removed and the quench on manual, stick your hand into the quench and "feel" if one side has more force than the other. Uneven quench will result in more distortion. Use a standard ball valve to adjust for even flow around the quench.

The quench impingement point, the angle at which the quench strikes the part, is important. It needs to be a perfect cooling circle. If a single hole in the quench head is not at the correct angle, it can cause the barber pole effect as shown in Fig. 2. Sometimes foreign matter can become lodged in the hole and cause the same barber pole effect. The smaller the diameter of the workpiece, the more important the impingement point is!

If the quench has a bad smell, it is growing fungi. Agitation or operation will induce oxygen into the quench, but this is only a quick fix to cover the smell. Disposal and cleaning should be done every six months to a year. Check with your quench sales representative.

Distortion

On scan heating applications, if you cannot heat a part and keep it straight, you surely cannot heat and quench it and expect it to be straight. If you are having distortion problems, run the normal cycle without quench applied. Let the part air cool and check the distortion. If it is not straight, you will never keep it straight with quench on. This distortion is usually caused by prestresses in the part. If the quench head is made of PVC material, you must remove it for this test because the radiant heat will melt it without quench running through it.

Special attention should be given to parts that require hardening over keyways or holes. To avoid overheating, melting or cracking, keep the kW density down by adjusting the power level and the scan speed. Look closely as the part is heating. Only experience teaches what 1550°F looks like. Once you have "the eye," you can see the difference between 1550° and 1900°F.

For those just learning, temperature sensitive sticks or paints work well as indicators. Paint small stripes of different temperature values (1500°, 1550° and 1600°F, for example) in the area to be heated. Leave the quench off and pay close attention to the part as it heats. You will see the paint melt and change colors. If the paint does not change color, the temperature was never achieved.

Never attempt to induction-harden frozen workpieces. Your part recipe is based on material at 70°F heating to 1550°F. If frozen material is processed, the same kW will yield 1470°F, resulting in low hardness.

Part Rotation

If the workpiece is rotating slowly enough to count the rpms visually, then rotation is too slow. Scanners with slow rotation can yield a barber pole effect. The barber pole's soft rings can sometimes be seen by the naked eye as shown in Fig. 2. Speeding up the rotation will narrow the rings to less than .125", which should result in a good part.

Rotation has less effect on single shot heat treating. However, short heat cycles can result in uneven heating. If in doubt, speed up the rpms.

Make sure the part rotates evenly and smoothly. There should be little, if any, noticeable wobble in a machine part as it is rotated. The exceptions to this rule are castings and some raw forgings. They will have a wobble equal to the casting tolerance. Make sure that there is a machine surface of reference for location of the part. Raw castings usually do not have the dimensional tolerances needed for induction. Without at least a rough location (within .005"), a good consistent hardness pattern is hardly achievable.

Induction Temper

Induction tempering on a scanner is usually only done with high-volume parts because of the time it takes to develop a part recipe, as well as the tying up of machine time. Small lots of parts with similar steel grades can be set in a basket and placed in the same oven at the same temperature and at a lower cost than induction.

In the cell approach to manufacturing, induction temper is a valuable tool, provided that the material can be cooled completely at the end of the temper cycle. Some alloy materials can not be quenched during the temper cycle. They must be allowed to cool slowly before any other operations can be performed.

Between the induction hardening cycle and the start of the temper cycle, make sure that the quench delay is long enough to cool down the part to at least 150°F. Rescan the part for temper using no more than one-third of the power that was used for hardening, usually at one-third to one-half of the scan speed. The temper cycle start position should go beyond the original start point of the hardening cycle. Do not attempt to develop a temper cycle until a good hardness pattern and hardness are achieved.

The merits of "slack quenching," or leaving residual heat from the hardening cycle in the workpiece, have long been reported, but it is next to impossible on a vertical scanner. Manufacturers use slack quenching on SAE 1045 steel for cylinder rods. These are processed on horizontal scanners. The smaller the diameter, the less merit slack quenching has. In order to even have a chance of controlling this process, a top-of-the-line PLC-type controller and a kW second monitor are needed. Tight control of quench temperature, polymer percentage, pressure and flow is an absolute must.

Fig. 2 — Barber pole type rings.

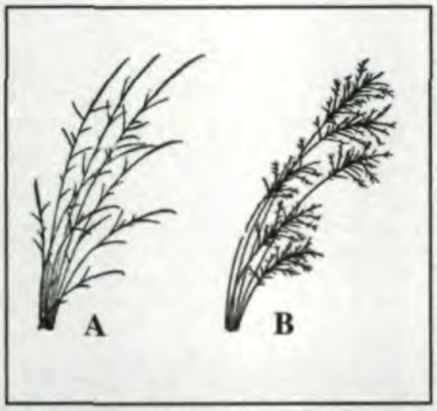

Fig. 3 — a) Sparks from SAE 1015 steel showing simple "forking effect." b) Sparks from SAE 1045 steel showing "secondary burst."

Nondestructive Testing

Sandblasting or shot peening will both yield identifiable hardness patterns: sand within seconds, and shot within minutes.

Never cut the sample unless the length of the pattern is correct. Reuse the same setup pieces or save them for next time. Full anneal before reuse. This may not work on long parts due to distortion from repeated processing.

Know how to use your Rockwell hardness tester. Get it calibrated as required. Do not let inexperienced personnel operate the tester. Use the correct load in relationship to depth of hardness. Do not be fooled by decarburization at the surface that results in soft, erratic readings. On rough-ground workpieces, check the hardness at the final grind depth, not at the surface.

After heat treatment, look for suspicious rings that are more than .125" wide. Check across and between the rings for soft barber pole. Look for uneven colors, such as silver (hard) and blue (soft) in the hardness area.

The File Check. One quick way to get a feel for part hardness is to use a file. Most files are 65 RC. Temper one file at 1100°F, one at 1000°F, etc. After slow cooling, check with a Rockwell hardness tester and inscribe the handles with the corresponding hardness. This will result in a set of files of known hardness. A file that is 45 RC will skate across a surface that is 55 RC, yet it will dig into a part that is 40 RC. Files must be replaced, depending on usage and as teeth wear off. These are to be used as a quick check only, and it does take some practice to get "the feel." They are especially useful in checking hardness in corners and between gear teeth.

The Spark Test. Much has been written over the years identifying various materials using the spark test. It is a great investigative tool when heat treating metals.

The spark test is a method for the classification of steels according to their chemical composition by visual examination of the sparks that are thrown off when the steels are held against a high speed grinding wheel. It is not a substitute for chemical analysis and is not intended for the identification of "unknown" samples. The character of spark streams is examined from a number of specimens supposedly of the same hardness. The spark burst, that is, the "carbon spark," is the most useful characteristic of the spark picture, since the variations in the number and intensity of the bursts indicate the changes in the carbon content. (See Fig. 3 for examples.)

As a commercial heat treater, I learned early that just because someone said the material was 1045 did not make it so. Many times a part is set up on the induction machine and processed with a normally good recipe. The part would show low hardness when checked on a Rockwell hardness tester. Even though the material should have gotten hard due to its carbon level, a repeated process with a little more heat would not yield the hardness required. This is the time to use the spark test.

Conclusion

Induction heat treating is a complex process that involves many intangibles. Just because the machine is producing parts does not make them right. The heat treater of today must use every advantage possible in his bag of tricks.

References:

1. Hildorf, W. G. and C. H. McCollam. "The Spark Testing of Steel," *ASM International Metals Handbook*, 1948.

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