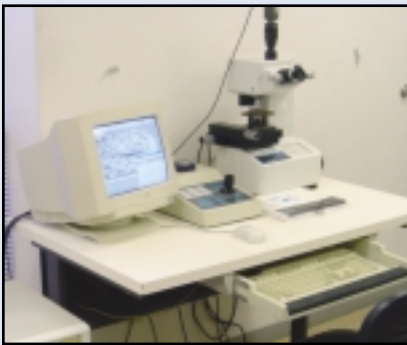


In addition to our work in failure analysis and manufacturing process problem solving, MAI provides a full range of ASNT Certified Nondestructive Testing services. We provide nationally qualified Level II and Level III inspectors to meet your testing requirements. Level III is the highest ASNT Certification. Testing can be performed on site at your facility, in the field for equipment in service, or in our laboratory.

MAI is constantly evaluating our current instrumentation to provide the finest cost effective service to our clients. Our Buehler Micromet Microhardness Tester has provided excellent service for many years, always calibrating spot on, and easily meeting collaborative testing standards. Reviewing the current state of the art in microhardness testing, however, we determined that it was time for a new instrument with expanded capabilities. Our recent purchase of the Buehler Omnimet



The MHT microprocessor controlled system provides faster throughput, digitally archived indent images, computer controlled traverse spacing and depth, and full compatibility with our network to collect, transmit, and archive microhardness reports, data, and graphs. These can then be emailed directly to our clients, either separately, or as part of a comprehensive report.

A wide variety of Nondestructive Testing, or NDT, techniques are used to solve both failures of components that have been returned from the field and problems that are related to manufacturing processes, including forming, casting, forging, and welding. In this article, we will provide a brief overview of these NDT techniques, including their advantages and limitations.

This NDT technique is sometimes discounted, wrongly, as just "looking at" a defect. In fact, proper VT is a methodical analytical examination which can yield a great deal of valuable information. On the other hand, conclusions drawn from an improperly conducted VT can lead the investigator on a "wild goose chase." Visual examination is performed with both the unaided eye and moderate optical magnification using a stereomicroscope. Features such as crack witness marks resulting from contact with other components, and corrosion can be identified. Cracks opened by sectioning, or complete fractures, are examined to identify fracture origins. Components or assemblies containing multiple fractures are examined to determine the initial, or first area at which failure began. Often, defects that may have contributed to a failure are evident by VT, such as casting porosities, lack of fusion or penetration in a weld, or rough machining marks at an apparent fracture initiation.



Visual Inspection is critical when examining complex, multi-fracture failures. Identifying the first location to initiate fracture is key to the analysis.

Nondestructive Testing

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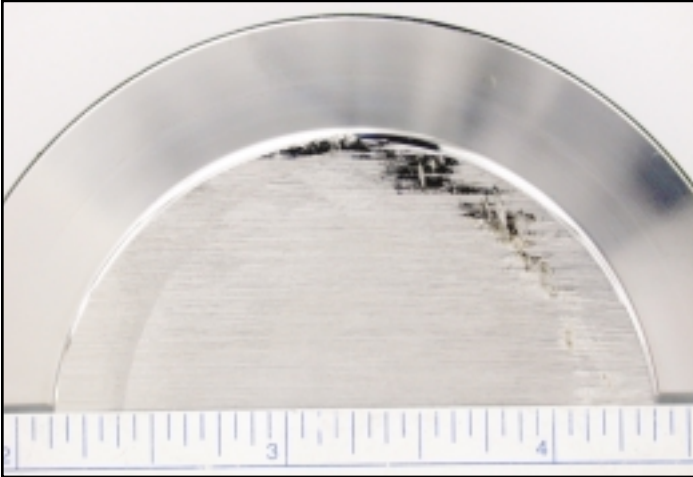


Figure 2 - Visual Inspection of this machine shaft, shown on end, revealed a suspected crack at approximately mid-wall

As an initial overview, VT is a critical first step in any failure analysis. However, as with all analytical techniques, VT has its limitations. Small, but significant features may be missed by VT due to the minimal magnifications available. Surface features may also be partially or completely obscured by adhering debris or corrosion, plating or coatings, and mechanical deformation or damage. Because of these limitations, various other NDT methods have been developed to detect features which cannot be resolved by visual examination.

