Macromechanical parametric amplification

Neumeyer, Stefan; Thomsen, Jon Juel

Publication date:
2013

Citation (APA):
1. What is it?

- Adding parametric excitations to externally driven near-resonant harmonic oscillations to amplify vibration amplitudes, e.g., a playground swing:

   - The ratio between the stationary vibration amplitudes of the directly and parametrically excited system, and the directly excited system, is defined as the gain.

2. This study?

- Phenomenological study
- Effects of third-order nonlinearities
- Optimal gain and tilt angle
- Parametric amplification of higher order vibration modes
- Superthreshold pumping

3. Realization in current study?

Tilted base-excited cantilever beam:

- Shaker
- Tilt angle
- Beam
- Acc
- Strain-gauge
- Fixture
- Laser displacement sensor

4. Current work? [1,2]

\[ \begin{align*}
2\pi \zeta z + \left( \epsilon \lambda \Omega^2 \cos \left( \Omega \tau + \phi \right) + \epsilon_1 \lambda \Omega^2 \cos \left( 2\Omega \tau + \phi \right) + \epsilon_2 \lambda \Omega^2 \cos \left( 3\Omega \tau + \phi \right) \right) z + \epsilon K_0 z^3 \\
&= \epsilon \lambda \Omega^2 \cos \left( \Omega \tau + \phi \right) + \epsilon_1 \lambda \Omega^2 \cos \left( 2\Omega \tau + \phi \right) + \epsilon_2 \lambda \Omega^2 \cos \left( 3\Omega \tau + \phi \right) \\
&\quad + \epsilon_3 \lambda \Omega^2 \cos \left( 2\Omega \tau + \phi \right) + \epsilon_4 \lambda \Omega^2 \cos \left( 3\Omega \tau + \phi \right)
\end{align*} \]

Amplitude vs excitation detuning

Gain squared:

\[ G_2^2(\sigma = 0) = \frac{1 + (\kappa \sin \alpha - 2\sin 2\alpha) \kappa \sin \alpha \cos^2 \alpha}{1 - \kappa^2 \sin^2 \alpha} \]

\[ G_{\alpha_{\text{opt}}}^2 = \frac{1}{1 - \kappa^2} \]

Gain vs tilt angle

Gain vs phase lag

5. Conclusions? ...and so what?

- Insight through derivation of analytical expressions
- Gain is realized (larger than unity)
- Optimal mix between excitation parameters
- Other nonlinear effects
- Energy considerations
- High-frequency excitation effects