PHD THESIS : Non destructive ultrasonic characterization of polymer ageing

This proposed PhD thesis will be based in the Acoustic & Piezoelectricity of GREMAN laboratory pole and be supervised by J. Fortineau and S. Boucaud Gauchet.

GREMAN laboratory (UMR CNRS 7347 - University of Tours - INSA Centre Val de Loire):

GREMAN, a research group on materials, microelectronics, acoustics & nanotechnology, is a laboratory of over 100 people with 42 permanent academic staff, 16 administrative & technical staff, 38 PhD students and 10 post-doctoral researchers. Since its creation in 2012, the main activities of GREMAN laboratory have focused on materials, components and devices for energy efficiency and microelectronics in 5 key topics:

- functional oxides for energy efficiency: combinatory synthesis and nanostructuration;
- magnetic and optical properties of ferroic and electronic correlation materials;
- innovative materials and components for power and RF microelectronics: wide bandgap and porous semiconductors and their applications;
- piezoelectric and capacitive micro and nano systems for ultrasound transducers and energy conversion;
- methods and instrumentation for ultrasonic characterization of complex media.

This PhD thesis involves the last research topic, which is performed at the INSA Centre Val de Loire in the Acoustic & Piezoelectricity pole. The skills of the researchers are to develop innovative approaches with a new instrumentation for nondestructive ultrasonic characterization of polymer materials, based on linear and nonlinear technics [1,2,3,4] [5]. The experimental equipment of the pole is composed of ultrasonic transducers (in contact and in immersion), pulse generator, function generator, oscilloscopes, spectrum and network analyzers, water tank, L.A.S.E.R interferometers and acoustic microscopy device.

Background and motivation:

Polymer materials are used in a wide field of industrial applications. Most of them require better mechanical properties and more specifically fatigue resistance. In high technological applications, such as storage tanks for compressed gas, polymer products should offer extremely high levels of durability under more and more critical conditions of use: complex mechanical cyclic solicitations and environmental conditions such as high temperature or high temperature variation cycles. Today, the study of polymer products degradation needs a use of several technical analysis that induce their destruction in order to collect samples. The aim of the PhD thesis is to develop a specific non-destructive ultrasonic instrumentation in order to monitor the degradation in time of polymer material induced by both environmental conditions and mechanical solicitations. The final interest is to provide new tools for nondestructive technic to optimize quality products. This study consist of an original research approach based on both polymer material sciences and ultrasonic characterization.

Objective and method:

The propagation of the acoustic waves depends greatly on the mechanical characteristics of materials. The measurement of the linear properties as celerity or attenuation or nonlinear parameter of the acoustic wave can be used to characterize the thermo-mechanical ageing of polymer materials.
Polymer material samples with varied ageing conditions (thermo-oxydative ageing, mechanical ageing, themo-mechanical ageing) will be prepared in order to allow ultrasonic, mechanical and physicochemical characterizations.

Microstructural evolutions of polymer caused by thermo-oxidative ageing and mechanical damages will be monitoring by mechanical test, microscopy analysis, thermal and chemical analysis such as differential scanning calorimeter. The results obtained will be compared in order to establish the thermomechanical degradation behaviour and the effect on the durability of material.
The material results will be compared to ultrasonic characterizations. The linear ultrasonic parameters, such as celerity and attenuation of the acoustic wave will be measured using a calibrated insertion / substitution 3D spectroscopy method. The comparison of the experimental data with theoretical ones based on the modeling of acoustic wave propagation in a polymer sample will give a degradation level of the polymer material. This approach will be completed by a characterization of the microstructure based on the acoustic microscopy. Secondly, the measurements of the nonlinear acoustic parameters will be performed to characterize the presence of micro-cracks in polymer samples to add to linear measured parameters. The nonlinear parameter measurements will be performed by example using shift of the structural resonance frequency in function of the amplitude of solicitation. The results obtained will open new prospects in order to further understand local damage mechanisms in polymer products and to propose a real new device to help developing new polymer formulations and to follow the properties evolution in time during the life of the products.

References:
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key words: polymer material, polymer ageing, ultrasonic characterization, mechanical and physicochemical characterization, acoustic propagation modelling

Required profile:
The applicant should have theoretical skills in materials science and in physical acoustics. Good bases in signal processing and some experimental capabilities will also be essential.

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