Liquid Penetrant Inspection

Liquid Penetrant Inspection, or PT, permits detection of cracks that are open to the surface of a part. Other surface defects, such as porosities, are also detectable with this technique. PT can be used in a wide range of materials including ferrous and non-ferrous metals, plastics, and ceramics. In this method, a low viscosity liquid penetrant is applied to a part

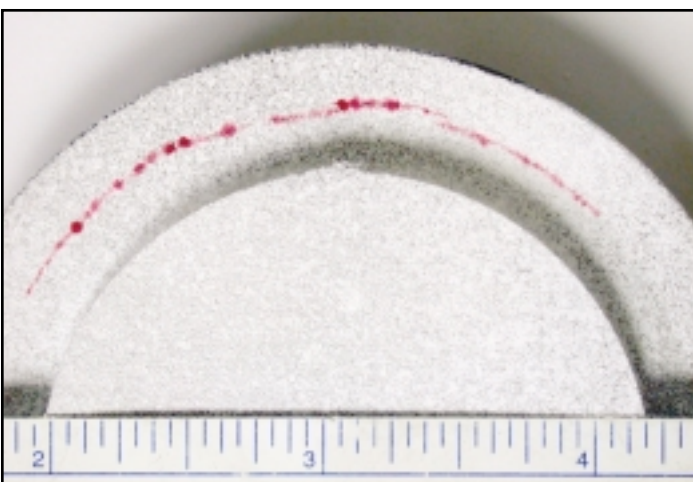


Figure 3 - Liquid Penetrant Inspection of the shaft produced an indication which confirmed the suspected mid-wall crack.

and allowed to “soak” into any cracks that may be present for from five minutes to 24 hours. This “soaking” phase is called the dwell time, and its duration depends on the specific objectives of the inspection. When the dwell time is completed, the excess penetrant is removed from the surface of the part. Penetrant which has entered any cracks or small openings, remains. A second, less viscous fluid, called the developer, is now applied to the part. The developer is of a contrasting color (typically white) compared to the penetrant (typically red) and has absorbent properties which draw the penetrant to the surface, producing a contrasting color “indication” of the crack. These indications mirror the shape and location of the crack or defect. A variation on this technique is the use of a fluorescent penetrant and ultraviolet light to display crack or defect locations. Once identified, the crack indications can be photographically documented, then sectioned and opened for examination to determine fracture mode and origin.

In order for this inspection technique to successfully identify a defect, several conditions must be satisfied. First, the penetrant must be able to enter the defect. If the defect is not open to the surface or is filled with debris, the penetrant will not enter, and no indication will form. Mechanical damage, resulting in smearing, may also prevent penetrant from entering a defect. Second, the excess penetrant must be completely removed, without removing the penetrant within the defect, to provide maximum contrast. Improper cleaning can decrease the sensitivity of this inspection method, either by not removing all of the excess penetrant or by removing the penetrant within the defect. Third, the developer must be applied in a uniform layer that provides contrast with the penetrant, while not being so thick that small amounts of penetrant from small defects cannot reach the surface to form an indication.

When performed by a trained and skilled inspector, liquid penetrant inspection is an excellent technique for identifying surface defects. This method has the added advantage of portability and can be performed “in situ” in most field locations.

Magnetic Particle Inspection

In this inspection method, electric coils are used to generate a magnetic field within a part. Therefore, this method only works with ferromagnetic materials. These include carbon and alloy steels, some stainless steels, cast irons, nickel alloys, and cobalt alloys. With the coils energized, and the part held in the resulting magnetic field, powdered iron is applied to the part surface. Leakage of the magnetic field occurs at defects, such as cracks, at the part surface and attracts the powdered iron to these locations. The powdered iron may be colored to provide contrast, or can be treated with fluorescent dye for examination under ultraviolet light.

