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Keynote Paper

Noncontact Strain Mapping Using Laser-Induced Fluorescence from Nanotube-Based Smart Skin

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Abstract:

Stress fields around structural discontinuities, such as cracks, usually cause complex but distinct strain contours/maps when structures are subjected to load. Hence mechanical strain on structural surfaces can provide useful information on the condition of the material, such as the damage location and the severity. The phenomena of stress concentration or strain concentration around discontinuities (such as holes and cracks) can be used to perform non-destructive evaluation (NDE) of structural components. Among analytical computation, numerical simulation, and experimental studies to investigate the stress/strain field around a structural discontinuity, experiments are the most accurate in revealing the actual complex strain conditions. In this study a Strain-Sensing Smart Skin (S4) film sensor is invented, developed and used to investigate the strain distribution in metallic plates near different structural discontinuities. S4 is a newly developed non-contact, full-field strain technology that utilizes the strain-sensitive photoluminescent properties of single-walled carbon nanotubes (SWCNTs). Aluminum bars in tension have been studied in two cases: (1) with a central hole, and (2) with an edge notch. In both cases, S4 film sensors measured the residual strain contours near structural discontinuities under large axial loading at room temperature. Linear elastic fracture mechanics (LEFM) was used to compute the closed-form solution of strain fields. Finite element (FE) elasto-plastic nonlinear models were also constructed and validated by using strain gage data from the experiments. The FE analysis results are found to match the strain distribution obtained from S4 measurements. S4 technology can be usefully applied in the realms of non-destructive evaluation, experimental mechanics, and structural health monitoring.

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Dual-layer nanotube-based smart skin for enhanced noncontact strain sensing
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