Transducers and Sensor-near Signal Processing for SHM of Composite Structures

Research project:

This 3-year research project is funded by the Marie Curie program of European Union through the Innovative Training Network GW4SHM (Guided Waves for Structural Health Monitoring).
The activity that will be carried out at the University of Bologna concerns the development of novel sensor technologies for ultrasonic guided waves (GWs) inspections.
The permanent integration of GWs technology in composite and metallic structures is limited by several factors: bulky hardware instrumentation and large number of connecting cables, high power consumption and, consequently, high integration costs. Such limitations hampers the adoption of the GW technology in application domains with stringent weight requirements (e.g. aerospace and automotive).

The aforementioned limitations will be addressed with both 1) novel transducers and 2) damage imaging algorithms compatible with embedded signal processing. The transducers will consist of a set of devices with inherent beam steering capabilities, able to generate and detect directional ultrasonic guided waves within a structure with minimal hardware requirements. The peculiarity of the proposed devices is the capability to generate ultrasonic waves along arbitrary directions on the structure depending on the frequency content of a single excitation signal (frequency steerable transducers- FSAT), or to automatically detect the direction of arrival of mechanical waves generated by impacts and propagating within the structure. Advanced damage imaging algorithms will be used to process the signals measured by transducers. Super-resolution tools will be integrated into correlation-based imaging algorithms. Time- and low-depth-encoding approaches to enhance power efficiency in probe actuation and readout will be implemented. In parallel, dedicated signal-processing algorithms will be developed and the specifications for the front-end electronics will be provided.
The principal result of the research activity will consist in the assessment of the performances of the FSAT technology. Thanks to its unique features, FSAT will rely on an extremely simplified circuitry, wireless communications and “sensor near” signal processing. The novel transducers and their dedicated signal conditioning electronics will be a cornerstone for the realization of distributed sensor networks for SHM aimed at commercial aircraft or automotive vehicles, because it will allow a consistent volume and weight reduction w.r.t. the currently adopted laboratory instrumentation.

Training programme

The research training programme combines uniquely, inter-sectoral and multidisciplinary research activities (simulation, signal processing, sensor integration) in the field of SHM technologies. One of the most exciting features of the GW4SHM project is that its activities directly respond to the result of an online-survey revealing the particular needs of European companies for SHM technologies. Only the proposed multidisciplinary approach of combining simulation and signal processing tools, transducer integration, reliability studies, and standardisation activities with the goal of fostering the acceptance of SHM technologies in practice can fully exploit the huge potential of this cutting-edge technology. The training curriculum starts with methodological training in physics and materials science basics,

simulation, signal processing of guided waves and ultrasound and continues with technical training in SHM methods. Training on state-of-art tools and instruments will be carried out in close interaction with partners from application areas of the aviation, petrochemical and automotive industries.

The specific training objectives are:

- to convey substantial fundamental knowledge of all aspects of guided wave-based SHM, including simulation, data analysis and reliability,
- to ensure awareness of industrial needs regarding guided wave-based SHM, enabling encompassing insight into aviation and petrochemical industry, and specific detailed knowledge in the automotive field thanks to the secondment in an industry of this sector,
- to develop researcher's transferable skills: to work effectively and efficiently during and after the PhD, to communicate with different audiences, to identify and exploit entrepreneurial opportunities and to prepare him/her for leadership roles in academia and industry.

To achieve the training objectives, a network-wide Training Events (TE) and the training during secondments will be supplemented by local training.