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PCMI-simulating Mechanical Tests of Nuclear Fuel Cladding for RIA Application

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1. Introduction

In the early 90's, the integral simulation tests of Reactivity Initiated Accidents (RIAs) on Light Water Reactor fuel performed in CABRI (France) and later on in the NSRR (Japan), pointed out as the cladding breach by the fast loading induced by the pellet expansion, known as Pellet Clad Mechanical Interaction (PCMI), as a new limiting failure mechanism for higher burnup fuel. The increase in fuel temperature resulting from an RIA induces a rapid fuel expansion, causing a severe PCMI [1]. This PCMI forces the cladding to experience a multiaxial tension such that the maximum principal strain is in the hoop (i.e., transverse) direction of the cladding tube. The survivability of a fuel cladding irradiated to a high burn-up under postulated RIA conditions is thus a response to a combination of the mechanics of a loading and the material degradation during a reactor operation [2]. Therefore, there has been an increasing effort to characterize the cladding mechanical behavior, such as the PROMETRA program, and its embrittlement mechanism, under the fast loading conditions characteristic of RIA. In this paper, some available mechanical test methodologies for simulation of deformation of a cladding during RIA are discussed.

2. Methodologies of PCMI-simulating hoop properties of cladding during RIA

Many test methodologies has been applied to simulate deformation of a cladding by PCMI during RIA. The test methodologies such as burst test, ring tensile test and Expansion-Due-to-Compression (EDC) test have intrinsic advantages and disadvantages. Among the available mechanical tests in order to simulate deformation of a cladding during RIA, the Expansion-Due-to-Compression (EDC) test method was developed by Studsvik. In this test, a polymer pellet is axially compressed inside a sample of the cladding tube. The pellet produces a load in the cladding, basically in the circumferential direction. This experimental set-up, allows reaching a strain rate of the same order to that experienced by the cladding during a RIA, typically 1 s^{-1}. During the test, a data acquisition system records continuously the applied load and the cladding diameter such that the cladding deformation at rupture can be determined later. In addition, if pre-test calibrations are performed to determine the energy absorbed by the pellet and the machine, the work done to break the sample can be determined and the Critical Strain Energy Density, CSED, calculated. Therefore, the test also allows knowing the cladding deformation at fracture and the measured CSED. The test parameters were set to result in a cladding strain rate of ~1 s^{-1} and, also, to produce the rupture of the sample. In this case, the measured SED at the moment of the break can be considered as the CSED. This CSED is calculated from the work done by the testing machine once the energy spent in processes different from breaking the cladding, such as polymer pellet extrusion and machine compliance is deducted. The resulting net work done to break the cladding is divided by the specimen volume to calculate an energy density [3].

3. Summary

In this paper, some available mechanical test methodologies for simulation of deformation of a cladding during RIA were reviewed and discussed, by focusing on EDC test methodology. This test methodology a polymer pellet is axially compressed inside a sample of the cladding tube. The pellet produces a load in the cladding, basically in the circumferential direction. The work done to break the sample can be determined and the Critical Strain Energy Density, CSED, calculated. Therefore, the test also allows knowing the cladding deformation at fracture and the measured CSED.

REFERENCES

[1] S. K. Kim, *et al.*, "Ductility Degradation of High Burn-up Cladding in PCMI-Simulating Condition", *OECD/NEA RIA Workshop*, Paris, France, 2009.
[2] S. K. Kim, *et al.*, Mechanical Property Evaluation of High Burn-up Nuclear Fuel Cladding Using the Ring Tensile Test, 2006 International Meeting on the LWR Fuel Performance, Salamanca, Spain, pp.132-136, 2006.
[3] M. Quecedo *et al.*, "Expansion-Due-to-Compression Test Results on High Burnup ZIRLO Cladding", *OECD/NEA RIA Workshop*, Paris, France, 2009.

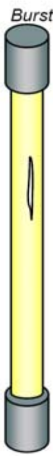

Fig. 1. Burst test method

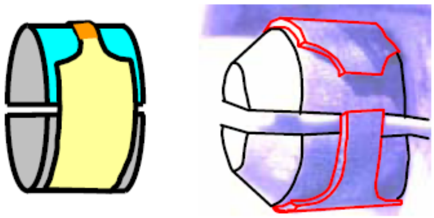

Fig. 2. Ring Tensile Test method

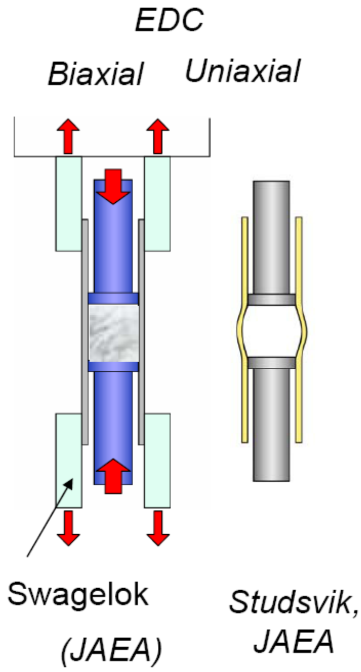

Fig. 3. Expansion-Due-to-Compression (EDC) test method