Modelling of Dampers and Damping in Structures

The present thesis consists of an extended summary and four papers concerning damping of structures and algorithmic damping in numerical analysis. The first part of the thesis deals with the efficiency and the tuning of external collocated dampers acting on flexible structures. The dynamics, and thereby the damping, of flexible structures are generally described in terms of the dominant vibration modes. A system reduction technique, where the damped vibration mode is constructed as a linear combination of the undamped mode shape and the mode shape obtained by locking the damper, is applied. This two-component representation leads to a simple solution for the modal damping representing the natural frequency and the associated damping ratio. It appears from numerical examples that this system reduction technique provides very accurate results. Analytical expressions for the optimal tuning and the maximum attainable damping are found by maximizing the expression for the damping ratio. The theory is formulated for linear damper models, but may also be applied for non-linear dampers in terms of equivalent linear parameters for stiffness and damping, respectively. The format of the expressions obtained by the present system reduction technique is similar to that for damping of cables. The characteristics of dampers are governed by the relation between the damping component (energy dissipation) and the stiffness component (restoring force). This relation is conveniently described by the representative angle of the damper force in phase-plane. It is demonstrated how efficiency of the damper increases with the phase angle, and in particular how phase lead, where the damper force acts ahead of velocity, implies large damping. However, phase lead is equivalent to negative stiffness, and therefore only realizable by means of active control. The present thesis demonstrates how stiffness affects both the performance and the tuning of the damper. The final part of the thesis considers algorithmic damping in connection with Newmark time integration. The damping characteristics of the Newmark method are improved by introducing a negative damping component, governed by a first order linear filter. This additional force component is designed so that it compensates for the undesirable damping introduced by the Newmark method in the low-frequency range, while it provides adjustable high-frequency damping. The filter method gives a general synthesis for the various alpha-modifications of the Newmark method and an improved weighting of the external load.

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