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Analysis of a 3-DOF shear building dynamics with nonlinear stiffness

José E. Montiel[1]
Faculdade de Engenharia, Departamento de Engenharia Civil, UFGD, Dourados, MS
Marcus Varanis[2]
Faculdade de Engenharia, Departamento de Engenharia Mecânica, UFGD, Dourados, MS

This paper aims to model and analyze a three-story shear building (Figure 1) excited by an umbalanced motor in two cases, in order to identify the influence of non-linearity on such a system. In the first case, all the columns behave as linear springs whereas in the second case the second floor columns behave as Duffing nonlinear springs.

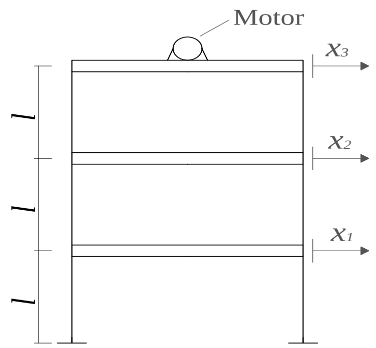


Figure 1: Three-story shear building

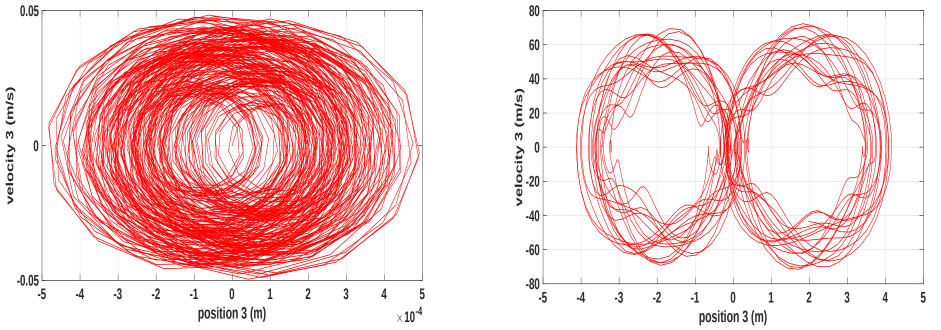
The parameters used are mass $m_i (i = 1, 2, 3)$ of 0.416, 0.416 and 0.726 kg, stiffness of columns $k_i (i = 1, 2, 3)$, all equal to 1.966 kN/m, and the motor frequency ω_3 of 20 Hz. The umbalanced mass m_u was 6.59 g and its distance R from the axis of rotation was 15 mm. The coefficients related to the nonlinear spring are $\alpha = -1.966 * 10^3$ and $\beta = 0.4915 * 10^3$.

The motion equations are given by equations 1 and 2 and they have been solved by the fourth-order Runge-Kutta algorithm. The frequency domain responses (Figure 3) were obtained by using the Fast Fourier Transform (FFT).

$$\begin{cases} m_1\ddot{x}_1 + k_1x_1 - k_2(x_2 - x_1) = 0 \\ m_2\ddot{x}_2 + k_2(x_2 - x_1) - k_3(x_3 - x_2) = 0 \\ m_3\ddot{x}_3 + k_3(x_3 - x_2) = m_u\omega_3^2 Rcos(\omega_3 t) \end{cases} \tag{1}$$

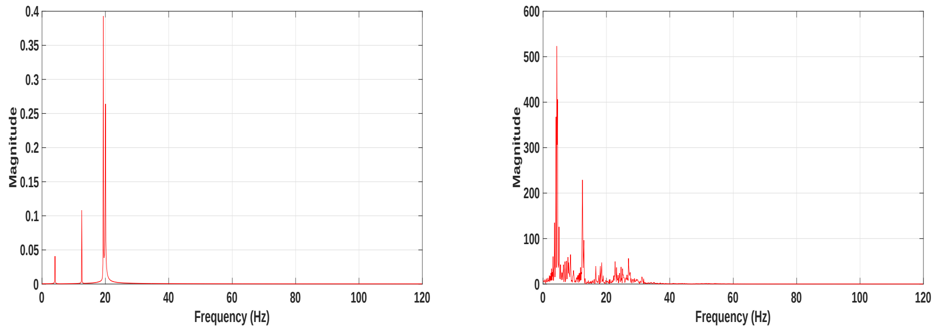
[1]joseemontiel95@gmail.com
[2]MarcusVaranis@ufgd.edu.br

$$
\begin{cases}
m_1\ddot{x}1 + k_1x_1 - \alpha(x_2 - x_1) - \beta(x_2 - x_1)^3 = 0 \\
m_2\ddot{x}_2 + \alpha(x_2 - x_1) + \beta(x_2 - x_1)^3 - k_3(x_3 - x_2) = 0 \\
m_3\ddot{x}_3 + k_3(x_3 - x_2) = m_u\omega_3^2 Rcos(\omega_3 t)
\end{cases}
\tag{2}
$$



(a) Phase space of the linear system (b) Phase space of the nonlinear system

Figure 2: Phase space of the third floor for each system



(a) Linear system frequency domain response (b) Nonlinear frequency domain response

Figure 3: Frequency domain responses obtained by using the FFT algorithm

These simulations showed the effects of nonlinearity on the characteristics of an oscillation. This can be seen in Figure 2 and also in Figure 3, where the appearance of the signal frequencies have changed drastically, indicating chaotic movement.

References

[1] M. A. Savi and P. M. C. L. Pacheco. Chaos in a Two-Degree of Freedom Duffing Oscillator, *J. Braz. Soc. Mech. Sci.*, 2002. DOI:10.1590/S0100-73862002000200006.

[2] M. Varanis, A. L. Silva, A. G. Mereles. On mechanical vibration analysis of a multi degree of freedom system based on arduino and MEMS accelerometers, *Revista Brasileira de Ensino de Física*, 2018. DOI: 10.1590/1806-9126-rbef-2017-0101.