THREE-DIMENSIONAL COMPUTATIONS FOR STRESS AND STRAIN ANALYSIS OF A PWR PRESSURE VESSEL

G. CHEVALIER, R. BASTIEN

Commissariat à l'Énergie Atomique, Centre d'Études Nucléaires de Saclay.
Département des Études Mécaniques et Thermiques, B.P. n° 2, F-91190 Gif-sur-Yvette, France

Y. LECOURTOIS

Technicatome, B.P. n° 18, F-91190 Gif-sur-Yvette, France

SUMMARY

The pressure vessel of a French project of a medium power pressurized water reactor has been calculated with several programs of the CEASEMT system. These calculations have been carried on towards the domain of plasticity up to 2.5 times the design pressure according to the French Regulation. The required material for this pressure vessel is the SA 508 Class 2.

I. Axisymmetric analysis

The first study concerns a cross section of the vessel between two nozzles, and the structure thus represented was assumed to be axisymmetric. We employed the PASTEL program for this analysis at eight levels of pressure. For the calculation in plasticity we introduced into the program the characteristic tensile strength curve of the steel of the vessel at 340 °C in the form of a series of points. At each loading step the program follows an iterative procedure.

II. Calculation of a pressure vessel flange

This project of reactor has been designed to have a compact primary circuit. For this reason, the three blocks of steam generator and pump are held by three flange connections. Each flange has a double aim;
(a) To sustain all the loadings from the block of steam generator and pump.
(b) To warrant water tightness of the primary circuit.
Therefore the behaviour of these three flanges has a great importance for the feasibility of this reactor. The loading on each flange includes:
— the pressure of water (160 bars);
— the effect of the weight of a portion of the pressure vessel;
— the effect of the weight of a steam generator with its pumps;
— the effect of a seism with an horizontal acceleration and an increase of vertical acceleration.
For this project, it was important to use a reliable three-dimensional program in order to combine the effects of different loadings and to see the results obtained with loading combinations.
The meshing for these calculations has been obtained with the Program COCO, and the calculation has been made by the Program BILBO using an isoparametric element with twenty nodes.

III. Calculations on plastic strain concentrations in ligaments

With the same Programs COCO, BILBO and ESPACE another special calculation has been performed: it concerns the upper head which contains thirty two control rods and twelve instrumentation ports, these rods are hooped in the cover. The pressure hooping is 241 bars. The part of the structure considered for this study consists of a portion of a sphere and the limit conditions are those imposed on a spherical pressure vessel.

The water pressure is applied over all the inner side of the cover and inside the holes where it is added to the pressure hooping.

The calculations have been made for eight pressure levels from 160 bars to 400 bars. These calculations aim at knowing the elastic and plastic behavior of the perforated structure at 2.5 times the design pressure. With the program BILBO we can obtain the plastic strains concentrations in the ligaments of the spherical upper head. Although the strain rate reaches 1.97% at several nodes these calculations needed a little number of iterations.

All these works confirm our programs are able to make elastic or elasto-plastic analyses of complicated parts of pressure vessels.