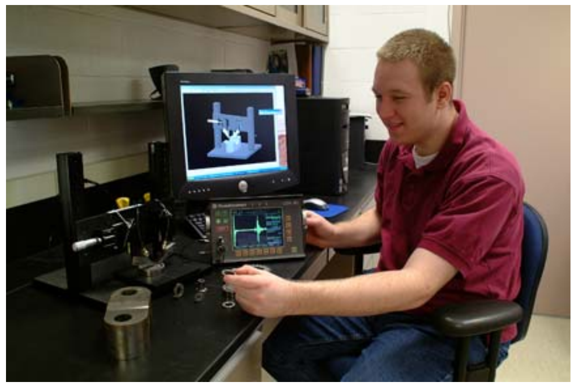
Penn State University ESM Ultrasonics R&D Laboratory – Joseph L. Rose

Research Activities

- ***Crack Detection in Green Compacts – The Center for Innovative Sintered Products***

  Identifying cracked green parts before sintering and removing them from a sintering batch reduces the cost of producing P/M parts by eliminating added procedures on defective parts. To date, a highly successful ultrasonic surface wave mediator technique has been developed and effectively used for crack detection in a variety of green parts. The technique has high sensitivity to the presence of surface breaking cracks and has a high repeatability rate. Future research of this technique will lead to the technology transfer through the development of a system for real time crack detection and automated inspection of green compacts during the manufacturing process.

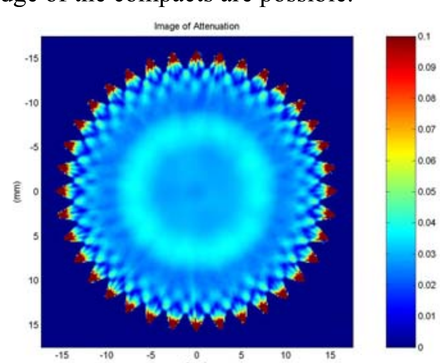


- ***An Ultrasonic Sensor System for Crystal Manufacture – International Sematech***

  Crystal lenses are being used to carry out the very detailed and sensitive photolithography process required in chip and semi-conductor high tech manufacture. The crystal lenses are very expensive and take over six weeks to manufacture. If for some reason small imperfections occur in the lenses, a tremendous amount of money is lost and the manufacturing process is to begin again. Penn State has therefore taken on the project of improving efficiency in the lens manufacturing process. A dual rod guided wave ultrasonic technique has been developed at Penn State University to monitor the growth of single crystals during manufacture. The guided wave technique is used to detect the solidifying material interface during crystallization. The technique was demonstrated using a production furnace to grow a 12 inch diameter crystal while operating at temperatures of ~ 1500° C under high vacuum. Bottom side inspection through the crucible is also being studied.

- ***Ultrasonic Tomography for Net Shape Powder Metal Part Production Via Cold Compaction – National Science Foundation***

  Our group recently used a contact tone-burst excitation system to get the cross-sectional tomographic images of density gradients of power metal compacts in the P/M industry. When using a point ultrasonic source, equiangular fans pattern were applied for cylindrical compacts. The results showed great potential for finding density gradients and flaws in powder components. In our new laser non-contact excitation system, we use a laser beam to excite ultrasonic energy, employing an air-coupled transducer to receive the ultrasonic waves. Full resolution areas up to the outer edge of the compacts are possible.

