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Simulation of wave propagation in remote bonded FBG sensors using the spectral element method

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Ultrasonic guided waves (GW) due to their ability to monitor large areas with few sensors, are commonly employed for structural health monitoring (SHM) in aerospace, civil, and mechanical industries. The FBG sensors in the edge filtering setup are re-emerging as a favored technique for GW sensing. The FBG sensors offer embeddability, ability to be multiplexed, small size, and immunity to electric and magentic fields and as such are seen as ideal sensors. To enhance the sensitivity of these sensors, these sensors are deployed in the so-called remote bonding configuration where the optical fiber is bonded to the structure while the FBG sensor is free. This configuration not only enhances the sensitivity but also opens up possibility of self-referencing.

In this setup the GW in the structure is coupled to the fiber and converted into fiber modes. These modes propagate along the fiber and then are sensed at the FBG. The conversion of the plate modes to fiber modes is a phenomenon which is still being studied. The effect of the adhesive layer and the material properties of the adhesive on the coupling are still not known. Furthermore the directional nature of this coupling and its marked difference from the directly bonded configuration needs to be studied in detail. For this detailed study a computationally efficient model which captures the physics of the coupling is necessary.

Hence, in this research we develop a numerical model based on the spectral element method for the modelling of the remote bonded configuration of the FBG. The model comprises four meters long optical fiber bonded to the centre of the plate by the adhesive layer and the piezoelectric disc (PZT) used for wave excitation. All components are modelled by 3D spectral elements, with second-order elements used for the fiber and adhesive layer. Parametric studies were performed for various thicknesses and the Young's modulus values of the adhesive layer, the FBG distance from the bonding fiber to the plate, PZT location and signal excitation frequency.

The model is validated with experimental results and shows that it indeed captures the physics of the coupling and is computationally more efficient than other methods using conventional finite element software.