Spectral Finite Element Model For A Curved Beam With An Edge Crack Using Classical Love'S Shell-Type Theory

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Cracks in structures at a particular location change the flexibility or stiffness property, which should be incorporated to evaluate the exact behavior. This paper discusses a Fourier transform-based spectral finite element model (SFEM) for an isotropic curved beam with an edge crack. The coupled longitudinal and flexural modes in a curved beam increase the complexity of its dynamic behavior compared to a straight beam. The proposed model is based on the classical Love's shell-type theory (CST), neglecting rotary inertia's shear deformation and effects. Here the damage is modeled as a spring with specific stiffness calculated based on the crack function, which varies depending on the depth of the crack. SFEM formulation is derived using the nodal displacements at ends, boundary conditions at the crack location, and the nodal spectral forces. The exact dynamic stiffness matrix is formulated using the exact wave propagation solution. At the end node, a throw-off/semi-infinite element is taken to dissipate the energy due to reflections. A numerical study is performed for cracked beam models of CST and a healthy beam with no crack. The models are subjected to an impact force of high frequency as tone burst signal of very small duration in the order of micro-seconds with a sinusoidal variation of a certain number of cycles and multiplied by a triangular signal lasting for the duration. The applied force and the sensor location are taken at the respective nodes of interest. Two nodes are considered for which one is free and the other is attached to a semi-infinite element; each node has three degrees of freedom (DOF), i.e., axial displacement, transverse displacement, and the in-plane rotation of cross-section, respectively. The force resultants corresponding to the DOFs are axial, shear, and moment; hence, the dynamic stiffness matrix obtained will have the size 6-by-6. The analysis obtains the responses in the frequency domain at all number of steps by converting the applied force to the frequency domain using FFT. The dynamic stiffness matrix is obtained at each frequency point, and the displacements are calculated; all the obtained values for a particular DOF are transformed using the IFFT to get the time domain response. The displacement and velocity responses are then studied for the proposed model and compared with the healthy beam. The reflections caused due to the presence of a crack are observed in the responses obtained. The study is conducted for different crack depths, and the obtained responses are observed to have reflections with different intensities.