Computer program for pressure vessels and piping – Systems nozzles subject to transient – Thermomechanical loadings

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1 INTRODUCTION

The complete calculation of a nozzle requires the following operations :

- Meshing of the structure. This operation is quite difficult when the junction zones are of complex form.

- Computation of the temperature field (mean temperatures and gradients in the thickness), which will be transferred to each of the mesh elements.

- Input of pressure loadings and external forces.

- Computation of displacements and stresses.

- Analysis of results.

The difficulties in coordinating these various operations all individually executed by general programs led Stein Industrie to produce a set of modules called "PIETEMENT PROGRAM" specially adapted to the geometry and loading of such structures.

2 DESCRIPTION OF PROGRAM

The pietement program is divided into modules corresponding to each of the tasks described above and communicating by means of files organized into data bases.

2.1 Pietmail module

The Pietmail module executes three-dimensional meshing with the aid of four-node quadrilateral elements and three-node triangular elements. The mesh is broken down into 7 zones (shown in Fig. 1) :

1 - Part of header directed to $z > 0$
2 - Part of header directed towards $z < 0$
3 - Tube
4 - Tube-header junction
5 - Junction window

6 - Part of header opposite junction
7 - Head (if any)

If the structure is of symmetrical geometry and loading, only a quarter or half of the structure is meshed.
The meshing module transmits to the other modules the node coordinates, the element connections and the description of the main lines of the structure.

2.2 Pietther module

The pietther module computes the thermal field in steady-state and transient conditions.
The main hypothesis is to disregard conduction in the plane of the mesh elements in favour of conduction in the thickness.
Temperature distribution in the metal thickness consequently depends only on the following factors :

- thickness
- material
- boundary conditions (heat exchange coefficients, fluid temperatures).

The structure is divided into zones where the above-mentioned factors are invariable. These zones are created automatically by intersection of the various thickness, material or boundary-condition zones. Zones where the boundary conditions (fluid temperature, heat-exchange coefficients) are interpolated between several other zones can be defined.

Computation is effected by partitioning the thickness into 25 points. The mean temperature, the equivalent linear gradient and the nonlinear part of the gradient are deduced from these points by integration.

2.3 - Pietmeca module

The pietmeca module is a module of thin-sell computation by the finite-element method. The triangular and quadrilateral elements used comply with Kirchhoff's hypotheses (ref. [1] and ref. [2]). The stiffness matrix is partitioned into blocks and only non-zero terms below the diagonal are stored.
The resolution subroutines have been optimized to minimize computation time. The boundary conditions can be imposed displacements, symmetry conditions, linear relations between degrees of freedom, and flatness conditions.

Loadings can be pressure, nodal forces, temperature fields, and global forces due to adjoining piping.

2.4 Pietresu module

The results module now permits load combination, stress analysis according to the mesh lines (preset or not), and classifying of the most heavily laden elements. Drawing of deformed lines and isovalues is possible.

3 APPLICATION

We show below the calculation of the nozzle connection of a drain line to a steam generator - pump line for a fast breeder reactor power plant. The mesh is as shown in Fig. 2. Fig. 3 gives the isotherms obtained at time t = 360 s of a transient corresponding to a hot thermal shock.

The calculated mechanical loadings are the temperature fiels at various times, unit pressure and piping forces. All stress conditions can be obtained by combining these loadings. Fig. 4, 5 and 6 give the isostresses obtained for a thermal loading, for a pressure, and for the moments on the nozzle.

4 CONCLUSION

The advantages of a finite-element program specifically designed for a structure are :

- reduction of data preparation time (by at least a factor of 2)

- reduction of computation costs (by a factor of 3 as compared with the general programs)

- possibility of making a results analysis module adapted to the structure studied.

The cost of such a development is quite high but the whole of the finite-element computation part can be reused for other structures. Only the meshing and results analysis modules and possibly the loading computation module will have to be changed.

The principal development envisaged is the creation of an algorhythm using the unit loading computation to estimate the maximum allowable forces that the tube could exert on the nozzle.

REFERENCES

Jean-Louis Batoz, Klaus Jürgen Bathe and Lee-Wing Ho - A study of three-node triangular plate bending elements. Published in the International Journal for Numerical Methods in Engineering, Vol. 15, 1771-1812 (1980).

Jean-Louis Batoz and Mabrouk Ben Tahar - Evaluation of a nex quadrilateral thin plate bending element - Published in the International Journal for Numerical Methods in Engineering, Vol. 18, 1655-1677 (1982).