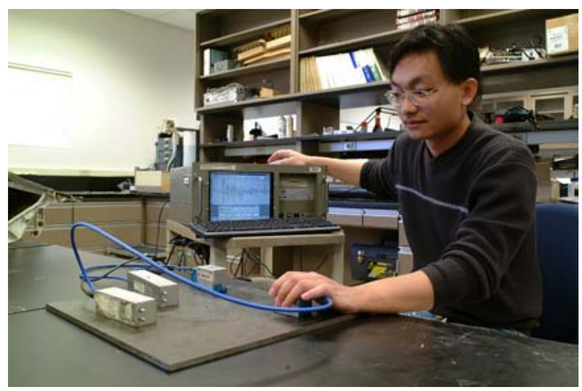


- ***A Novel Wireless System for Structural Integrity Monitoring of Aircraft – Intelligent Automation, Inc., US Navy***

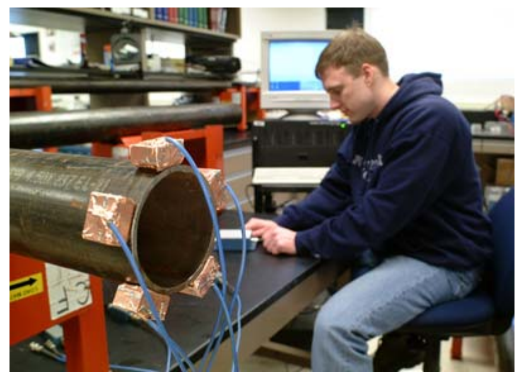
  Nondestructive evaluation has been carried out for decades. The trend is now towards the applications of structural health monitoring. We want to be able to monitor continuously a structure so we can get some idea of what's happening with respect to defect generation, propagation, corrosion, etc. The emphasis today is therefore placed on the utilization of leave-in-place sensors. Costs are critical. We're developing a whole series of low cost efficient comb like PVDF and MEMS type cMUT sensors that can be mounted on a structure to monitor problems instantaneously. This project is associated with going beyond some of our cabled techniques for monitoring defect growth in various aircraft structures to a wireless mode. The initial work is looking at cracking in the transmission beam of an H-60 Navy helicopter.

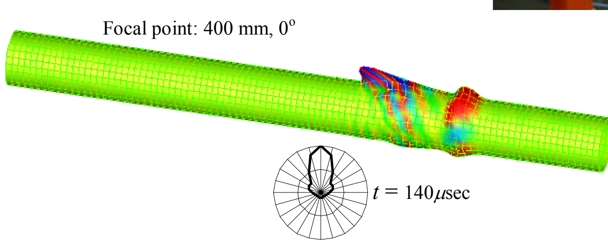

- ***Guided Wave Sizing and Discrimination for SCC Research – PRCI***

  This project is associated with the development of crack detection and sizing in hollow cylindrical structures for the gas industry. Circumferential guided waves could be used from a moving robotic type device in the pipeline that can detect cracking by magnetic flux leakage. Complementary to the technique is a consideration of EMAT or magnetostrictive based circumferential guided waves. We are developing boundary element method wave scattering techniques that allow us to calculate reflection and transmission factors from a defect in such a manner that simple algorithms for sizing can be developed. The computational techniques make use of dispersion curve analysis in obtaining the appropriate wave structures as a boundary condition to a segment of a pipe structure. By modal superposition it then becomes possible to calculate the mode types at a particular frequency that will reflect and transmit from a defect. This study provides us with a means of coming up with the best modes and frequencies with the best possible chance at flaw discrimination and sizing. Both 2 and 3 dimensional wave scattering from defects is being considered for pipes with viscoelastic bitumen coatings. Both Lamb type waves and horizontal shear waves are being studied.

