A Null Space Technique for Damage Localization

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The fundamental difficulty in localizing damage by updating resides in the large number of parameters that must be considered to allow for all possible damage scenarios. This paper shows that the localization question can be entirely uncoupled from the quantification and solved rigorously in a formulation that avoids the definition of a free parameter space entirely. The uncoupling is realized by means of a theorem, presented and proved in the paper, which maps the null space of the change in the transfer matrix ΔG to the spatial position of stiffness related damage. The theorem states that the null space of ΔG contains vectors that are Laplace transforms of excitations for which the resulting stresses field is zero over the damaged portion of the domain (small in the presence of truncation and other inevitable errors). It is shown that the transfer matrix change is guaranteed to be rank deficient when the rank of the change in the stiffness matrix associated with the damage is less than the minimum dimension of the experimentally available transfer matrix. Implementation of the theorem into a localization approach is illustrated first in the time domain, where it is shown to be computationally expensive and then in the Laplace domain, where the approach proves to be computationally efficient. Application of the theorem at $s = 0$ is equivalent to a null space interrogation of changes in flexibility. The improvement in resolution limits realized by extracting information available in ΔG evaluated away from the origin is shown to be significant in many cases.

Key words: Damage localization, null space, transfer matrix

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