Active Vibration Control based on Modal Test Data

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The conventional approach in active control is matrix based, usually employing numerical models formulated in the state space. This has the significant disadvantage of incompatibility between the model and the reality it seeks to represent. Not only do finite element models used in active vibration control contain assumptions and approximations, but also they generally have many more degrees of freedom than the number of sensors used in a test. Consequently, unmeasured states must be estimated using an observer.

An alternative approach based on modal test data in the form of receptances, or frequency response functions (FRFs) generally, will be presented. It has the advantage that there is no need to know or to evaluate the **M**, **C** and **K** matrices. Also, inversion of the dynamical system of equations, to form receptances, releases the controller from the necessity to estimate unmeasured states. A particular advantage is its ease of application to variants of essentially the same structure (e.g. different vehicle payloads, engine configurations, suspensions etc.) using vibration test results for each one-by-one.

The multi-input–multi-output (MIMO) receptance method enables the active control of vibrations by eigenstructure assignment (assignment of eigenvalues and eigenvectors) and admits a closed-form minimum-norm, least-energy solution in form of an inverse Rayleigh quotient.

In practice input-output transfer function matrices are obtained by fitting rational functions to measured FRF data. The method is made robust to misfitting using analytical local sensitivity formulae, which are computationally efficient even in the presence of large numbers of random parameters. In nominally identical systems, typically components from a production line, controller performance must be effective in the presence of aleatory (inherent) variability. Then, the controller is formulated to minimise the spread of the system poles by variance minimisation using a polynomial chaos (PC) expansion, which significantly reduces the number of samples required compared to other methods such as Monte Carlo simulation.

Nonlinear control is also available using feedback linearisation developed in terms of measured receptances and based on the harmonic balance method when considering the fundamental frequency component present in the response spectrum. Theoretical research is supported by experimental examples including a three degree of freedom rig with non-smooth nonlinearity and the suppression of unstable flutter instabilities in the Liverpool low-speed wind tunnel.