10th World Congress on Structural and Multidisciplinary Optimization
19 May – 24 May 2013, Orlando, Florida, USA

Structural optimization of flexible components under dynamic loading within a multibody system approach: application to a 2-dof robot.

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Nowadays, with the evolution of virtual prototyping, mechanical systems are commonly analyzed using a multibody system approach which enables to study the behavior of the whole system and the dynamic interactions between the components. This evolution leads to a system-level approach.

When dealing with the optimization of mechanical systems, the classical approach to carry out the component dynamic optimization is to refer to the techniques of static optimization which are well established. Basically, this approach is composed of two steps. First, a multibody system simulation enables to precompute the loads applied to each component; secondly, each component is optimized independently using a quasi-static approach. For example, the Equivalent Static Loads approach developed by Kang, Park and Arora (2005) relies on iterations between these two steps.

In this work, we compare these iterative methods to an integrated method where the optimization loop is directly based on the dynamic response resulting from the flexible multibody system simulation, as described in B. *et al.* (2011). However, this fully integrated approach is not a simple extension of static optimization. Indeed, coupled vibrations and interactions between components generally result in complex design problems and in convergence difficulties. The formulation of the optimization problem is essential in order to obtain good convergence properties. Depending on the formulation, the design space can be drastically modified and therefore, gradient-based methods are more or less able to converge.

The numerical application is focused on the mass minimization of a 2-dof robot subjected to a tracking trajectory constraint. This application is inspired from Kang, Park and Arora (2005). Gradient-based methods are used to solve the optimization problem. Design variables are the beam parameters. Concerning the simulation of the multibody system, the nonlinear finite element method proposed by Géradin and Cardona (2001) is used which enables to account for large amplitude motions and elastic deflections in an integrated manner. A generalized α-time integration scheme is used to solve the nonlinear equations of motion. The study concerning the optimization problem formulation for the integrated approach is carried out and the remaining work studies the major differences between the Equivalent Static Load approach and the fully integrated approach.

References

Brüls, O., Lemaire, E., Duysinx, P., & Eberhard, P. (2011). Optimization of multibody systems and their structural component. In: Multibody Dynamics: Computational Methods and Applications, vol 23, Springer, pp. 49-68.

Géradin M., Cardona A. (2001) Flexible Multibody Dynamics: A Finite Element Approach. John Wiley & Sons, New York.

Kang, B., Park, G., & Arora, J. (2005). Optimization of flexible multibody dynamic systems using the equivalent static load method. AIAA Journal, 43(4), 846-852.