Can Non-Resonant Limit Cycle Vibration Absorbers Control Self-Excited Instabilities?

Pankaj Wahi
Professor
Department of Mechanical Engineering, IIT Kanpur

Brief Biographical Sketch

Dr. Pankaj Wahi completed his BE in Mechanical Engineering from Government Engineering College, Bilaspur, Chhattisgarh followed by a PhD from Indian Institute of Science, Bangalore. He has been with the Mechanical Engineering Department at IIT Kanpur since 2007. His primary research interests are in nonlinear dynamics, vibration control and time-delayed systems.

Abstract

Several engineering applications involve structures which are susceptible to large amplitude vibrations due to self-excited instabilities, e.g. vortex-induced vibrations due to shedding vortices from structures. Several control approaches have been explored in the literature to prevent large amplitudes in these structures either using active or passive means. Whenever possible, passive means are preferable due to its reduced complexity as well as simplicity as it does not require sensors and actuators to be integrated with the structure. One of the most popular passive control techniques for such structures is the tuned mass damper where a secondary spring-mass-damper system with its natural frequency tuned to the critical natural frequency of the structure and an optimum damping is attached to the structure at an appropriate location. This has been shown to be fairly effective and its generalisation for nonlinear primary systems in the form of nonlinear energy sinks have also been widely studies for systems with nonlinear stiffness. However, their effectiveness in getting the desired performance in self-excited vibration scenarios has not been fully established yet. These methods require the parameters of the secondary system to be well tuned to the primary system and performance deteriorates significantly even in the presence of slight detuning which can never be avoided in practice since there are uncertainties associated with estimation of the parameter of the system as well as these parameters can change with time due to several environmental and weather related factors. Hence, there is a need to develop non-resonant or untuned vibration absorbers which do not require precise tuning for effective operation.

In this talk, I will explore an untuned secondary system which itself can have a limit cycle for the purpose of controlling self-excited instabilities in structures. I will motivate a physical secondary system for the purpose and will explore all possible qualitative regimes of operation for this system and study each one of them using a similar archetypal mathematical model. I will explain the qualitative dynamics of the coupled system in detail first using a primary linear system with a negative damping and then, on a more applied problem of tool chatter during turning wherein nonlinearities in the primary system are also included. I will demonstrate that the secondary limit cycle oscillator can help delay the onset of tool chatter as well as can change the nature of the bifurcation from subcritical to supercritical.