A general rule for the effect of arbitrary damping on the numerical stability of time integration analyses

A. Soroushian

[1]Department of Structural Engineering Research Centre, International Institute and Earthquake Engineering (IIEES), S. Lavasani (Farmaniyeh), North Dibajee, West Arghavan, No. 21, Tehran 19537, Iran
a.soroushian@iiees.ac.ir, aramsoro@yahoo.com

Abstract

True behaviors of structural systems are dynamic and nonlinear, and for the analyses, time integration is a versatile tool. The resulting responses are approximations. Accordingly, the accuracies need to be controlled, and the numerical instabilities should be prevented (in analysis of physically stable systems). The conventional approach to check numerical stability is concentrated on linear analyses, and studies numerical stability based on the largest absolute eigenvalue of the amplification matrix, i.e. spectral radius, and the changes of spectral radius, with respect to the changes of $\omega \Delta t$ (ω stands for the natural frequency and Δt is the integration step size). The external force, i.e. the right hand side of the equation of motion, has no effect on numerical stability. However, damping can have considerable role in the amplification matrix and the spectral radius. A numerical study in this regard is presented in ECCOMAS 2016, where, it is displayed that for many broadly accepted time integration methods, viscous damping is beneficial for numerical stability. The observation is later explained theoretically and extended as a general rule for the effect of viscous damping on the numerical stability (presented in WCCM XII). The achievements reported in ECCOMAS 2016 and WCCM XII are significant. Nevertheless, considering the everyday newer materials and structural systems suggested in the world of structural earthquake mechanical and aeronautical engineering, the discussion would rather be extended to systems subjected to general damping.

In this paper, the objective is to review and extend the achievement of WCCM XII, to analysis of generally damped systems, while the general damping force is considered as arbitrary functions of displacement, velocity and its different derivatives with respect to time, leading to the decrease and decay of the responses amplitude. This is materialized by implementing an approach similar to that presented in WCCM XII and checking the effects of the specific features of viscous damping compared to general damping. As a main consequence, for analyses of equations of motion representing well-posed behaviors, any type of damping is beneficial to numerical stability, in the sense that time integration analyses will be numerically stable if the analyses of the corresponding undamped systems are numerically stable. This is regardless of the time integration scheme.

Keywords: Structural dynamics, Time integration, Numerical stability, Damping, Well-posed ness, Convergence.

References

[1] Soroushian, A. (2016) On the effect of viscous damping on the stability of time integration methods. *ECCOMAS Congress 2016* (Accepted if registered).
[2] Soroushian, A. (2016) A general rule for the effect of viscous damping on the numerical stability of time integration analyses. *WCCM XII Congress 2016* (Accepted if registered).
[3] Belytschko, T., Hughes, T. J. R. (1983) *Computational Methods for Transient Analysis*, Elsevier, The Netherlands.
[4] Wood, W. L. (1990) *Practical Time Stepping Schemes*, Oxford, UK.
[5] Richtmyer, R. D., and Morton, K. W. (1967) *Difference Methods for Initial Value Problems*, John Wiley & Sons, USA
[6] Soroushian, A. (2015) *Development of an Algorithm and Computer Program to Evaluate the Numerical Stability and Consistency of New Time Integration Methods.* Report of Research Project 7517. International Institute of Earthquake Engineering and Seismology (IIEES), Iran. (in press) (in Persian)