OCTOBER 2002 / VOLUME 54 / NUMBER 10

▶ BY BRAD LEWIS, ASSOCIATE EDITOR

Current Events

Automakers are adopting eddy-current technology as a fast, reliable way to meet zero-defect requirements.

It's 2:00 a.m. and the phone is ringing. A line engineer for a major automaker—an automaker who happens to represent 80 percent of your firm's revenue—has found a defect in one of the 250,000 threaded parts you shipped last week. That one defective part has interrupted a $1-million-per-day assembly line, and the line engineer is demanding that you fly to the plant and personally verify that the remainder of the order is defect-free. Right now.

Welcome to the world of *poka-yoke* (poka-yoKAY). It's a quality-control regime imported from Japan by U.S. automakers. Basically, it requires that part shipments have zero defects.

Achieving this level of QC means conventional sampling techniques—whereby, say, one part out of 10 is tested—simply don't cut it.

To help achieve this requirement, as well as avoid a red-eye flight to some far-off assembly plant, every threaded feature and machined surface of a given shipment would need to be tested. At a minimum, this requires a GO/NO-GO, in-process measurement technology that can look at a feature as soon as it's machined and reject a flawed part before more value-added operations are performed. Meeting these stringent requirements has led some automakers and automotive-parts suppliers to turn to eddy-current technology.

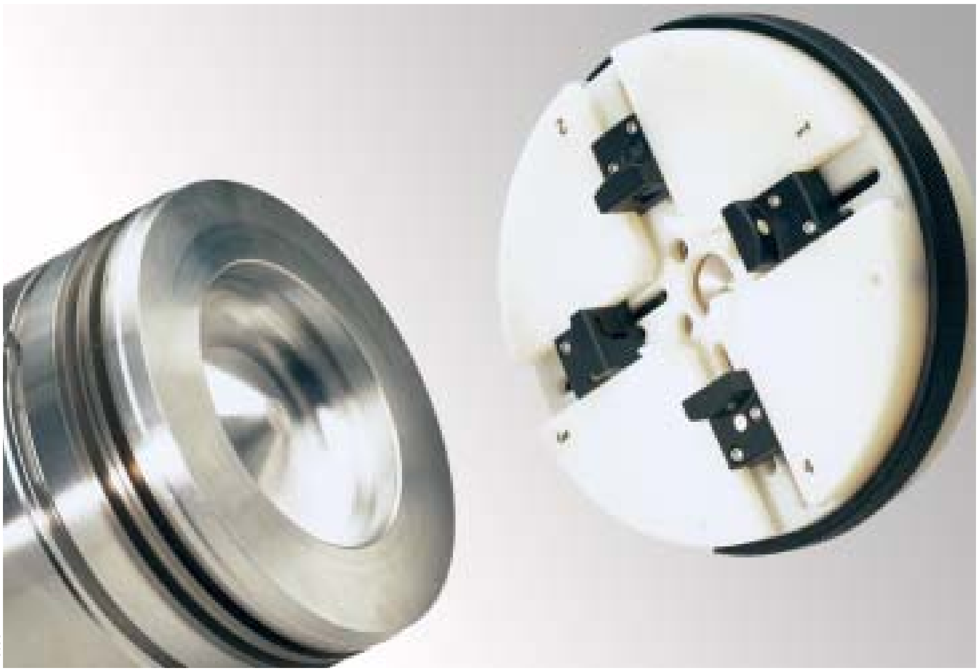
The basic science behind the technology has been known practically since the discovery of electrical conductivity itself. Furthermore, eddy-current testing (ECT) had been reliably used to test aircraft components for the U.S. during World War II. However, for technical reasons to be explained later, EC has enjoyed a renaissance of sorts as a means to quickly test machined surfaces of aluminum automotive components, particularly threads.

For example, General Motors' engine-manufacturing plant in Flint, Mich., uses EC probes to detect untapped holes and prevent those parts from getting to the vehicle-assembly plants.