Magnetic Particle Inspection will detect defects that are open to the surface as well as slightly sub-surface defects. Indications, resulting from the attraction of the powdered

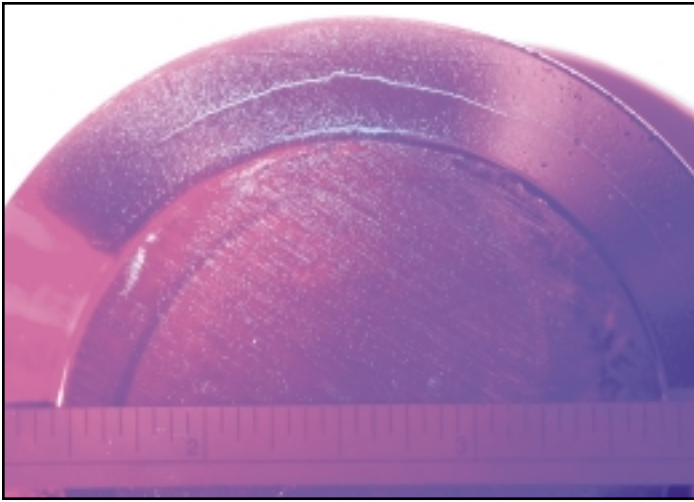


Figure 4 - Magnetic Particle Inspection, using fluorescent particles illuminated by ultraviolet light, revealed the crack in detail. Subsequent sectioning and examination by Scanning Electron Microscopy determined it was a quench crack resulting from defective heat treatment.

iron to the defect, form only when the magnetic field is approximately perpendicular to the defect. Therefore, it is necessary to apply the magnetic field at various orientations to the part to detect all defects that may be present.

Magnetic Particle Inspection is initially more expensive than Liquid Penetrant Inspection because of equipment requirements. Because Magnetic Particle Inspection requires an electric power source, it is of limited suitability for use in the field.

Ultrasonic Inspection

Ultrasonic Inspection, or UT, has a distinct advantage over Visual, Liquid Penetrant, and Magnetic Particle inspection techniques due to its ability to detect defects well below the surface of a part. Furthermore, UT can accurately identify the distance from the surface of a part to an internal defect. In fact, UT is also an excellent technique for determining material thickness in large fabrications such as storage and pressure tanks, reactor vessels, and brew kettles where only one side of the material is accessible, precluding the use of conventional thickness gauging techniques.

Ultrasonic Inspection uses high frequency sound energy (typically 1-10 MHz) which is projected into a part through a transducer. This high frequency beam travels through the part at the speed of sound until it encounters a “reflector”, such as a defect, or the opposite side of the part, and is reflected back to the transducer at the surface of the part. This process is graphically displayed on a CRT, which is calibrated to indicate the distance from the transducer at the part surface, to the reflector (either defect or opposite side of the part). The principles of this process are virtually identical to those used in “fish finders” used by sport fishermen, as well as medical ultrasound examination used in prenatal health care and other medical examination procedures.



Figure 5 - Ultrasonic Inspection to identify internal defects. The high frequency signal response is displayed on an oscilloscope CRT, which identifies the depth of the defect.

