

Center for Nondestructive Evaluation Facilities

The Center for NDE (CNDE) at Iowa State University (ISU) is widely regarded as the premier research center in NDE in the U.S. and has established a strong relationship with industry in the development and application of NDE technology. The Center is housed at the Applied Sciences Complex, Buildings II and III, with an area of ~52,000 square feet. State-of-the-art technology enables quantitative NDE measurements and supports development of innovative techniques. Included are well-equipped facilities, valued in excess of \$3.6M in all of the major NDE modalities, with a suite of instruments typically used by industry, as well as state-of-the-art research instrumentation. In addition to the equipment described below, CNDE researchers have access to a number of materials preparation and characterization services through the ISU College of Engineering and the US DOE Ames Laboratory.

Ultrasonics

Ultrasonic inspection and research is carried out in eight laboratories at CNDE using scanning systems mounted on immersion tanks, as well as portable instruments. Five scanning systems are available: 1) SONIX 50" x 40" x 26" immersion tank with 6-axis motion control and 500# sample capacity, UTEX UT340 pulser-receiver, SONIX STR81G 1GHz 8-bit A/D and Gage Compuscope 14100 100 MHz 14-bit A/D digitizers, and UTEX Winspect control software, 2) Testech 48" x 28" x 24" immersion tank with 3-axis motion control with manual gimbal-gimbal goniometer, UTEX UT320 pulser-receiver, and LeCroy Waverunner LT342 500 MHz digital oscilloscope, 3) Testech 40" x 18" x 12" immersion tank with 5-axis bridge (x-y-z-gimbal-swivel) plus a small, high precision micro-stepping x-y-z stage mounted on the end of the tank to accommodate an Ultra NDE Acoustic Microscopy unit, pulser-receiver hardware including a Panametrics 5601A pulser-receiver, Panametrics 5058PR high-voltage pulser-receiver, a LeCroy 9101 Arbitrary Function Generator, ENI 2100L RF power amplifier, and digitizers including LeCroy 9450 350MHz and LeCroy 9310L 300MHz digital oscilloscopes, 4) Testech 40" x 18" x 12" immersion tank with 3-axis motorized bridge, Panametrics 5052PR pulser-receiver, and LeCroy Waverunner LT342 500 MHz digital oscilloscope, 5) SONIX 48" x 30" x 24" immersion tank with 3-axis motion control, which can be either x-y-z or x-y-turnstile, Panametrics 5052PR pulser-receiver, SONIX 100 MHz 8-bit digitizer, and SONIX Flexscan operating software. The first two scanning systems can be interfaced with one of two available phased array systems: 1) RD-Tech Tomoscan Focus system with 32/128 electronics (32 delay-law generators, 128 probe element capacity) and DDF (dynamic depth focusing) upgrade, or 2) RD-Tech OmniScan MX portable system with 16/128 electronics. Available phased array transducers include conventional 5MHz and 10 MHz linear 1-D arrays operable in immersion or using wedges, as well as specially designed transducers (e.g., large aperture sectorial-annular probes, small aperture checkerboard pattern probe) for billet or forging inspection. Portable UT instruments include Krautkramer-Branson USD-15 and Panametrics Epoch 3 units, as well as Panametrics 26DL and 25 Multi-Plus ultrasonic thickness gages, and an ultrasonic leak detector. A small (8" x 8" x 8" travel) motorized scanning stage is

mountable either on a benchtop for contact UT measurements or on a small tank for immersion testing. A wide range of ultrasonic transducers, including conventional immersion and contact probes as well as high frequency (50 MHz) highly focused probes for acoustic microscopy are available.

Composite Materials Analysis

Within the Ultrasonics Group at CNDE, a subgroup specializes in analysis of composite materials. Their facilities include air-coupled ultrasonic instruments, including a QMI Sonda CX007 pulser/receiver and associated transducers at 50, 120, and 400 kHz. Air-coupled ultrasonic transducers from the Ultran Group include both composite transducers (100 kHz) and gas matrix piezoelectric (GMP) transducers (200 kHz). Conventional ultrasonic equipment includes various pulser/receivers (Panametrics 5052, 5058, and 5600) and an assortment of contact, immersion, and dry-coupling transducers. Contact transducers cover the frequency range of 0.25 - 30 MHz, immersion transducers cover the range from 0.5 to 50 MHz, and dry-coupled transducers are available at 1 and 3 MHz. The group has three ultrasonic immersion tanks and four LeCroy oscilloscopes, two of them can be operated over the Internet. Ultrasonic scanners in the Composite group include a SONIX automated motorized scanner that can be used for making water-coupled and air-coupled C-scans. The group is a developer of manual portable scanners and has on hand a number of unique prototypes, including the Flock-of-Bird magnetic encoder scanner, the PC NotesTaker-based acoustic encoder scanner, and the Mimio-based acoustic-encoder scanner (the "GenScan"). The group has a Santec Systems model AS200 Acoustic Scope with a 3MHz source and a 3" liquid crystal acousto-optic detector for inspecting small parts with complex shape in real time. The Composite group was the developer of the Computer Aided Tap Tester (CATT) and has two units for in-house inspection of composite parts.