"We only check tapped holes, such as motor-mount holes that don't get anything installed in them on the engine assembly line," said Bruce Holdwick, a GM manufacturing engineer. "We very rarely have defective tapped holes, so the eddy-current check doesn't have much opportunity to find bad parts, but it does offer an additional level of protection."

The Current Technology

ECT is a means by which a varying, alternating-current magnetic field is introduced into a conductive material via an electrical coil. As the magnetic energy moves through the target metal, it generates a low-level electron flow



Zetec

Zetec offers eddy-current probes to check the internal machined sections of pistons.

within the metal, at frequencies ranging from 500Hz to several megahertz. This electron flow, called the eddy current, is a secondary magnetic field, which opposes the original AC magnetic source. The eddy current is the impedance of the original charge from the coil that the test measures.

William A. Keely, vice president of sales and marketing for NDT Technologies Inc., Pontiac, Mich., said most EC systems rely on a single-coil probe, wherein a coil generates and reads its own electromagnetic field, similar to how a radar system emits and reads its own signal. Only, instead of acoustic or radio waves, EC systems emit and read electrical energy.

Because this is, essentially, a test of a material's electrical conductivity, nonferromagnetic materials, such as aluminum, make excellent candidates for ECT. Thus, with the increasing popularity of aluminum automotive parts, the technology is gaining ground with automakers.

An aptitude for nonferromagnetic materials, however, does not restrict ECT to only aluminum and austenitic stainless steels. Ferrous workpieces, such as iron castings, can be tested using ECT, but only after modifying the equipment to compensate for their decreased conductivity.

If the metallic compositions of the good part and the unknown part are slightly different, due to the unknown part's heat-treat state, material composition or shape, the instrument indicates this difference. Dan DeVries, marketing manager for Zetec Inc., Issaquah, Wash., pointed out that surface and subsurface material defects are also detectable with ECT.

Of course, to make the test valid, the instrument must learn what a good part is. Therefore, prior to implementation, the instrument is "nulled," or balanced, on this part, after which the profile is compared to an unknown part in an actual test. The material profile from a known good part becomes the master against which all other parts are measured. The test often simply matches the signatures and rejects parts if they are out of spec. However, the profile also can be expressed as a bell-curve signature for in-depth study.

NDT Technologies

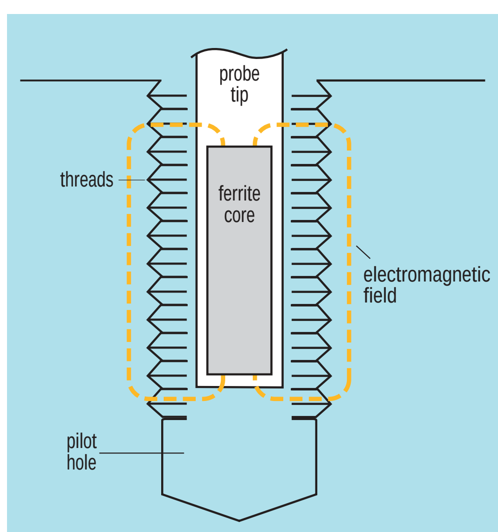
At General Motors' engine plant in Romulus, Mich., an eddy-current test system checks multiple tapped holes simultaneously.

NDT's Keely told CUTTING TOOL ENGINEERING that ECT can discern four specific parameters of a material: chemistry, hardness, geometry and temperature. All these parameters affect the conductivity of the material and, therefore, the eddy currents generated within the material.

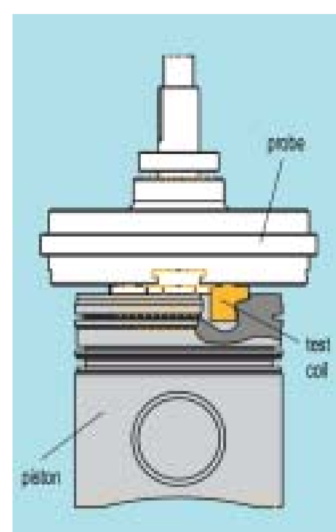
The hardness parameter is used when testing a material's heat treatment. Chemistry differentiates material suppliers. According to Keely, temperature is often an irrelevant parameter, since all materials are tested at the same temperature.

