

Modal Frequency Response Analysis using MSC.Nastran

1. Theoretical background for calculations in Nastran

In this section, a very brief description is given of how the calculation of frequency response functions works with Nastran's modal frequency response analysis. Therefore, the most important equations are given in a chronological order as applied by the program.

After input of an bulk data file (*.bdf), Nastran assembles the system's mass and stiffness matrices, leading to a set of differential equations, displayed by eq. (1), already transformed in the frequency domain (damping is neglected at first).

$$\mathbf{M} \ddot{\mathbf{x}} + \mathbf{K} \mathbf{x} = \mathbf{f}(\omega) \quad (1)$$

Secondly, Nastran solves the characteristic equations (eq. (2)) for eigenvalues and computes the corresponding eigenmodes.

$$\det(\mathbf{K} - \omega^2 \mathbf{M}) = 0 \quad (2)$$

With the separation approach in eq. (3), a modal transformation[1,3] is performed, which diagonalizes the system from eq. (1), using the orthogonality properties of the eigenvectors in the modal matrix Ψ , consisting of the calculated eigenvectors.

$$\begin{aligned} \mathbf{x} &= \Psi \mathbf{q}(\omega) \\ \text{with } \Psi &= [\psi_1, \psi_2, \psi_3, \dots, \psi_N] \end{aligned} \quad (3)$$

Hereby the system, consisting of N degrees of freedom, is decoupled, leading to a system of N single-mass oscillators, with each oscillator representing an eigenmode of the system in general coordinates q_i (eq. (4)).

$$m_i \ddot{q}_i(\omega) + k_i q_i(\omega) = p_i(\omega) \quad (4)$$

Here, m_i is the modal mass, k_i the modal stiffness, and $p_i = \psi_i^T \cdot \mathbf{f}$ the modal force. With the eigenfrequencies $\omega_i^2 = k_i / m_i$, eq. (4) can be transformed to eq. (5). Furthermore, damping can be introduced by a modal damping ratio ζ_i (eq. (6), [1]).

$$\ddot{q}_i(\omega) + \omega_i^2 q_i(\omega) = \frac{p_i(\omega)}{m_i} \quad (5)$$

$$\ddot{q}_i(\omega) + 2\zeta_i \omega \dot{q}_i(\omega) + \omega_i^2 q_i(\omega) = \frac{p_i(\omega)}{m_i} \quad (6)$$

The solution of this differential equation is well known and given by eq. (7).

$$q_i(\omega) = \frac{1}{\omega_i^2 - \Omega_i^2 + i2\zeta_i \omega \Omega_i} \cdot \frac{p_i(\omega)}{m_i} \quad (7)$$

Then, the solution for the system ist a linear combination of the solutions for all oscillators (eq. (8)).

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