DETAILED NON-LINEAR ANALYSIS OF THE RESPONSE OF THE DECK OF A FAST BREEDER REACTOR UNDER ACCIDENTAL SODIUM IMPACT

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SUMMARY

Introduction. — After an accidental explosion in the sodium, the deck of the Fast Breeder Reactor Super Phenix is submitted to a high impulse load, due to the sodium impact. This paper presents a detailed three-dimensional finite element analysis of the response of the deck.

Finite element analysis. — The deck of the Super Phenix Fast Breeder Reactor is made of "structural" steel plates and filled by a special "biological" concrete. It has a large center hole and openings for pumps, heat exchangers in a configuration presenting 14 symmetric sectors.

A three-dimensional analysis of half a sector was performed using the F.E. program PAM NEPD and its following capabilities:

- Large displacement, elasto-plastic (von Mises with kinematic hardening) shells for the steel plates;
- large displacement, elasto-plastic 3D solids (model of plasticity with controlled strain hardening/softening properties for compressive stresses, and caps for tensile stresses) for the biological concrete.

The accidental sodium impact was taken into account through a pressure impulse determined by previous studies.

In a preliminary analysis, the effect of concrete on the static behavior of the deck under body load, and the first linear modes of vibration were computed. These calculations gave the initial state of stress in the concrete, before the dynamic loads, and indicated that the first mode would be predominant in the response. Therefore, the nonlinear effects were more demanding than the dynamic effects for the selection of the time step used in the implicit β-Newmark step by step integration scheme.

The dynamic problem was first solved without taking into account the stiffness and strength of the concrete. The response showed an increase of the rise time by a factor of more than 2 compared to elastic response due to an extensive plastification in the steel plates, the maximum displacement being large. The response with concrete resistance showed a reduction of about 30% of the maximum deflection, and of about 25% of the rise time. In the compressive part of the deck the maximum stresses in the steel were reduced, while they remain roughly the same in the tensile part. However, the compressed rings of concrete added a local shearing effect on plate junctions.

Conclusion. — This study allowed to take into account the elasto-plastic resistance of concrete in a three-dimensional analysis of a complex composite deck structure submitted to an accidental sodium impact. It showed a global reduction of the maximum deflection and stresses, but also an increase of shearing stresses between steel plates.