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Review

Finite elements in the analysis of pressure vessels and piping, an addendum: A bibliography (2001–2004)

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Abstract

The paper gives a bibliographical review of finite element methods(FEMs) applied for the analysis of pressure vessel structures/components and piping from the theoretical as well as practical points of view. This bibliography is a new addendum to the Finite elements in the analysis of pressure vessels and piping—a bibliography [1–3]. The listings at the end of the paper contain 856 references to papers and conference proceedings on the subject that were published in 2001–2004. These are classified in the following categories: linear and nonlinear, static and dynamic, stress and deflection analyses; stability problems; thermal problems; fracture mechanics problems; contact problems; fluid–structure interaction problems; manufacturing of pipes and tubes; welded pipes and pressure vessel components; development of special finite elements for pressure vessels and pipes; finite element software; and other topics.

Keywords: Finite element; Bibliography; Pressure vessels; pipes; Linear and nonlinear static and dynamic analysis; Fracture mechanics; Contact problems; Thermal problems; Fluid–structure interaction; Welding

1. Introduction

Pressure vessels and piping are widely used in reactor technology, the chemical industry, marine and space engineering. They often operate under extremes of high and low temperatures and high pressures, are becoming highly sophisticated and therefore also need advanced methods for their analyses. Advances are also made with materials applied for their fabrication. Concrete and composite materials are used more frequently in pressure vessels and their components to replace, in some cases, conventional steels.

During the last three decades considerable advances have been made in the applications of numerical techniques to analyze pressure vessel and piping problems. Among the numerical procedures, finite element methods are the most frequently used.

Pressure vessel and piping analyses may have a variety of phases such as: elastic stress and deformation analysis where both mechanical and thermal loads may be applied; heat transfer analysis; dynamic analysis; plastic and creep analysis; etc. There is in existence a large number of general purpose and special purpose finite element programs available to cope with each phase of the analysis.

This review on the subject is divided into the following parts and it concerns:

- linear and nonlinear, static and dynamic, stress and deflection analyses (STR)
- stability problems (STA)
- thermal problems (THE)
- fracture mechanics problems (FRA)
- contact problems (CON)
- fluid–structure interaction problems (FLU)
- manufacturing of pipes and tubes (MAN)
- welded pipes and pressure vessel components (WEL)
- development of special finite elements for pressure vessels and pipes (ELE)
- finite element software (SOF)
- other topics (OTH)

The status of finite element literature published between 1976 and 2004, and divided into the categories described above, is illustrated in Fig. 1. Data presented in this figure

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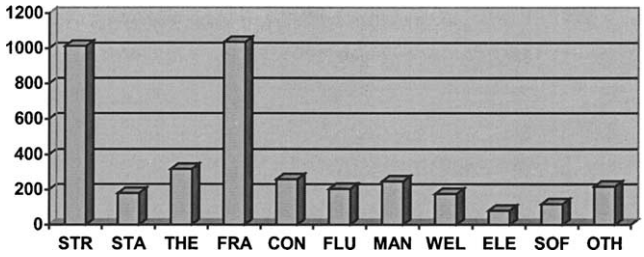

Fig. 1. Finite elements and various topics in pressure vessels and piping (1976–2004).

include published technical papers in the primary literature; this means papers appearing in the various general and specialized journals, conference proceedings as well as theses and dissertations. If we take the number of published papers as a measure of research activity in these various subjects, we can see the priority trend in research.

This paper is organized into two parts. In the first, each subject listed above is briefly described by keywords where current trends in application of finite element techniques are mentioned. The second part, Appendix A, is a listing of references on papers published in the open literature for the period 2001–2004, retrieved from the author's database MAKEBASE [4,5]. Readers interested in the finite element literature in general are referred to [6] or to the author's Internet Finite Element Book Bibliography(http://www.solid.ikp.liu.se/fe/index.html). The presented bibliography is an addendum to the author's earlier bibliographies [1–3]. Also the bibliography on creep and creep fracture/damage finite element modelling [7] may be of interest.

2. Finite elements in the analysis of pressure vessels and piping

2.1. Linear and nonlinear, static and dynamic, stress and deflection analyses (STR)

The main topics included deal with the static and dynamic finite element analyses of pressure vessels, their components and piping, namely: stress and deformation analysis; 2D and 3D linear elastic static and dynamic analysis; material and geometrical nonlinear static and dynamic analysis; seismic response analysis; impact analysis; response to detonation loading; damping characteristics; analysis of residual stresses; shakedown analysis; vibroacoustical analysis; mechanical behaviour studies; local mechanical behaviour studies; determining plastic and limit loads; stress concentration factors; stiffness evaluation; wrinkling; probabilistic studies.

Applications to: pipes; tubes; pipelines; tubesheets; piping elbows; pressure vessel components; containment vessels; pressure vessel heads; reactor vessel heads; nozzle models; thick-walled cylinders; reinforcing pads; tubular structures; saddle supports; anchorage.

Materials under consideration: steels; stainless steels; aluminium; composites; polymers; filament wound composites; fibre-reinforced composites; polymer matrix composites; titanium; foam filled aluminum tubes; steel reinforced plastics; structural foams.

2.2. Stability problems(STA)

Stability problems are the main subject of this section Other topics included are: static and dynamic buckling; thermal buckling; inelastic buckling pressure; inelastic local buckling; buckling response to seismic loading; creep-induced buckling; critical, buckling strains; buckling of cracked components; post-buckling analysis; buckle propagation; bending instabilities; stability for cone–cylinder intersections.

Applications to: pipes; tubes; pipelines; linepipes; reeled pipe-in-pipe; pressure vessel components.

Materials: steels; low-alloy steels; aluminium; composites; titanium.

2.3. Thermal problems (THE)

Heat transfer problems and thermomechanical finite element analyses are the main subjects of this section. The following topics are also included: thermal loading and temperature cycling; temperature attenuation; thermal shock; pressurized thermal shock; heat transfer analysis; convective heat and mass transfer; turbulent forced convection and thermal radiation; thermal stratification; thermal striping; freezing problems; creep; local creep; high-temperature structural integrity procedures; design for elevated temperature service; thermal fatigue; fire performance; thermal management studies; parametric studies.

Applications to: pipes; tubes; pipelines; boiler tubes; banks of tubes; tube coolant piping systems; tube condenser; pressure vessels; reactor pressure vessels; cryogenic pressure vessels; heat exchanger components; heated sterilizers; tube–fin exchangers; bellows; tanks; valves; subsea flowlines.

Materials: steels; concrete; composites; polymers; ceramics; thermal insulations.

2.4. Fracture mechanics problems(FRA)

In this section fracture mechanics and fatigue problems are handled. The listing of references in the Appendix includes: linear and nonlinear 2D and 3D static and dynamic fracture mechanics problems; mechanical and thermal loading; macromechanical and micromechanical modelling; global/local analysis; crack tip opening; crack growth and propagation; delamination growth; crack arrest behaviour; stress corrosion cracks; multiple cracks; microcracking; fracture toughness; strength; shear strength; cleavage fracture; burst pressure prediction; predicting the failure pressure; prediction of crack coalescence; progressive