Optimization of SHM systems for Fibre-Metal-Laminates with integrated sensors by means of acoustic impedance matching

Max Rottmann[1], Wolfgang Weber[1]

[1]Chair of Strutural Analysis, Helmut Schmidt University, Germany

Materials for the aerospace industry must be of high-strength, as light as possible, durable and maintainable to achieve safety, economic and ecological objectives. Composites like Fibre-Reinforced-Plastic (FRP) and new material compositions such as Fibre-Metal-Laminates (FML) meet these requirements. The state of the art for non-destructive testing for thin-walled structures is structural health monitoring (SHM) with guided ultrasonic waves (GUW). The process involves the emission of a wave-field, also referred to as GUW, by actuators. Damage in the structure e.g. delamination can affect the wave-field, thereby changing its propagation characteristics. The interaction between damage and GUW is measured by sensors and can be used to identify and localize damage and thus determine the system's health state. The SHM hardware (sensors and actuators) can be embedded into the structure to meet the objective of a maintenance-friendly structure. However, embedded hardware causes a local jump in the material properties, leading in most cases to wave-filed distortion, similar to structural damage. This results mainly from the change of the acoustic impedance, which is the parameter that primarily affects the reflection behaviour of wave-fields. Disturbances of the wave-field can be reflections, mode conversion or scattering. Reflections of the wave-field in particular can cause damage to be over or under-estimated in terms of quantity, location, and severity. To minimize false detections, this contribution focuses on reducing wave-field distortion and reflections caused by embedded sensors. Previous work introduced a step gradient interphase around the sensor to minimize the impedance jump and thus the reflections of the wave-field. This was achieved using a functionally graded material and an acoustic impedance matching using tungsten particles in an epoxy matrix. To adjust and manipulate the acoustic impedance, tungsten particles were incorporated into an uncured epoxy resin. This novel approach allows for designing an interphase between the sensor and its surrounding material, where the interphase properties are controlled by the tungsten particle content. For simple isotropic and homogeneous material combinations such as epoxy as hosting material and glass as sensor material, acoustic impedance matching could be achieved. The first approach showed (i) reduced reflections from the sensor (less distortion) and, for specific configurations, (ii) amplified transmissions to the sensor. This contribution extends the previously described approach for an application in FML to improve the understanding of acoustic impedance matching for more complex materials. The challenge with FML is that material changes occur in the thickness direction and that FRP layers are inhomogeneous and anisotropic. By considering the influence of anisotropic and inhomogeneous laminate layers on impedance matching, the study contributes to the optimization of non-destructive testing and SHM techniques. The findings offer a valuable framework for acoustic impedance matching of sensors in complex composite structures.