UKf 3B Reintegration Grant (01.10.2009 - 30.09.2011)
http://www.ukf.hr

Project manager: Dr. Marko Budimir, INETEC

Organizations involved in the project:

- Swiss Federal Institute of Technology Lausanne (EPFL), School of Engineering (STI), Institute of Materials, Ceramics Laboratory (LC), http://lc.epfl.ch
- Georgia Institute of Technology, The George W. Woodruff School of Mechanical Engineering, Smart Materials and Devices Laboratory, http://www.mse.gatech.edu/index.html
- University of Zagreb, Faculty of Electrical Engineering and Computing, Department of Electroacoustics (ZEA), http://www.zea.fer.hr

Total estimated funding of the project (UKF Grant + INETEC co-funding): 1,6 mil. kn

PROJECT TITLE: STUDY AND DEVELOPMENT OF ULTRASONIC NON-DESTRUCTIVE EXAMINATION SYSTEMS (acronym: SONDE)

PROJECT ABSTRACT:

The aim of this project is to create, from scratch, an ultrasonic applications research group with its own, relatively independent but strongly networked with other R&D institutions, laboratory and equipment. This group is supposed to be formed within the Institute for Nuclear Technology - INETEC, which is a privately owned research and development company.

The group’s initial aims, apart from setting up and equipping the lab, are design, development, production and testing of "made in Croatia" customized ultrasound probes for non-destructive evaluation of structural health in nuclear and fossil fuel power plants, from one hand, and doing more fundamental-science-based research on novel materials, techniques and theoretical models in the branch of physics and material science and engineering that is focused on ultrasound, piezoelectrics and ferroelectrics, from the other hand. The first and the primary use of the produced probes is to incorporate them into INETEC's robotized systems for NDE inspections of nuclear power plants.
The significance of this project is manifold. From the industrial point of view, classical NDE products not being manufactured in Croatia at the moment, but needed in our industry, especially accenting here INETEC as a large NDE products consumer, will now be fabricated in Zagreb, and novel techniques and materials will be investigated aiming, in long term, to create new and innovative methods and products for the global NDE market.

The industrial part of the project will be largely facilitated by INETEC's extensive experience in NDT inspection (performed according to international standards and procedures), mechanical and electrical engineering, and software data acquisition.

From the scientific point of view, the project aspires towards creation of new NDE technologies, and to increase Croatian and regional interest in this branch of physics, material science and technology, which is not high at the moment, due to lack of a corresponding industry. There is a vibrant and networked worldwide community doing fundamental and applied research on these materials and techniques, with which we aim to communicate and collaborate - some members of this community, Ceramics Laboratory of the EPFL (http://lc.epfl.ch) and Smart Materials and Devices Laboratory of Georgia Tech Atlanta (http://www.mse.gatech.edu/index.html), have already been officially involved in this project, and we have also had some technical and educational assistance from the Piezo Institute Network of Excellence (http://www.piezoinstitute.com). This networking and collaboration will provide us a fast information and knowledge flow that will facilitate our laboratory development.

The project SONDE is divided into 4 work packages. These work packages represent 4 future subgroups in the INETEC's laboratory for ultrasound applications. Each package has its own milestones and goals. The first work package, WP1: Numerical simulations, deals with ultrasound transducer properties modeling by using software packages and numerical and analytical models. In the second work package, WP2: Materials management, different piezoelectric and acoustically passive materials needed for ultrasound prototypes are experimentally tested and engineered. The next work package, WP3: Transducer assembly and electronics, deals with techniques, methods and technologies of fitting together optimized parts of prototype ultrasound transducers. It includes the design of appropriate transducer housings, that are geometrically constrained by demands of larger non-destructive evaluation INETEC robotized inspection systems planned to incorporate the transducers, then, further, of mechanical processing, fitting, casting and gluing of materials that are under complex acoustic demands, as well as the electronic impedance matching of transducers to pulser-receiver systems. The fourth work package, WP4: Transducer performance testing and quality management, is focused on building and setting up ultrasound transducer performance testing systems on one hand, and, on the other, ensuring that both the internal and international quality control certificates are obtained for each produced ultrasound NDE probe planned to be commercially distributed or implemented in some of the complex INETEC robotized testing systems.

