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Dynamic Energy Harvesting And Motion Control In Randomly Excited Mdof Structures Via Bi-Objective Optimally Designed Tuned Mass Damper Inerter

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This paper studies the potential for energy generation from structural vibrations concurrently with motion control in white-noise excited multi-degree-of-freedom (MDOF) primary structures equipped with the energy-harvesting-enabled tuned mass damper inerter (EH-TMDI). The latter is a regenerative passive dynamic vibration absorber which combines an electromagnetic motor (EM) with a tuned mass damper inerter (TMDI). In the TMDI configuration, an inerter element resisting relative acceleration is used to link the secondary mass to a different location of the primary structure from the one that the secondary mass is attached to via a linear spring in parallel with a dashpot. In the EH-TMDI configuration, the EM is connected in series between the inerter element and the secondary mass. In this regard, the EH-TMDI has richer dynamics than the TMDI as it effectively becomes a two degree of freedom (2-DOF) appendix, while the inerter simultaneously amplifies the dynamical effects of both the secondary mass and the EM. To date, the EH-TMDI performances in terms of energy harvesting and vibration suppression have only been parametrically assessed for EH-TMDI sub-optimally tuned for motion control. Herein, optimal bi-objective tuning of EH-TMDI is undertaken for simultaneous structural dynamic response minimization (objective 1) and energy generation maximization (objective 2) in MDOF structures under white noise base excitation with arbitrary EH-TMDI connectivity. To this aim, an optimal design problem is formulated which utilizes weighting factors between the two objectives, represented by carefully normalized performance indices, gauging displacement response statistics of the primary structure and energy generation at the EM. Further, a reduced-order 3-DOF mechanical model (ROM) is used to facilitate the optimal EH-TMDI design, derived from first principles such that it faithfully represents the fundamental mode dynamics of the MDOF primary structure equipped with an EH-TMDI. In the ROM, the connectivity of the EH-TMDI terminals is explicitly accounted for through the modal coordinate difference, $\Delta\varphi$, between the two locations that the EH-TMDI is attached to the primary structure. In the numerical part of the work, special attention is focused on highlighting the relative importance of $\Delta\varphi$ to the dual performance of the EH-TMDI, namely vibration suppression and energy generation, for different predefined weighting factors in the definition of the objective function of the optimal EH-TMDI tuning problem, as well as on the assumed EH-TMDI inertance property. It is shown that by increasing $\Delta\varphi$ while keeping inertance fixed, both the energy dissipation by the EM and the vibration suppression efficacy improve. In addition, the influence of the inertial EH-TMDI properties on vibration suppression efficacy and energy generation are also assessed parametrically. Overall, numerical data provided demonstrate that the EH-TMDI is a promising regenerative passive vibration absorber, effectively supported by the herein developed bi-objective optimal design framework.