FLUKE

Precision component manufacturer increases quality with induction heat treating

Application Note

Testing Functions
Case Study

Tools: Fluke 771 Milliamp Process Clamp Meter, 381 Remote Display True-rms AD/DC Clamp Meter with iFlex™, Fluke 289 True-rms Industrial Logging Multimeter with TrendCapture, Fluke 190-204 ScopeMeter® portable oscilloscope, Tektronix P6021 current probes

Operator: Leigh Copp, Chief Engineer and Business Unit Manager for the Linamar Advanced Systems Group

Applications: Identifying problems in solid state heat induction systemst

Creating precision metallic components that stand up to the elements and hard use requires a unique combination of art and science.

As a leading designer and manufacturer of machined components for today's sophisticated vehicle transmission and driveline systems and mobile industrial products, Linamar continues to pioneer new ways of achieving the highest quality and consistency as well as the longest wear life.

Started in Guelph, Ontario, Canada in 1966, Linamar Corporation operates manufacturing facilities in North America, Europe, and Asia, where it produces virtually every precision-metallic component used in today's light and heavy duty vehicles. Linamar also designs, develops, prototypes, tests, and manufactures complete transmission modules. In the process it turns engineering concepts into real-world products, while maintaining lean, cost-effective operations.

One key aspect of producing those parts is achieving the correct metallurgical structure to provide maximum strength and durability. To achieve that, in the past some of Linamar's customers heat-treated parts in a furnace and then quenched them with water when they had reached the specified temperature.

"The furnace heat treating process was very slow," says Leigh Copp, Chief Engineer and Business Unit Manager for the Linamar Advanced Systems Group. "Ideally you want to harden just the outside of the part where it's going to wear, and where the material provides the most strength to the part. With convection, you'd have to heat the entire part, which meant you didn't really get the quality that you'd like and it was very slow."

Linamar's alternative

In the late 1980s Linamar began moving to induction heating systems and eventually started building its own systems around induction power supplies from Inductoheat in Madison Heights, Michigan. "We have a unique mechanical design to our machines that is very robust, compact, and cost effective. We developed a very solid PLC [programmable logic controller] control system that replaces a lot of proprietary architectures. It's more serviceable, more flexible, more user friendly," says Copp.

With induction heating, a coil (or inductor), is placed in proximity to the part that is to be heated and high-frequency current is run through the coil. Through electromagnetic induction, circulating currents are induced in the part. The part acts as a short circuit so the current heats it up very rapidly. Each part requires its own unique heat treating process based on the metal, the application, and a host of other variables.

"The part has a relatively low resistance and we apply very high current (several thousand amps) to it and use high frequency—typically between 10 and 30 kilohertz—to make sure the current crowds the surface of the part," says Copp. A 10 kilohertz application would typically be used to heat the part to a depth of about 4 millimeters. To heat it deeper would require using a lower frequency. "Some of the machines that our team has built heat at 1 kilohertz and to a depth of almost 13 millimeters," he adds.

Many advantages

The advantages of induction heat treating are obvious. The parts are more consistent. It is more energy efficient because the furnace isn't idling hot all the time. Induction heating is also greener because it doesn't vent a lot of excess heat into the atmosphere.

"With induction heating, the only thing that really gets hot is the part, and the inverter is more than 90 percent efficient," says Copp. "We water-cool all the magnetic components, transformers, inductors, capacitors, power semiconductors, and the coil that wraps around the part."

Water cooling allows a much higher power density, so the power supplies take up less space. Induction heating systems are also more reliable and less maintenance intensive than furnaces because they are mostly solid state with no moving parts.

Those advantages help to explain why, since 2002, Linamar has ramped up the installation of induction heat treating systems at its facilities around the world. "We've put in over 100 pieces of induction heating equipment in the last decade. Some of those have been quite groundbreaking in terms of technology," says Copp.

Adding groundbreaking hardening techniques

The most recent innovative heat treating technology that Linamar installed was a system that employs simultaneous dual frequency. This addresses the need for different depths of hardening for various parts of a component. For example, on a gear both the tips of the teeth and the root at the base of the tooth need to be treated to prevent having a hard tooth that can be easily sheared off.

A company in Indianapolis, Contour Hardening, Inc. (CHI) pioneered a "contour hardening" technique. "With contour hardening, the hardened pattern follows the same shape as the teeth on the gear, which gives you the ideal combination of strength and ductility," says Copp.