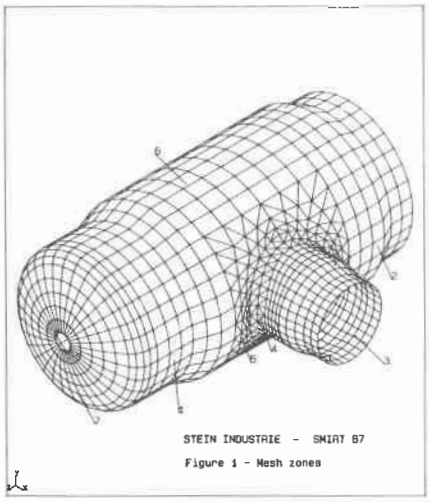

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Figure 1 - Mesh zones

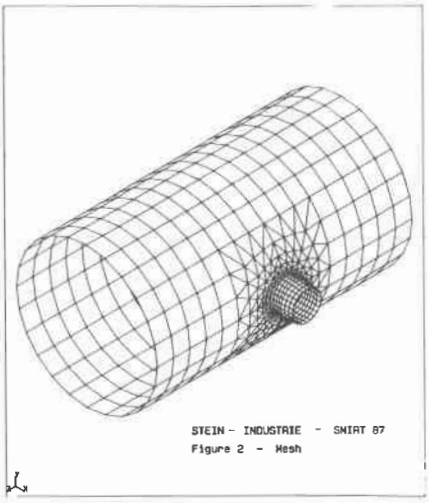

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Figure 2 - Mesh

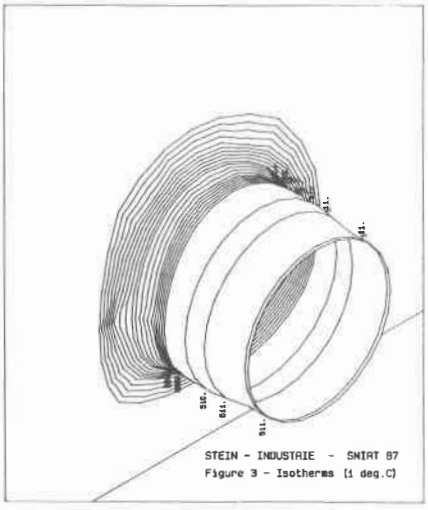

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Figure 3 - Isotherms (1 deg.C)

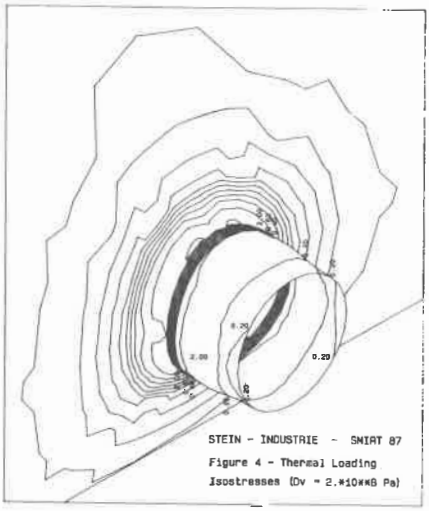

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Figure 4 - Thermal Loading

Isostresses (Dv = 2.*10**8 Pa)

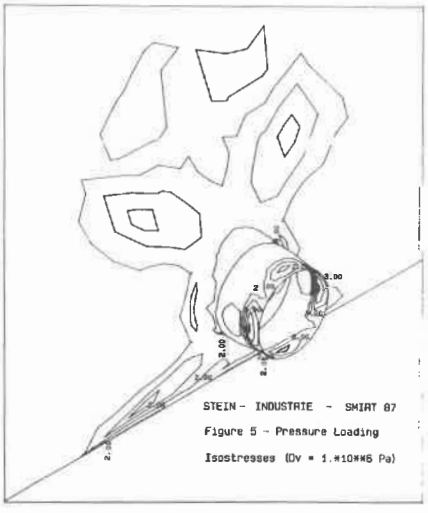

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Figure 5 - Pressure Loading

Isostresses (Dv = 1.*10**5 Pa)

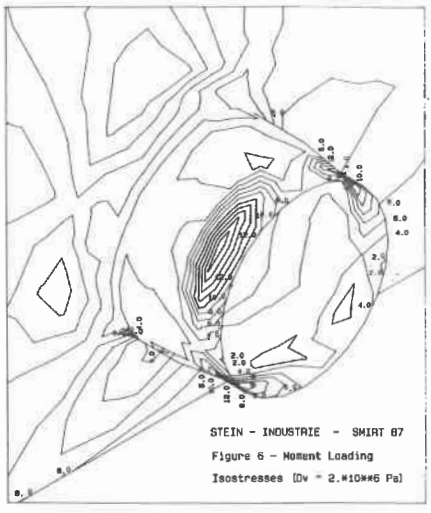

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Figure 6 - Moment Loading

Isostresses (Dv = 2.*10**6 Pa)