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Résumé

Mechanical systems (e.g. flexible structures) are usually lightly damped so that they vibrate severally in response to dynamic loads. Therefore, vibration control strategies should be adopted in order to reduce the undesired vibration of mechanical systems. The objective of this thesis is to develop multiple vibration control techniques, which are either passive or active. All systems under investigation are in the mechanical and/or electrical domains, for which analytical optimization and theoretical analyses are performed.

The first part focuses on the application of inerter to enhance the vibration control performance of two existing control devices, the tuned mass damper (TMD) and the series double TMD (SDTMD). The inerter is employed to relate the tuned mass to the ground. In the case of TMD, a mechanical system under stiffness uncertainty is considered and the worst-case H_∞ optimization is addressed by means of an entirely algebraic approach. In the case of SDTMD, the vibration of a deterministic mechanical system is to be controlled and the H_∞ optimal design is carried out via an extended version of fixed points theory (FPT).

Instead of using the inerter, the second part consists in improving the control effect by incorporating a linear negative stiffness between the ground and the tuned mass. Two case studies are conducted based on the non-traditional TMD and inerter-based dynamic vibration absorber (IDVA), whose tuned mass is related to the ground by a viscous damper or an inerter-based mechanical network, respectively. Later, the exact electrical realization of non-traditional configurations with or without negative stiffness is proposed, which is based on the piezoelectric transducer enclosed by a particular shunt circuit. This electromechanical analogy enables to extend the applicability of mechanical control devices and to facilitate the precise tuning.

In the last part, active and semi-active vibration control techniques are developed. The first strategy consists in enhancing the control capability of passive TMD and IDVA by feeding back the displacement signal of mechanical system to the electromagnetic actuator. The proposed controller can be regarded as one or multiple basic units arranged in series, which is featured by one pole at the origin and two coalesced zeros on the real axis. It is analytically proven that such a controller design is always stable if and only if the magnitude of introduced zeros resides within the magnitudes of the smallest and largest eigenvalues of coupled system, whose expressions are analytically formulated in both cases of TMD and IDVA. Distinguished from the previous strategy, the semi-active control technique is based on electromagnetic shunt damping (EMSD), therefore, no additional sensor is required to measure the information of mechanical system. In order to artificially increase the shunt damping performance, the employment of negative inductance (NI) in the shunt circuit is considered. Three possible layouts of NI in the EMSD are assessed in terms of the electromechanical coupling factor, which quantifies the energy conversion efficiency between mechanical and electrical domains. Finally, six types of shunt circuits are optimally tuned according to the FPT and the beneficial effect of NI and the influence of its layout can be underlined.