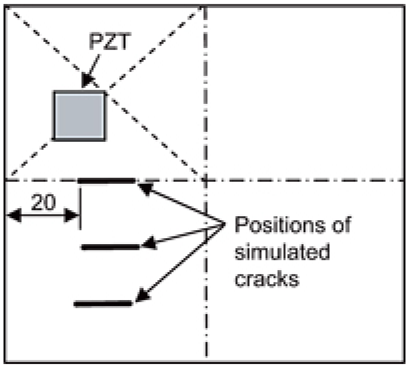
Ability of Impedance-Based Health Monitoring To Detect Structural Damage of Propulsion System Components Assessed

Impedance-based structural-health-monitoring uses piezoelectric (PZT) patches that are bonded onto or embedded in a structure. Each individual patch behaves as both an actuator of the surrounding structural area as well as a sensor of the structural response. The size of the excited area varies with the geometry and material composition of the structure, and an active patch is driven by a sinusoidal voltage sweep. When a PZT patch is subjected to an electric field, it produces a mechanical strain; and when it is stressed, it produces an electric charge. Since the patch is bonded to the structure, driving a patch deforms and vibrates the structure. The structure then produces a localized dynamic response. This structural system response is transferred back to the PZT patch, which in turn produces an electrical response. The electromechanical impedance method is based on the principle of electromechanical coupling between the active sensor and the structure, which allows researchers to assess local structural dynamics directly by interrogating a distributed sensor array. Because of mechanical coupling between the sensor and the host structure, this mechanical effect is picked up by the sensor and, through electromechanical coupling inside the active element, is reflected in electrical impedance measured at the sensor's terminals.

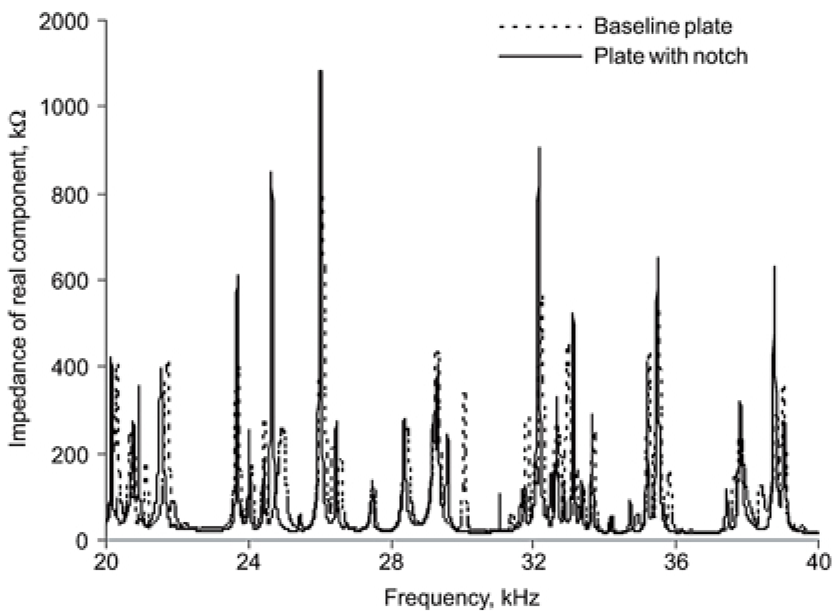
Experiments on simple-geometry specimens (thin-gauge aluminum square plates) were conducted to assess the potential of the electromechanical impedance method for detecting structural damage. Plate specimens (100 by 100 by 1.53162 mm) were made from 6061-T6 aluminum alloy sheet. Each plate was instrumented with one 10- by 10-mm PZT patch (0.1905-mm-thick PSI-5A4E material) purposely located at a location sensitive to vibration. This location was determined by conducting a finite-element analysis focusing on the modal response of the plate. Researchers used 10-mm straight electrical-discharge-machining notches to simulate cracks.



Progression of specimen geometries with simulated cracks at various distances from the PZT sensor.

Multiple scenarios were addressed. A single notch was placed at three different locations with increasing distance from the patch as shown in the preceding figure. Multiple plates were used, with each plate having only a single notch at one of the three locations. Electromechanical impedance data were obtained with an HP 4194A impedance analyzer (Hewlett Packard, Palo Alto, CA). During the experiments, the specimens were supported on foam to provide an unconstrained support condition.

A series of 15 experiments were conducted over the frequency band 20 to 40 kHz, which was selected on the basis of repeatability results. The data were processed to consider the real part of the electromechanical impedance spectrum. The change induced in the spectrum by the presence of damage, for the notch located closest to the PZT sensor, is shown in the following figure. The presence of the notch significantly modified the frequency response function. This was indicated by shifting of the resonant frequencies and by the appearance of new resonances. The calculated correlation coefficient for this case was 0.497.



Averaged electromechanical impedance results for a plate with and without a notch.

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