In the realm of threading, geometry is, of course, the parameter that concerns manufacturers most. Not only can ECT determine all the geometric parameters that would be gleaned from a manual thread gage, such as major, minor and pitch diameters, Keely said ECT can also detect the roughness of the threads and thread depth, all within 0.1 seconds.

Because the technology is relatively straightforward, it's applicable to most machining operations. According to



Eddy-current thread probes discharge electrical energy as a means of checking major, minor and pitch diameters.

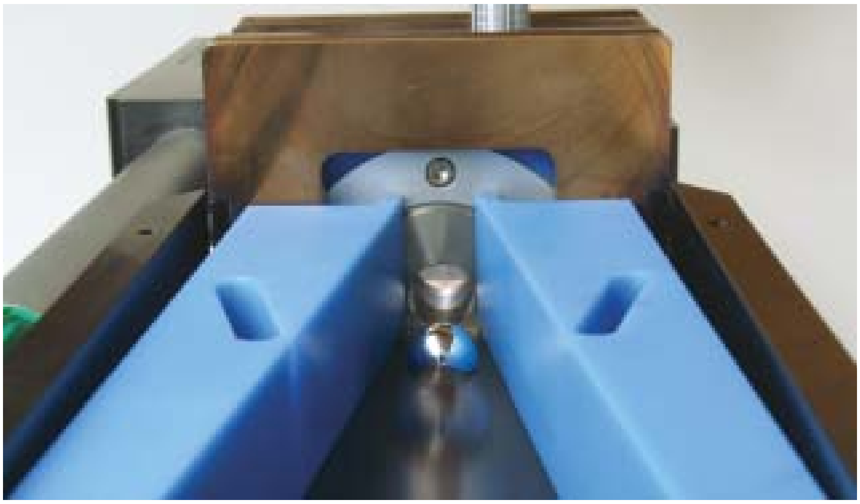


Zetec

This cutaway diagram shows that proper alignment is critical to effective ECT.

Greg Nygaard, president of General Inspection Inc., Davisburg, Mich., ECT can be customized for use "anywhere you add, remove or displace metal." This, he said, includes splines, ball bearings, keyways and external threads.

The downside to applicability, however, is that once an ECT system is set up for an operation, it only applies to *that* operation. It is not a full-geometry inspection regime. It only applies to the feature that has just been machined.



Zetec

Besides tapped holes, eddy-current technology can also test ball bearings.

Material Thoughts

A manufacturer must take into account certain factors when considering whether to use ECT. The first is the material to be tested.

Again, highly conductive materials, such as aluminum, provide ECT the greatest depth of surface penetration into the machined features of the workpiece, from 0.10" to 0.25", or greater, according to DeVries.

He said steels allow only a minimal depth of penetration, because they're ferromagnetic. However, he explained there are ways to get around that. For example, magnetic saturation is a process whereby a large magnet is put on the steel workpiece and "arranges" the material to nullify its ferromagnetic properties.

"One of the ECT products we manufacture is for testing tubes and bars, and it includes two halves of an electromagnet," DeVries said. "The coil is right in the middle of it, creating a magnetic field that allows the probe to 'look' deeper into the material," he said.

Testing cast material from different suppliers is completely manageable.

"Since ECT is a mastering process, if you have two suppliers, you have to have a good master for each," Keely said, "The base material for those two suppliers' blocks is going to be different."

Of course, machinists have to keep track of what part's running and what master is being tested against. A computer-based ECT system can track the signatures of each supplier. "When you run materials from another supplier, the computerized checker automatically drifts the bell-curve signature of the workpiece material to match the characteristics of the new blocks," Keely said.

