Universität Karlsruhe (TH)
Forschungsuniversität • gegründet 1825

Institut für Mechanik

On the Accuracy of Local Quantities in Adaptive Analysis of Plate and Shell Structures under Transient Loading

J. Neumann, K. Schweizerhof
Universität Karlsruhe, Institut für Mechanik

2001

Institut für Mechanik
Kaiserstr. 12, Geb. 20.30
76128 Karlsruhe
Tel.: +49 (0) 721/ 608-2071
Fax: +49 (0) 721/ 608-7990
E-Mail: ifm@uni-karlsruhe.de
www.ifm.uni-karlsruhe.de

On the Accuracy of Local Quantities in Adaptive Analysis of Plate and Shell Structures under Transient Loading

J. Neumann, K. Schweizerhof^*
Institute for Mechanics
University Karlsruhe, Germany
e-mail: Karl.Schweizerhof@bau-verm.uni-karlsruhe.de

Abstract

Summary When the FE method is applied to partial differential equations such as in solid mechanics only global a posteriori error estimates can be given. For the momentum balance equations in solid mechanics, however, also error estimates for local quantities of the approximate solution are possible based on the application of duality principles. Such dual methods suggested by Johnson/Hansbo have been applied successfully by Suttmeier/Rannacher to problems involving material nonlinearities as well as contact and by Ramm/Cirak to linear and nonlinear analysis of shell structures.

For the equation of motion, a hyperbolic differential equation, also procedures based on duality considerations have been proposed e.g. Suli ? Ramm/Cirak/Maute based on suggestions by Eriksson. If the latter are used for a global error estimation, mesh modifications are almost impossible or very difficult to include. At least only linear transient problems can be analyzed with such a procedure. For wave propagation a local - in time - error estimation is performed by Aubry et.al., where the backward analysis needed applying duality is only applied in one load step. With the Discontinuous Galerkin scheme for time integration mesh adaptation is performed in each load step. However, the examples presented give no indication, how tolerances are set, which accuracy is reached and how the time step size enters the accuracy measures. Similar analyses have been performed by Neumann/Schweizerhof/Riccius (Buenos Aires) based on the consideration of Suli using this as an error indicator.

Within the current contribution the duality idea is used to modify the FE mesh within the analysis of the transient problem, however, a procedure as in statics is followed. Thus the same dual problem as in the standard static equations of equilibrium is used, neglecting the inertia terms. This has the consequence that general propagation problems cannot be treated and the application is restricted to stationary resp. quasi-stationary vibration problems. Then also only mesh refinement can be considered.

The numerical examples, plate and shell structures, analyzed show that the exact error of the local quantity, on which the duality idea is applied, is really smaller than following an error estimation with global error estimators and subsequent mesh modification as proposed by Riccius/Neumann/Sf. Thus a more efficient mesh can be achieved with the dual method. A closer look at the time history of the results, however, reveals that the estimated errors - dual and global estimator - and the exact error show major differences. This is the result of the phase error introduced by the spatial approximation. A rather small error in the lower eigenfrequencies which cannot be avoided with reasonably efficient FE meshes results in a major phase error after some cycles of vibration. This error is mostly larger than any error introduced by the time integration scheme. In order to achieve an idea about the quantity of the mentioned phase error an estimation of the eigenfrequencies, as proposed by Wiberg et.al is needed.

The numerical examples - shell structures under transient loading followed by a stationary vibration - show that with this combination of methods a reasonable error estimation for local quantities

seems to be possible.

References

[1] F. Cirak, E. Ramm. *A posteriori error estimation and adaptivity for elastoplasticity using the reciprocal theorem.* Submitted to Int.J.Num.Meth.Engrg. (1998).

[2] G. Hulbert, T.J.R. Hughes. *Space-time finite element methods for second order hyperbolic equations.* Comp.Meth.Appl.Mech.Engrg. 84, 327-348, (1990).

[3] G. Hulbert. *Time finite element methods for structural dynamics.* Int.J.Num. Meth. Engrg. 33, 307-331, (1992).

[4] C. Johnson. *Discontinuous Galerkin finite elemet methods for second order hyperbolic problems.* Comp.Meth.Appl.Mech.Engrg. 107, 117-129, (1993).

[5] X.D. Li. *Adaptive finite element procedures in structural dynamics.* Ph.D.Thesis, Publ. 96:2, Dept. of Struct. Mech., Chalmers Univ.of Techn. Göteborg, Sweden, (1996).

[6] X.D. Li, N.-E. Wiberg. *Structural dynamic analysis by a time-discontinuous Galerkin finite element method.* Int.J.Num.Meth.Engrg. 39, 2131-2152, (1996).

[7] J. Neumann, J. Riccius, K. Schweizerhof. *Adaptive analysis of dynamically loaded shell structures.* Proc. ICIAM World Congress, Buenos Aires, Argentina (1998).

[8] J. Riccius, K. Schweizerhof. *Aspects of hierarchical h-adaptive dynamic analyses.* Proceedings of 3rd Int.Conf. on Comput. Structures Techn. in "Advances in Finite Element Techniques" ed. B.H.V.Topping, Civil-Comp Press, Edinburgh 1996.

[9] N.-E. Wiberg, X.D. Li. *Implicit and explicit discontinuous Galerkin finite element procedures for linear and nonlinear structural dynamic analysis.* In Proc.COMPLAS V: Computational Plasticity, Fundamentals and Applications, eds. D.R.J. Owen, E. Onate and E. Hinton, CIMNE, Barcelona, Spain, 224-237, (1997).

[10] N.-E. Wiberg, X.D. Li. *Adaptive discontinuous Galerkin FE procedures for linear and nonlinear structural dynamics.* Proc. ICIAM World Congress, Buenos Aires, Argentina (1998).

[11] O.C. Zienkiewicz, Y.M. Xie. *A simple local error estimate and an adaptive time-stepping procedure for dynamic analysis.* Earthquake Engrg. Struct.Dynamics, 22, 871-887, (1991).