Nonlinear Dynamic Analysis of Steel Plates Subjected to Missile Impact

N. Chiba, S. Shida

The 3rd Department, Mechanical Engineering Research Laboratory, Hitachi, Ltd., 3-1-1 Saiwai-cho, Hitachi-shi, Ibaraki-ken 317, Japan

S. Ohte, H. Yoshizawa

Toshiba R & D Center, Toshiba Corporation, 4-1 Ukishima-cho, Kawasaki-shi, Kanagawa-ken 210, Japan

Summary

A numerical analysis of missile impact problems was carried out using the multi-purpose finite element code ADINA, and calculated results were compared with experimental ones obtained from impact tests with carbon steel plates used for primary containment vessels and rocket-propelled projectiles of stainless steel.

In the calculations, projectiles and target plates which showed large residual deformation after the tests were treated as consisting of elastic-plastic materials with large strains, and axisymmetric finite elements were used. Contact and penetration phenomena of conical heads of projectiles were analyzed with nonlinear truss elements, which were tension-free at the strain corresponding to the gap distance between the two nodes on each side of a projectile and a target. The dynamic elastic-plastic responses of projectiles and target plates after impact were solved as a function of time by the direct integration method. The projectiles in the calculation had the same masses and initial velocities as those in the corresponding experiments, which were evaluated to have been carried out under the critical conditions for fracture of target plates.

The calculated residual deformation of the target plates is compared with the experimentally-obtained residual deflection curves and thickness distribution at the plate centers, where fracture had been observed to initiate when projectile energy was large enough to reduce the thicknesses of the plates to about one third of their original values. The comparison showed that this method of calculation is capable of simulating impact behavior presuming that the target plate deforms and undergoes thickness reduction in a ductile manner due to the contact effect with the projectile.

Impact forces of the projectiles obtained from the calculations were also found to agree well with values obtained from two other methods, namely, estimated force in the impact tests and experimentally determined critical fracture load obtained from the static loading tests, which were conducted with the same target plates and indentors as used in the impact tests. Consequently, the calculated results of impact forces confirmed the relation, which had been obtained from the impact and static tests, that the critical load for fracture is proportional to the second power of the thickness of the target plate.