High frequency is used to harden the surface of the gear teeth while relatively low frequency current, with its greater depth of penetration, heats the root of the tooth form. "The CHI process was really unique and used large vacuum tube oscillators at high voltages to produce the high frequencies. These power supplies can be challenging to maintain, however," says Copp.

Linamar wanted a solid state electronic version of this contour

A six-axis robot places axle shafts in the induction heat treating scanner. The process induces a very high current in the shafts, which instantly heats them. Rapid cooling or quenching hardens them.

The back of the fixture houses the power to drive the heat treating process. Leigh Copp de-energizes the entire system before going inside to take measurements.

hardening process, so they turned once again to Inductoheat. "Inductoheat came up with a hybrid solution that combines two standard products—a medium frequency (10 kilohertz) power supply and a high frequency (450 kilohertz) power supply—on the same coil," says Copp. This system hits the coil with 10 kilohertz and 450 kilohertz simultaneously from two different power supplies.

Hunting down problems

Even though solid state heat induction systems are more reliable and require less maintenance, they still act up from time to time. Occasionally, Copp and his team get calls about a heat treating machine that isn't producing consistent metallurgical results. The first step is to determine whether the problem is with the machine control or the power supply.

"If I'm asking for 75 percent of 500 kilowatts, and I've got zero to 10 volts or 4 to 20 milliamps going out there, I use a simple voltmeter to verify that I've got 75 percent," says Copp. "Then I use a Fluke 771 Milliamp Process Clamp Meter to verify the 4 to 20 milliamp loops."

Next, he opens the inverter cabinet and uses the Fluke 381 Remote Display True-rms AD/DC Clamp Meter with iFlex™ to measure the line current coming in. "The 381 is an amazing tool because of the remote display," Copp notes. High power inverters have very high incident energy on the line terminals and live bus bars inside the doors. Looking at a clamp meter inside the panel could be very dangerous.

"The 381 remote display meter was a game changer," says Copp. "I put my clamp meter inside the panel and put the display outside of the panel so I can run the inverter with the doors closed and never have to come near the live energized parts."

The controls for the inverters operate at very high frequencies and the insulated gate bipolar transistors (IGBTs) and metal–oxide–semiconductor field-effect transistors (MOSFETs) are operating very close to their limits. "With induction heat treating, we've typically got short cycles—from fractions of a second to maybe a minute—and we've got very high power density," Copp explains. "The device gets pretty hot and then just as quickly cools down with the water cooling. The power is continually cycling on and off, causing thermal cycling of the device. This in turn results in thermal fatigue of the devices as they expand and contract."

Copp uses the resistance function on the Fluke 289 True-rms Industrial Logging Multimeter with TrendCapture to measure the resistance of all the IGBTs and MOSFETs and compare

With only low-voltage control power on and the main system power locked out, Leigh uses his Fluke 190-204 ScopeMeter® and 289 multimeter to check some of the internal circuits and verify gate pulses on the large silicon-controlled rectifiers (SCRs) that switch the high frequency current.

Now that the access door is closed and the system is returned to full running order, Leigh is safe to do some electrical testing on the low-voltage display panel while, at the same time, monitor the full current draw on the internal buss with the remote display of the Fluke 381 Clamp Meter.

them. "Many of the IGBTs use a lot of parallel and series devices internally, so if you have a baseline resistance on the collector emitter junction, and you compare that down the road, you can sometimes tell if there's been a partial failure of the device," Copp notes.

If those static tests don't answer the question, the next step is to run tests with the main breaker of the machine off but with the control still on. "We force the inverter control to gate all of the power semiconductors. Then we check all the gate pulses in phase and amplitude with the Fluke 190-204 ScopeMeter® portable oscilloscope and a pair of Tektronix P6021 current probes to make sure that they're okay. As soon as you see a bad gate pulse you're almost guaranteed that you've found a bad gate driver/semiconductor device pair," says Copp.

Shortening the learning curve

While there's good science behind heat treating techniques, many of these techniques have been learned the hard way over the years. As a result, Linamar has found training to be a critical part of introducing induction heat treating. "Heat treating is often referred to as a 'black art,' and induction heat treating is mixing that black art with electrical engineering," says Copp. "A lot of the technology around induction heating seems very mysterious to many electricians and engineers, so we try to involve the plant maintenance teams in the design/build process. That way they can take ownership and have a less abrupt learning curve," says Copp.

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Fluke Corporation
PO Box 9090, Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or
Fax +31 (0) 40 2675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

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