Prediction of ratcheting in piping elements using direct methods

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ABSTRACT

Piping systems are the most critical components of industrial facilities and usually are subjected to strong cyclic loading conditions. Their components, like nozzles, elbows and tee-junctions, normally operate under high levels of cyclic thermo-mechanical loads. As a result of these loading conditions, the materials usually exceed the elastic regime, plastic strains occur and a final state appears, which may be either elastic shakedown (safe state), or plastic shakedown (unsafe state), or ratcheting (unsafe state).

This state may be derived either using a time consuming step by step analysis or adopting modern Direct Methods. These methods are capable to estimate any steady state right from the beginning of the analysis, without tracing the whole loading history. Towards this direction, many researchers have introduced methods, such as the Linear Matching Method [1] and the Residual Stress Decomposition Method (RSDM) [2]. The RSDM is a recent Direct Method, which may predict the final state in an efficient way and has been mainly applied to two dimensional structures.

In the present work, the RSDM is implemented in a finite element analysis program, named FEAP [3]. The method is formulated using three dimensional brick elements in order to deal with more complicated structures and loading conditions. The material law adopted is elastic perfectly plastic, governed by the von Misses yield criterion. Moreover, a related to the RSDM, new procedure is developed, which may be used to predict structural ratcheting. Finally applications of the approach to the piping components, subjected to combined cyclic mechanical loadings, are presented.

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