As an added bonus, this data allow manufacturers to do statistical reviews of the manufacturing process. Keely said GM downloads ECT data into a physical-analysis, statistical-process-control program and runs trend analysis on the standard deviation over a 1-week or 1-month run.

NDT Technologies

Eddy-current thread probes can be placed in a toolholder and become part of the machining process.

Line It Up

Another factor that demands attention in an ECT regime, especially as it applies to thread inspection, is probe alignment. Keely said this is the biggest problem he encounters when implementing a system. "It's a lot easier to tap a hole than to probe a hole," he said. "To get a probe into a hole is not a trivial thing, especially if you have 20 probes that you're trying to position simultaneously."

Scott DeJong, manufacturing engineer for Skilled Manufacturing Inc., Traverse City, Mich., a maker of automotive parts for the Big Three, agreed with this assessment. "The part must be consistently and securely located prior to inspection for ECT to function properly."

Keely explained how NDT's system works at GM's plant in Romulus, Mich. "Our probes are mounted in a holder that is controlled by an air cylinder. The cylinder moves in, so that all the probes are simultaneously positioned over their respective holes." The system's programmable logic controller then determines whether the hole is good or bad.

To guard against misalignment, as well as protect the probes themselves, Keely said it's a good idea to monitor the electrical conductivity between the probe and the workpiece, so that the system warns the operator to check the probes.

In Line and On Time

Among the top advantages of ECT is its speed and versatility. ECT allows for in-line testing, meaning tests can be run on every part right after machining a feature. Will Meenan, applications engineer for Kaman Instrumentation Corp., Colorado Springs, Colo., said, "Within a fraction of a second, you know whether you have a good hole or a bad one." He added that testing can be done simultaneously with other operations, saving additional time.

DeVries related that concept in dollars and cents. "One bad 5-cent bearing in an automobile can cost several thousand dollars in warranty costs," he said.

Because eddy-current testing measures only the target material's electrical conductivity, parts need not be in pristine condition for testing. That, according to General Inspection's Nygaard, is a terrific selling point. "It works in harsh environments with coolants, oils, water and dust," he said.

The caveat, however, is that, since the probes key on the presence of material, no chips can be in the part during testing. To get the best results, therefore, Keely recommends performing the test after washing the part.

A related advantage to in-line ECT implementation is that it's automatic.

DeVries said, "If there's a problem with a part, the system indicates the problem (for example, with a red light) and automatically pushes the part out of the line."

Bottom Line

Perhaps the most significant consideration to take into account is the volume of parts a manufacturer is running. For an ECT system to be cost-effective, the volume needs to be high.

According to DeVries, typical instruments range from $8,000 to $30,000. The probes alone range from $100 apiece for off-the-shelf pencil probes to $5,000 for custom multicoil units. Material-handling systems add another $5,000 to $250,000 to the bottom line.

Costs, however, are often easily justified, given the zero-defect regime the Big Three have imposed on their suppliers. DeJong explained that clearly enough.

"If the vehicle-assembly plant can't use a threaded hole, that vehicle can't be produced. Therefore, the assembly line is shut down and there are repercussions because of that, with one being cost. So it's very easy to cost-justify this system."

Given these prices, it might be easy to conclude that ECT is not worth the expense. After all, if none of your vendors are asking for zero-defect parts, why incur the cost of providing them? Because the Big Three adopted their standards from the Japanese, and Big Three mandates have a way of setting trends that other large-scale vendors follow.

Thus, given the enormous expense of stopping an assembly line—any assembly line—zero-defect parts may be an added requirement coming to an invoice near you.

The following companies contributed to this article:

General Inspection Inc.
(248) 625-0529
www.geninsp.com

Kaman Instrumentation Corp.
(800) 552-6267
www.kamaninstrumentation.com

NDT Technologies Inc.
(248) 332-0709
www.ndttechinc.com

Skilled Manufacturing Inc.
(231) 941-0290

Zetec Inc.
(800) 643-1771
www.zetec.com