Force-Limited Random Vibration

Units (English and metric)

English: mass [lbm] /386, force [lbf], $g = 386$ in/sec^2

Metric: [kg], [N], $g = 9.81$ m/sec^2; acceleration PSD [G^2/Hz] in both

Apparent mass of the test item (base driven, fixed-base modes)

$M_A(\omega) = F/\ddot{x}_b = M_0 + \sum_k m_k \frac{\omega^2}{\omega_k^2 - \omega^2 + 2i\zeta\omega_k\omega}$, $\zeta = 1/(2Q)$

$m_k = L_k^2$, $L_k = \phi_k^T M_{ib} r_b$ (Craig-Bampton effective mass)

$M_0 = r^T M r$ minus the base (shaker / fixture) mass

Single oscillator: $M_A = m\,(\omega_n^2 + 2i\zeta\omega_n\omega)/(\omega_n^2 - \omega^2 + 2i\zeta\omega_n\omega)$

Force limit (NASA-HDBK-7004C) and notched acceleration

Semi-empirical: $S_{FF} = C^2 M_0^2 g^2 S_{AA}$, $f \le f_0$; $S_{FF} = C^2 M_0^2 g^2 S_{AA}(f_0/f)^n$, $f > f_0$ ($n = 2$: -6 dB/oct)

Mc^2 flat: $S_{FF} = C^2 M_0^2 g^2 \max(S_{AA})$; Mc^2 shaped: $S_{FF} = C^2 M_0^2 g^2 S_{AA}$

Unnotched force $S_{FF,u} = |M_A|^2 g^2 S_{AA}$; notched input $S_{AA,n} = \min\left(S_{AA},\ S_{FF}/(|M_A|^2 g^2)\right)$

Notch depth $= 10\log_{10}(S_{AA}/S_{AA,n})$ dB; rms $= \sqrt{\int S\,df}$

Guidance: C^2 about 2 to 5; notches deeper than about 10 to 14 dB need justification