INELASTIC DYNAMIC ANALYSIS OF PIPING SYSTEMS

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SUMMARY

Nuclear power plants must be designed to insure safe shutdown following a loss of coolant accident initiated by a guillotine type break in a primary piping system. Satisfaction of such a stringent design criterion requires a thorough understanding of the nonlinear response of a pipe subjected to large impulsive thrust loads. These loads are generated by the rapid expulsion of fluid from the broken ends of the pipe, and the ensuing motion of the pipe has been aptly termed "pipe whip". The nonlinearity of pipe whip motion is attributable to large deformations, inelastic material behavior, and gapped pipe supports. This paper describes an investigation of the nonlinear aspects of the pipe whip phenomenon pertaining to inelastic material behavior.

Several authors have investigated the pipe whip problem. Palusamy, *et al.*, employed simple spring-mass-damper elements and an elastic-perfectly plastic material model in a parametric study of pipe restraint systems. Anderson and Singh studied pipe whip motion using bilinear beam elements and an idealized deformation model which represented inelastic behavior by concentrated plastic hinges at nodal points where yielding occurred. The Babcock & Wilcox nonlinear piping analysis code NOPAP is an attempt to more rigorously analyze the elastic-plastic response characteristic of pipe whip motion.

NOPAP is an extension of the NONSAP code and thus its development is a continuation of the work done by Wilson and Bathe at the University of California, Berkeley, in the area of nonlinear structural analysis. This paper describes a materially nonlinear pipe element developed for NOPAP. This is a hollow circular beam element employing a nonlinear, uniaxial material model. The material model accepts a multi-linear description of the stress-strain curve and assumes a kinematic strain hardening rule.

In an effort to quality assure the NOPAP code, the Babcock & Wilcox Company initiated a pipe whip test program. This paper is a result of that program and presents experimental verification of the materially nonlinear analysis capability of the NOPAP pipe element using both static and dynamic test results.

The dynamic pipe whip tests use a dropweight method of loading to apply an impulsive type load to the end of a cantilevered section of pipe. Selected locations along the pipe are strain gaged to provide strain histories of the inelastic response. In addition, high speed motion pictures provide a record of the displacement history of the free end.