

The past decades have marked significant progress in structural design using a variety of new materials. Some developments in this field – that include for example composites and multi-materials offered by additive manufacturing – have been already exploited by designers and engineers. Manufacturing defects, material degradation and in-operational damage (e.g. material fatigues or contact-type defects such as adhesion or debonding) are quite common, and pose many challenges to engineers and require reliable methods for material evaluation with respect to manufacturing quality and structural integrity. However, detection of the incipient material degradation and monitoring for contact-type damage are among the most challenging problems.

This project offers establishing international research collaboration between the AGH University of Science and Technology in Krakow, Poland and the Hong Kong Polytechnic University Shenzhen Research Institute in China, set up to solve one of the most challenging and unsolved problems in nonlinear wave propagation, being the physical understanding of non-classical nonlinear phenomena associated with the shear wave field. The third harmonic generation and the ultrasonic wave modulation transfer mechanism – that is equivalent to the Luxemburg-Gorky effect observed for electromagnetic waves - will be investigated. Although the linear and nonlinear shear wave propagation have been investigated for decades both nonlinear effects are still far from being fully understood.

The major focus will be on physical explanation of these effects and will lead to new theoretical models and numerical tools. It is anticipated that the results of the project will not only extend the current theory of nonlinear shear wave propagation but will also bridge the gap between basic and applied research. The latter relates to one of the most challenging problems in structural health monitoring, i.e. monitoring for defects in structural joints (e.g. delamination in composites or adhesive bonds). Shear waves have been always considered as good candidates for monitoring of contact type-defects in multi-layered materials. In addition, there is enough experimental evidence that non-classical nonlinear effects in longitudinal ultrasonic waves are more sensitive to damage than their linear equivalents. Therefore, it is anticipated that the combination of both elements – i.e. the nonlinear shear wave field with non-classical nonlinear phenomena – could offer an attractive solution to the aforementioned structural damage detection problem. It is expected that the importance of the results of the project could go far beyond structural health monitoring since shear wave propagation is an attractive research area in other fields such as seismology or medical diagnosis.

Various classical and non-classical elastic and/or dissipative nonlinear effects will be investigated to explain the described wave propagation effects. The major novelty will be associated with the interaction of shear waves with structural damage that will be modelled using non-frictional and non-hysteretic nonlinear dissipation mechanism that could be linked to thermo-elastic losses and stress concentrations previously observed in polycrystalline materials. Intrinsic nonlinearities associated with material properties or measurement chain will be also investigated in order to separate damage-related nonlinearities from these undesired effects and will also offer a significant level of novelty.

The perturbation approach will be used to tackle the nonlinear wave propagation problem. Numerical simulations will be performed using the Local Interaction Simulation Approach and the Finite Element Modelling. The results will be validated experimentally using simple plate-like adhesively bonded joint components. Following these investigations, a number of new damage detection procedures – based on the third harmonic generation and the nonlinear modulation transfer mechanism in shear wave propagation – will be proposed and demonstrated.