Eddy Current and Related Electromagnetic NDE

There are eight laboratories at the Center for NDE where electromagnetic NDE research is performed. There are five laboratories housing six motion-controlled eddy current measurement stations equipped with computer-controlled stepper motor driven n -axis stages, where the number n ranges from 2 to 8. Each station can be mounted with various types of eddy current (EC) probes and other sensors, and with specimens. Various types of data acquisition instruments are available, including four impedance analyzers [two HP4194A (100Hz-15MHz), and two Agilent 4294A (40Hz-110MHz units)], nine commercial EC instruments [two Staveley NDT-19, UniWest US 400, 450 & 454, Zetec MIZ 40, MIZ-22, MIZ 21A, and Nortec 1000], and other proprietary instrumentation. Three of the five stations are dedicated to EC scans with data collection by either impedance analyzer or EC instrument. One XYZ system is used for R&D purposes, linked with a variety of instruments, not only the EC instruments but also combination of network analyzer, amplifiers, signal generators, and various detectors. One XY system is also dedicated to the R&D of proprietary Pulsed EC instrumentation.

Beside the scanning stations, there are other measurement setups for R&D purposes. One is a high-frequency EC measurement system consisting of a signal generator, lock-in and other amplifiers, and a proprietary probe, operating up to 50MHz. A similar setup is built to perform AC potential drop measurements for research, operating at low frequencies. Another proprietary system is a laser-excited EC probe characterization instrument. There are also general-purpose equipment: a commercial laser profilometer (Solarius LaserScan) that has micron resolution (sub-microns in the perpendicular direction); a shotpeening system built around a commercial shotpeening chamber (TRINCO Model 24/BP) custom-fitted with a 2-axis (XZ) motorized sample mover. In addition, there are a number of laboratory-grade instruments (three network analyzers, eight lock-in amplifiers, five signal generators, etc), and general-purpose equipments such as a coating thickness gage (NDT Systems, Inc. TX-4L) and a conductivity meter (SigmaScope).

Magnetic Inspection

The magnetics laboratories are shared between programs at the Center for NDE and Ames Laboratory. Portable magnetic NDE equipment include the Magnescope for measuring magnetic hysteresis loops, the Magneprobe and the Stresscan 500C (American Stress Technologies, Inc.) for detecting Barkhausen effect signals, and the Magnescan for imaging magnetic properties using a scanning system. These NDE systems utilize surface sensor probes to measure magnetic properties of materials, from which information on the mechanical (e.g. stress state) and microstructural conditions (e.g. plastic deformation) of the materials can be inferred with the use of experimental calibrations or computer simulations. A computer controlled Hysteresisgraph (Model 3600, LDJ) allows dc and ac (up to 50 kHz) magnetic hysteresis measurements on laboratory samples with an accuracy of 0.1% full range. A Vibrating Sample Magnetometer (Model 4500, Princeton Applied Research) offers a high sensitivity (moment resolution of $\times 10^{-5}$ emu) for measuring magnetic properties of small or weakly magnetic materials. The VSM can be used with either a 7kOe or 23kOe (2.3 Tesla) electromagnet and is equipped with a furnace for measurements at temperatures ranging from ambient to 700°C. Systems for characterizing magnetomechanical properties and performance of magnetoelastic sensors include a magnetic torque sensor test bed capable of applying controllable torque up to ± 10 N•m and field up to 30 Oe at temperatures from -40°C to 100°C, a four-point bending system for evaluating magnetoelastic sensors on aerospace components up to 6 feet long, and an Instron Model 8500 100 kN hydraulic-driven dynamic testing system for conducting mechanical tests at various frequencies up to 500 Hz over a temperature range from ambient to 1200°C. Equipment is available for fabrication and characterization of advanced magnetic materials such as magnetic thin films. This includes an automated, 6-target, 2-gun ion beam thin film deposition system for producing high quality magnetic films and multilayer structures such as spintronic materials and sensors. An atomic force/magnetic force microscope (Dimension 3100 with Nanoscope IIIa, Veeco) offers a tool for imaging surface topography and magnetic structure of materials with routine lateral resolution of 50 nm under in-plane in situ applied magnetic fields of up to 600 Oe at temperatures

between -20°C and +35°C. Thin film BH looper (Model MESA-200HF BH , SHB Inc.) is available for measuring hysteresis loops, magnetoresistance and the magnetomechanical effect under fields up to 1kOe at frequencies up to 10 Hz. A magnetostriction tester (Model Lambda-09, Lafouda Solutions Inc.) is available for measuring magnetostrictive strains down to 10^{-8} on films as thin as 50 Angstrom under applied fields up to 100 Oe.

