Università Politecnica delle Marche

Dipartimento di Ingegneria Civile, Edile e Architettura
Prof. Stefano Lenci

Report of the PhD thesis "**Energy transfer in systems of coupled oscillators**," by **Piotr Brzeski**
Lodz University of Technology, Faculty of Mechanical Engineering, Division of Dynamics
Supervisor: Prof. Przemyslaw Perlikowski,
Auxiliary Supervisor: Dr. Anna Jach

The thesis deals with the dynamic analysis of various mechanical systems, the "main structure", equipped with Tuned Mass Absorber (TMA), a special version of Tuned Mass Damper (TMD) constituted by one or more pendula, and by a recently developed TMD equipped with an inerter. The main structure is basically constituted by a single degree of freedom (dof) nonlinear mechanical oscillator, which is governed by the Duffing equation.

This topic is timely and certainly worthy of investigation. It is interesting from both a theoretical point of view, because of the various underlying nonlinear phenomena occurring in multi-dof systems, and from a practical point of view, since TMD represent effective tools for vibration control, and are used in many fields of engineering.

In addition to an overall understanding of the systems dynamics, the main goal is that of reducing the vibration amplitude of the main structures, by allowing the energy of the main system to flow toward the attached damper. This goal is pursued systematically, and detailed parametric analysis are performed in order to highlight the influence of the various parameters, and to look for the optimal situation.

This objective is clearly relevant, and the proposed results (i) add knowledge and allows us to understand better the systems dynamics, (ii) permits to determine the sensitivity of the systems to the parameters investigated in the parametric analysis, and (iii) permits to identify to optimal operational conditions.

No theoretical/analytical methods are used, and the paper is entirely based on numerical simulations.
The performances are detected by means of the Frequency Response Curves, which have been built by the continuation method, performed by the well-known and largely used code AUTO97. Attention is focused around the natural frequency of the main structure, where the main structures exhibits the large displacement and where the necessity of reducing the vibration amplitude is more evident.
In a part of the thesis, also direct numerical integrations have been used to determine the probability of reaching a given attractor from random initial conditions.

The adopted methodological approach is more than adequate, and shows the ability of the candidate to deals with complicated nonlinear problems, in terms of both numerical solution techniques and detection of the most important dynamical behaviours.

The thesis is organized as a summary of five papers published (plus one to be published) on international scientific journals, which have been developed during the candidate research period. The thesis is divided in two parts.

Università Politecnica delle Marche

Dipartimento di Ingegneria Civile, Edile e Architettura
Prof. Stefano Lenci

In the first part, after a brief introduction containing a literature survey (Sect. 1), the various investigated models are illustrated, and their governing equations are reported (Sect. 4). Then, in Sect. 5, the main results are summarized trying to frame all of them under the same umbrella of energy transfer in coupled oscillators.

In the second part (Sect. 8) all papers are attached. It is worth to mention that all are published on renowned and high quality scientific journals. This is an implicit proof of the *quality* of the work developed by Dr. Brzeski. Furthermore, the ability to produce six journal papers during the PhD demonstrates the hardworking of the candidate, and shows that he has done a very good job also from a *quantitative* point of view.

In the first paper two coupled Duffing oscillator, each having an attached pendulum, have been considered. A lot of attention is dedicated to the problem of synchronization.

In the second paper three different TMA are considered: a simple pendulum, two pendula, and a spring pendulum. The performances of each TMA have been investigated, and successively optimized.

In the third paper a new type of TMA is considered. Here, in fact, the pendulum is attached to the main structure by a pivot, by a damper and by an inerter, a recently developed element capable of transmitting a force proportional to the relative accelerations. The parametric analysis is focused on the effect of the damper and inerter.

In the fourth paper the previous study is continued, and an inerter that enables changes of inertance is investigated. A design is first proposed, and then the nonlinear dynamics have been studied considering four different set of parameters. A very brief and preliminary investigation of the effects of noise is also reported.

In the fifth paper a pendulum is attached on top of a rocking rigid block to reduce its possible overturning due to seismic actions. The effect of the asymmetry of the block is considered, and the results are presented by means of probability behaviour charts.

Finally, in the sixth paper (the one not yet accepted) three different systems are considered: a standard TMA, a system with impact, and a beam with rotating pendula. The concept of "basin stability", which is a particular case of the "Dynamical Integrity" ideas and tools, have been use to determine the robustness of each attractor in the multi-stability situation.

In summary, I appreciated the quality and the quantity of the work done by the candidate, the methodological approach and the obtained results. Thus, I consider very positive the developed scientific work, I consider scientifically mature the candidate, and I strongly support the award of the PhD title to Dr. Brzeski.

Stefano Lenci

Stefano Lenci

Ancona, 6 June 2016

Via Brecce Bianche – 60131 Ancona - Italy
Tel.: +39-071-2204552 – Fax: +39-071-2204576
e-mail: s.lenci@univpm.it