SOME FUNDAMENTAL PRINCIPLES OF VOIDAGE INDUCED BOWING OF FUEL PINS IN SUB-ASSEMBLIES

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Abstract

The free curvature of fuel pins due to the differences of neutron-induced voidage induced by a cross-diameter temperature gradient is up to two orders of magnitude greater than the free curvature caused by thermal expansion in the same temperature gradient. It would be expected therefore that the spacing of lateral restraints for the pins (grids, wire-wrap contacts) would be determined by neutron induced voidage rather than thermal bow. Previous papers have examined the basics of the problem (Cornet and Capart, 3SMiRT, Paper D1/8) and the analysis necessary for a computer solution to the fully coupled thermohydraulic/ structural problem (eg McAreavey, 4SMiRT, Paper D2/1).

The current paper is a contribution to understanding the structural problem and its interaction with material data requirements. The problems solved are those associated with completely restraining a freely bowing pin at many lateral restraint points. The first major result of the analysis is a demonstration that the description of axial curvature distribution by a continuous, piecewise-linear fit through the curvatures at each lateral restraint can produce zero bow. The necessary conditions are:

i constant axial creep constant

ii suitable end conditions

This powerful result has been extended to solutions in which zero bow is produced by axial variations of pin curvature rate which are coupled to axial variations of creep constant. For example, curvature rates which are proportional to the creep constant at all points along a pin produce zero bow between built-in ends. The application of the results to test computer codes is discussed.

The calculation of pin bow between grids thus depends on an accurate knowledge of local variations of curvature rate ie between the lateral restraints of the pin. Methods are given of assessing the bow when the only additional data to the curvature rates at the lateral restraint points are the curvature rates at mid-spans. Examples are given for conditions related to reactor conditions.

Finally the lateral restraint loads are discussed based on exact solutions and approximations for complete restraint.