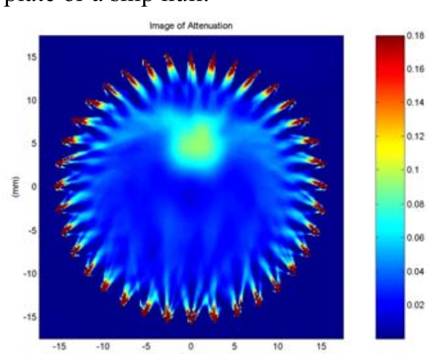


- ***High Frequency Guided Wave Phased Array Focusing in Pipe – The Office of Naval Research***
  Guided wave inspection systems are available today with axisymmetric loading that can inspect piping over very long distances, even under insulation, coatings and over road crossings, etc. This project deals with an improvement in the current technology by obtaining higher signal to noise ratios and better sensitivity to finding smaller defects in pipeline structures. By using frequency tuning and impinging non-axisymmetric ultrasonic energy into the pipe, the angular profiles vary as you move along the pipeline. The work is now being carried out to go beyond this natural focusing associated with the angular beam profiling by using phased arrays and sending multiple non-axisymmetric mode waves and controlling the superposition process so that focusing can occur at any position inside a pipe. This allows us to very quickly scan the entire pipe and obtain smaller defects less than one percent cross-sectional area compared to the state of the art that exists today on detecting a nine percent cross-sectional area reduction. The work will go beyond straight pipes to waves traveling beyond elbow sections. The idea here again is associated with the control of a phased array that would allow superposition of ultrasonic energy to occur at any point even beyond an elbow.

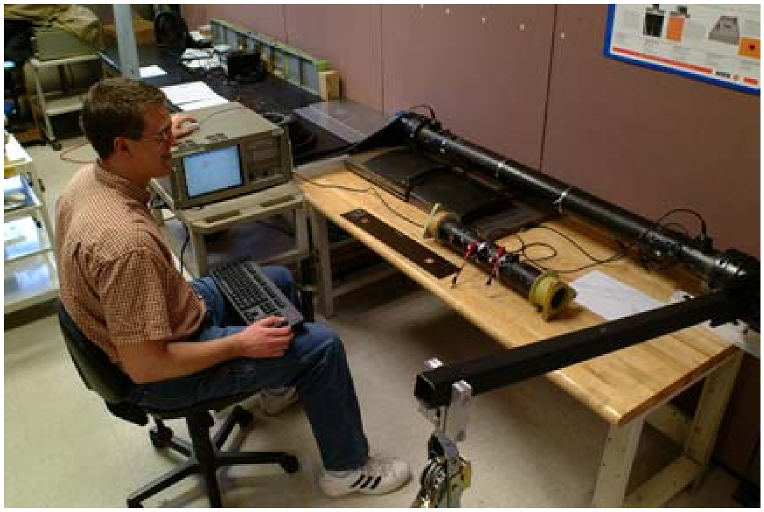




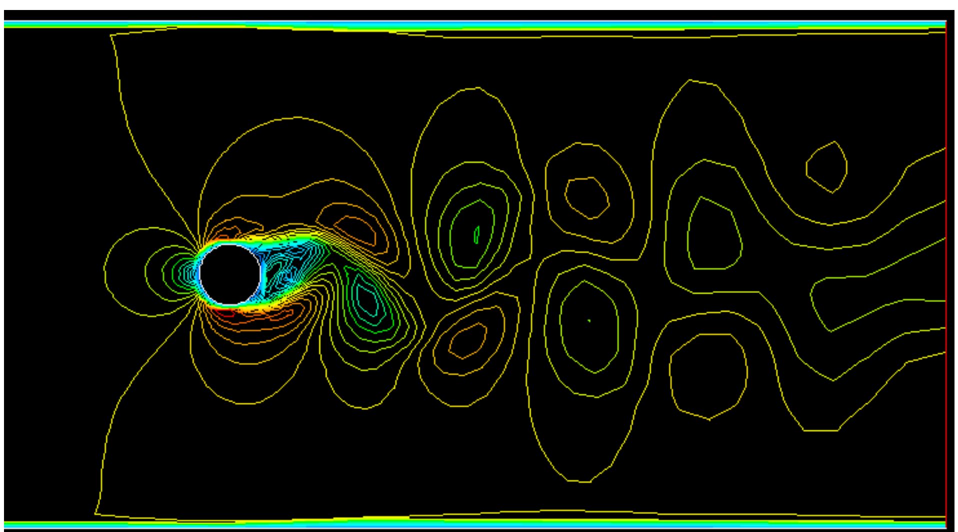
- ***Guided Wave Tomography - ASNT***
  One of the main goals of the work will be to come up with a limited number of sensor tomographic procedures that can make this technique practical in industry for a variety of applications including, for example, on an aircraft wing, on a plate or a ship hull.



