NEW DOCTORAL DEGREES

IN THE DEPARTMENT OF MATHEMATICS UNIVERSITY OF OSIJEK

Dr. Zoran Tomljanović received his PhD in Mathematics from the Department of Mathematics of the University of Zagreb on 31 May 2011 with the dissertation entitled "OPTIMAL DAMPING FOR VIBRATING SYSTEMS USING DIMENSION REDUCTION" (Mentors: Prof. N. Truhar, Prof. P. Benner and Prof. Z. Drmač).

Abstract

This thesis considers optimization of damping in mechanical vibrating systems. When one has to find optimal positions together with corresponding viscosities of dampers in a mechanical vibrating system based on energy minimization, then numerous Lyapunov equations have to be solved. Thus, we have introduced different approaches which significantly accelerate the optimization procedure.

First part considers the case when all undamped eigenfrequencies have to be damped and propose a dimension reduction technique which calculates approximation of the solution of the corresponding Lyapunov equation. We derive an error bound for this approximation which is then used in the process of viscosities optimization. Numerical experiments confirm the ability of this approximation technique to significantly accelerate the optimization process. On the numerical example we have shown that near optimal positions we can accelerate the optimization process around 15 times and still ensure that the optimal positions are found.

From the point of a dimension reduction technique, the case of damping a selected part of undamped eigenfrequencies is more interesting. This is also investigated in thesis. In this case, the right-hand side of the corresponding Lyapunov equation is low rank and this allows better approximation using the dimension reduction technique. In this case we have derived an algorithm for the approximation of the trace of the Lyapunov equation and the corresponding error bound which uses the structure of the system. Then, viscosities are optimized using this error bound. On numerical examples we have shown that the optimization process can be considerably accelerated, that is, we have shown that near optimal positions we can accelerate the optimization process around 800 times while ensuring that we still find the optima within the limit of tolerance.

Furthermore, we propose several approaches which accelerate optimization of dampers' positions. First, we propose two heuristics; i.e. the "Multigrid-like" and the "Discrete to continuous" optimization approach. They significantly reduce the number of Lyapunov equations which have to be solved and they show very good performance on numerical examples. Furthermore, we also present the optimization approach which combines approximation algorithms and heuristical approaches. This approach allows us to perform optimization of dampers' positions and corresponding viscosities on larger dimensions. Besides these approaches that use heuristics, we also propose an algorithm that determines the area which contains the optimal dampers' positions. That algorithm works efficiently for specially structured systems.

In thesis we have also investigated a case study for a very structured system. The main properties are that internal damping is zero and that undamped eigenfrequencies come in close pairs. We have derived a formula for the trace of the corresponding Lyapunov equation. This formula is the closest generalization of the case where rank one-dimensional damping was considered. With this approach we can significantly accelerate the optimization procedure, and the factor of acceleration is greater than 1000.

Published papers

[1] P. Benner, **Z. Tomljanović**, N. Truhar, *Damping optimization in linear vibrating systems using dimension reduction*, accepted for publication in Proceedings of the 10th International Conference on Vibration Problems, Prague.

[2] P. Benner, **Z. Tomljanović**, N. Truhar, *Dimension reduction for damping optimization in linear vibrating systems*, Z. Angew. Math. Mech. 91 (2011), no. 3, 179 – 191, DOI: 10.1002/zamm.201000077.

[3] **Z. Tomljanović**, N. Truhar, K. Veselić, *Optimizing a damped system - a case study*, International Journal of Computer Mathematics 88 (2011), no. 7, 1533–1545, DOI: 10.1080/00207160.2010.521547.

[4] N. Truhar, **Z. Tomljanović**, *Estimation of optimal damping for mechanical vibrating systems*, Intl. J. Appl. Math. Mech. 5 (2009), no. 5, 14–26.

[5] N. Truhar, **Z. Tomljanović**, R.-C. Li, *Analysis of the solution of the Sylvester equation using low-rank ADI with exact shifts*, Systems & control letters 59 (2010), no. 3/4, 248–257.