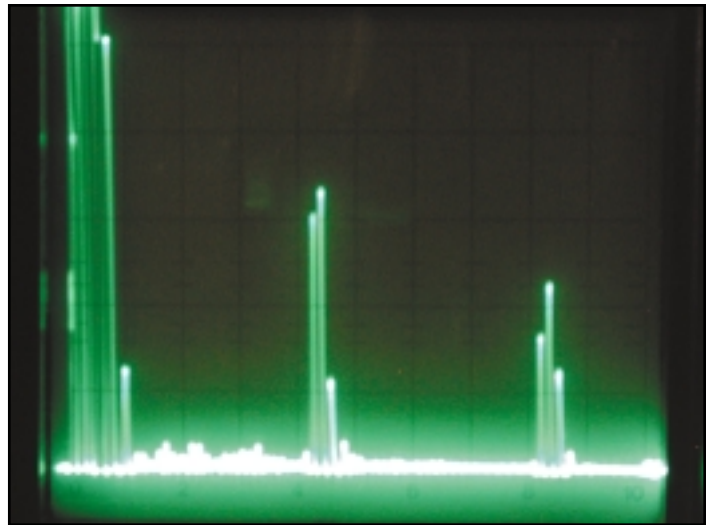


Figure 6 - Ultrasonic Inspection oscilloscope display. The peaks indicated the depth of “reflectors”, such as defects, from the sample surface.

Ultrasonic Inspection requires interpretation by a skilled and experienced inspector. Although this technique requires the use of relatively expensive equipment, it is portable and contains its own internal power supply. This makes Ultrasonic Inspection ideal for “in-situ” inspections in the field.

NDT at Metallurgical Associates

Metallurgical Associates is one of the few independent materials testing and engineering facilities in the United States which provides Level III NDT inspection services as well as full failure analysis capabilities. Level III is the highest level of certification awarded by the American Society for Nondestructive Testing (ASNT) and certifies that the holder of this certification is approved to develop NDT standards and specifications, train inspectors up to ASNT Level I and II requirements, and to certify them when they meet these requirements. ASNT Level

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III inspectors also select the appropriate inspection technique which best addresses the requirements of the material in hand. This is, of course, critical as the use of an inappropriate NDT technique may result in the non-detection of a defect easily identified if the right technique were applied.

MAI's combination of metallurgical and nondestructive testing capabilities and experience provides our clients with a thorough and efficient resource for detecting and analyzing defects to provide cost effective recommendations which prevent future failures and enhance the performance and profitability of our client's products. Our expertise also enables us to develop inspection methods "on the fly" where an instant response is required to solve problems before they become crises.

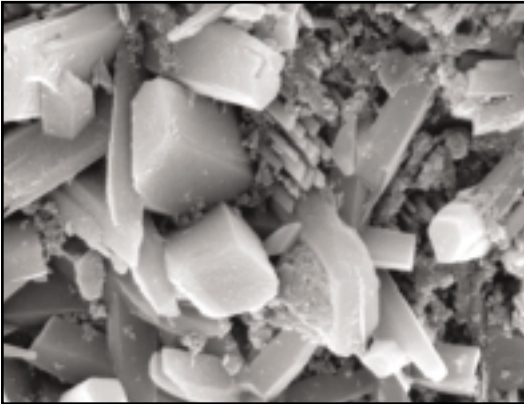
For further information on nondestructive testing, or for a quote on your testing requirements, contact Tom Tefelske at (262) 798-8098, Toll Free at (800) 798-4966 or by email at tomt@metassoc.com.

MAI Expands NDT Staff

In response to increased client demand, MAI has expanded our Nondestructive Testing capacity with the certification of Erik Andersson to ASNT Level II accreditation. In addition to his NDT expertise, Erik is a degreed metallurgist, with prior experience in the Oshkosh Truck Corporate Materials Testing Lab and two years as staff metallurgist at Metallurgical Associates. Erik's metallurgical training and experience in failure analysis and manufacturing processes enhances his evaluation of NDT results, providing additional value to our clients.

Metallurgical Associates Inc. is an independent materials testing and engineering facility accredited by the American Association for Laboratory Accreditation (A2LA-ISO/IEC 17025). Our expertise includes failure analysis, process problem solving and process/material certification and selection. For a quote or discussion of your analytical requirements, please contact Tom Tefelske (tomt@metassoc.com), Erik Andersson (erika@metassoc.com) or Rob Hutchinson (robh@metassoc.com) or phone (262) 798-8098, or Toll Free (800) 798-4966.

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