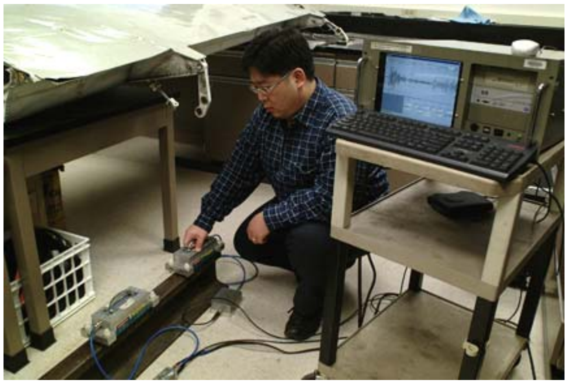
- ***A New Apache Helicopter Rotor Shaft – Boeing***
  Work is being initiated on a newly designed composite material rotor shaft to embed self diagnostic wireless MEMS type sensors for material degradation, defect detection, and performance variation. Both theoretical and experimental work is being carried out on a variety of different composite material structures.

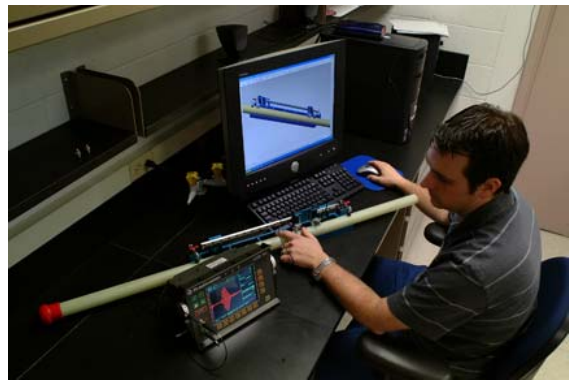


- ***Ultrasonic Flow Meter Development – General Electric***
  A new ultrasonic flow meter is being developed. By placing obstacles into the flow and using ultrasonic energy from the outside surface of the pipe, mass flow rate will be determined by density measurement via a torsional wave guide, and vortex shedding frequency by way of ultrasonic amplitude and wave velocity measurements across the vortices.



- ***Miscellaneous Laboratory Exercises – Internal, FBS***
  Work is also being initiated to study guided wave applications of defect detection in rail. Low frequency ultrasonic guided wave systems for frequency tuning, natural focusing, and phased array focusing for large pipe are also being investigated. Improved guided wave sensors, instrumentation, signal processing, and pattern recognition is also being explored. We are developing a guided wave inspection system for pole vault safety. We are also keeping an ear and eye for new opportunities in manufacturing and materials processing, new MEMS wireless leave-in-place sensor applications, homeland security potential, biosensors and data fusion, and tissue regeneration enhancement via ultrasound.





Laboratory Facilities

A fully equipped Ultrasonic Nondestructive Evaluation facility is available in the Engineering Science and Mechanics Department at Penn State University. A whole series of piezoelectric sensors and electro magnetic acoustic transducers are available over a frequency range from 50 KHz to 25 MHz. Five shock and tone burst instrumentation systems are available. We also have an 8 channel phased array tone burst system to do focusing in pipe, a laser based ultrasonic test system, and a set of air coupled sensors.

Computer modeling and computational software are also available to generate dispersion curves and wave structures for all sorts of geometries including plates, pipe, multiple layer structures, rail, rods and other shapes. Programs for anisotropic and viscoelastic structures can also be integrated into the programs. Elastodynamic wave propagation and scattering finite element and boundary element codes are also available for wave propagation and wave scattering from defects for a whole series of different wave guides.