PROJECT TEAM

- Nazanin Bassiri-Gharb, PhD, Assistant Professor, Georgia Tech Atlanta (SONDE Technical Advisory Board)
- Dr. Dragan Damjanovic, Adjunct Professor, EPF Lausanne (SONDE Technical Advisory Board)
• Prof. dr. sc. Bojan Ivančević, FER Zagreb (SONDE Technical Advisory Board)
• dr. sc. Antonio Petošić, FER Zagreb (physics of ultrasound researcher)
• dipl. ing. Neven Parat, engineer at INETEC and a PhD student at FER Zagreb (transducer manufacture and engineering)
• pro. spec. eng. sec. Nikola Pavlović, INETEC (transducer manufacture and engineering)
• dipl. ing. Lucija Gregov, INETEC (transducer theoretical modeling)
• dipl. ing. Sergio Galošić, INETEC (transducer design)
• dipl. ing. Leonardo Trupinić (transducer testing)
• dr. sc. Marko Budimir (principal researcher and project manager)

PUBLICATIONS

PROJECT ACTIVITIES
• mathematical modeling of ultrasound and electromechanical properties of high-frequency ultrasonic transducers for NDT
• engineering of piezoelectric and acoustically passive materials
• electronics engineering
• transducer testing accompanied by manufacturing the test setups
• QA
• networking and cooperation with research laboratories worldwide
• diploma thesis supervision

CURRENT PROJECT RESULTS
• an obtained set of mathematically modeled ultrasound NDT transducers properties by using Matlab, finite element methods and PiezoCAD software package (that incorporates the KLM model) and in collaboration with the Department of Electroacoustics, Faculty of Electrical Engineering and Computing; an extensive set of materials, and electronic elements, has been used for our modeling - different piezoelectric ceramics and single crystals (several PZT ceramics with different geometries, barium titanate, lithium niobate, piezoelectric polymers), passive acoustic materials (backing and front matching layers: foam, filled epoxy, Polystyrene, Acrylic PMMA, aluminum, steel), electronic matching and cabling; the figure below shows just a descriptive example of a modeled two-way pulse-
echo signal and frequency bandwidth characteristics of a transducer configuration parameters used as input values in the PiezoCAD software

- systematized and documented analysis of a large set of piezoelectric and acoustically passive materials that are to be used as building parts of ultrasound NDE transducers; the experiments and samples engineering have been performed using several experimental setups specially constructed or obtained within this part of the project; the figure below is a descriptive example of a typical measurement - the frequency dependence of the magnitude of the electric impedance of a metal electroded piezoelectric PZT ceramic disk around its resonance and anti-resonance frequencies is measured using an impedance analyzer.
• several designs of transducers; the figures below show some example designs

• transducer performance tests setups built; among several setups for testing the transducer prototypes electromechanical and ultrasound properties, the one measuring the angular beam profile is shown in the figure below; the setups are designed and constructed according to international NDE standards, for example ASTM E1065-08 standard
transducer prototypes assembled; the figure below shows several examples of assembled transducer prototypes - both manual type and manipulator sled type transducers are presented

prototypes testing results - the measurements of the electromechanical and ultrasound properties of assembled prototypes have been measured according to international standards - a descriptive measurement of an ultrasound response of side drilled holes in a testing block has been shown in figures below

networking - relations to other R&D projects; as mentioned, one of very important goals of the SONDE project is to develop a network of cooperation and collaboration with other research laboratories - one of the results of that activity is participation in the consortium of the EU FP7 project "Long range ultrasonic system for continuous in service inspection and structural health monitoring of high temperature superheated steam pipes in power
generation plant with 100% coverage" (acronym HotScan), that started 1st of February 2011, while several proposals for new research projects have already been submitted to the next FP7 call.

- diploma work supervision: it is also worth mentioning that a diploma work has already been done within the SONDE project, by an INETEC employee Sergio Galošić, and supervised by prof. dr. Damir Markušić from the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, while co-mentored by the SONDE Project manager, dr. sc. Marko Budimir; the title of the work was "Ultrazvučni pretvarač za ispitivanje zavara reaktorske posude nuklearnih elektrana" (in Croatian); within this diploma work, the first angle beam NDE probe within the project was designed, constructed and tested successfully.

PRESENTATIONS/LECTURES

- 8th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurised Component, Berlin, Germany, September 2010
- EAA Euroregio 2010 Congress on Sound and Vibration, Ljubljana, Slovenia, September 2010
- Faculty of Science, University of Split, March 2011 (invited/planned)
- 2nd Festival of Science Sinj, April 2011 (invited/planned)