X-Ray Inspection

There are five x-ray inspection laboratories at the Center for NDE equipped with three microfocus tubes and three standard x-ray tubes. A high resolution computed tomography facility with a microfocus x-ray tube (130 kV, 2-micron spot), 4-axis microstep positioner and an amorphous silicon array detector allows both high resolution (5 micron) digital radiography and 3D CT to be performed. High-speed CT reconstruction is done on a 64-node Linux cluster, and custom image analysis software is available for visualizing 2D and 3D data sets. Real-time radiography can be accomplished using three different image intensifier based systems: one is a cabinet system with a 160 kV, 0.2/2.0 mm spot tube, the other two tubes (200 kV, 5 micron microfocus, and 320 kV, 1.2/3.0 mm spot) are in a walk-in vault. All three systems have multi-axis sample manipulation capabilities. A standard x-ray tube (320kV, 1.5 /3 mm spot) with a multi-axis positioner coupled to a germanium/MCA photon counting detector allows for energy-sensitive materials characterization. Several germanium, CdZnTe and NaI detectors enable spectral analysis of x-ray transmission and scattering. A large (44x30 cm) phosphor screen/CCD camera imager can be positioned in one of the walk-in vaults for imaging and CT scans of larger objects. A cooled 14-bit 512x512 CCD camera with a range of lenses is used for digitizing film. X-ray detector testing and fabrication is carried out in a laboratory that includes an older 160 kV microfocus source. The suite of x-ray inspection techniques is complimented by an x-ray simulation capability, which provides unique analysis tools for evaluating the effect of various parameters on image quality. Through collaborations with the Department of Mechanical Engineering, we also have access to a real-time stereographic imaging system composed of two 200 kV x-ray tubes and two 16-inch diameter image intensifiers.

Thermographic Inspection

A thermographic NDE laboratory that will focus on SonicIR measurement is currently in the startup phase. Major equipment includes a FLIR SC6000 MWIR infrared camera (20 mK sensitivity, 640x512 resolution), a PolyTec laser vibrometer (bandwidth to 1.5 MHz, velocity detection only), a broadband 1-100 kHz 1 kW power amplifier (McIntosh 1201, factory modified), and data acquisition computer (Two 64-bit dual-core CPUs, 8GB RAM, plus waveform-capture and image-capture cards, Linux OS). Integration of a motion control system and a high-power sonic/ultrasonic actuator system will enable SonicIR inspection capabilities.

Visual and Mechanical Testing

At the Center for NDE, portable and stationary liquid penetrant and magnetic particle testing devices are available, including a wet horizontal MPI unit (Magnaflux AD-945), portable yokes, coils, and gaussmeters (FW Bell 5180, and 4048 units). Brightness measurements (of defect indications or other items) may be performed using a photo spotmeter (Photo Research PR-880). For visual examination, a variety of microscopes with white light illumination and CCD cameras are available, and a UVA-illuminated binocular microscope with a 12-bit cooled camera (Q-Imaging Retiga 1300) may be used to capture images of low light intensity objects. All microscopes, including a video microscope (Moritex MS-420), are connected to image acquisition and analysis software (Media Cybernetics' Image Pro). Borescopes, a fiberscope, and a hand-held video inspection unit (Aqua Communications' Snake Eye) are also available. A servo-hydraulic mechanical test unit (MTS TestStar I controller) with 22,000 lb axial and 10,500 in-lb capacity is maintained, along with a variety of extensometers, for tensile testing and 3 or 4-point bending fatigue work. CNDE also maintains a 3-axis electro-discharge machining unit (US EDM D55 with a maximum 4" x 4" x 11" specimen size), a salt fog corrosion chamber (Singleton Model 22 with a 4' x 3' x 2.5' chamber), and Rockwell, Leeb's, and durometer (for rubber and plastics) hardness testers. Also available is a commercial alloy analyzer (Metallurgist Pro) utilizing a radioactive source to perform XRF-type measurements.

Computing Services

Over 150 office and lab PCs at CNDE are networked together and connected to the ISU campus LAN and are gigabit ready, although most still run at 10/100 Mb. Publicly available Wireless Ethernet (802.11b/g) is provided throughout the CNDE buildings. CNDE maintains a MS Exchange server for email, a WWW/FTP server, Backup server with 22 tape LTO2 autoloader, and a File and Print server, all interconnected with gigabit Ethernet and on UPS power. For CPU-intensive analysis, CNDE has a Linux cluster consisting of 64 nodes, each with a 2.6GHz processor and 1 GB RAM. The server node is a 2 processor Xeon machine with 8GB RAM. The server is connected to the cluster switch via gigabit Ethernet. The nodes themselves all have 100 Mb Ethernet interconnects. Additional computing resources are available through ISU and Ames Lab.

Machine Shop

A basic machine shop with mill, lathe, band saws and drill press is available to CNDE staff and students for fabrication of custom components. Larger design or machining jobs can be submitted to facilities at ISU or Ames Lab.