Identification of Non-polynomial forms of Damping Nonlinearity in Dynamic Systems using Harmonic Probing and Higher Order FRFs

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Abstract. While modeling a dynamic system, damping is often assumed to be viscous and linear. However, damping inherently is nonlinear and can be of various forms. In this work, we have developed a structured methodology to classify non-polynomial forms of damping from polynomial forms. First, symmetric and asymmetric forms in general are identified from the response spectrum pattern under harmonic excitation. Then further polynomial and non-polynomial forms are classified analysing variation patterns of second and third harmonic amplitudes under varying excitation levels. The algorithm is numerically demonstrated and theoretically explained with Volterra series based response harmonic formulation.

Introduction

Damping is inherently present in all dynamic systems and more often in nonlinear form which can be symmetric or asymmetric and further of polynomial form or non-polynomial form as given below.

i) Cubic damping with $F_D[\dot{x}(t)] = c_1\dot{x}(t) + c_3\dot{x}^3(t)$ symmetric and polynomial form

ii)Quadratic damping with $F_D[\dot{x}(t)] = c_2\dot{x}(t)|\dot{x}(t)|$ symmetric but non-polynomial form

iii)Square damping with $F_D[\dot{x}(t)] = c_1\dot{x}(t) + c_2\dot{x}^2(t)$ asymmetric and polynomial form

iv)Bilinear damping $F_D[\dot{x}(t)] = \lambda c\dot{x}(t) \; for \; \dot{x}(t) > 0$ and $F_D[\dot{x}(t)] = c\dot{x}(t) \; for \; \dot{x}(t) < 0$

. asymmetric and non-polynomial form

Although identification work has been done for polynomial forms of damping [1-3], it is not yet done for non-polynomial forms. Here, we present identification of non-polynomial forms, i.e., case ii) and case iv).

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Results and Discussion

Fig.1a. shows the response spectrum of bilinear damping in which a second harmonic is present and it shows that bilinear damping is in the group of asymmetric nonlinearity forms. But a similar spectrum is exhibited by square damping also. Further classification is provided by the variation of second harmonic amplitude with excitation level as shown in Fig.1b. It is seen that second harmonic amplitude varies as a square function of excitation level for square nonlinearity, whereas it varies linearly for bilinear form. This distinctive behaviour can be explained, if second harmonic amplitude is formulated using Volterra series and second order Frequency Response Functions. Although, bilinear function is a non-polynomial function, it can be approximated by a polynomial function which shows that the polynomial coefficients are amplitude dependent which in turn is dependent on excitation level. Thus the second harmonic for a bilinear damping behaves differently from a square damping form. Similar comparative analysis has been also done for distinction between Quadratic damping and cubic damping

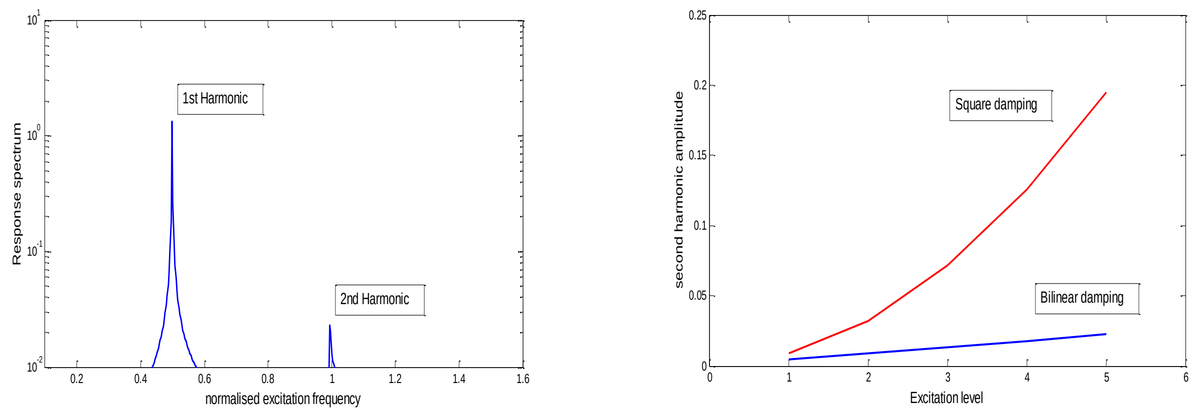

Figure 1: a) Response spectrum for bilinear form b) Second harmonic amplitude variation with excitation

. References

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