NEUTRONICS ASPECTS OF THE DESIGN OF THE A1 DROP-IN EXPERIMENT AT ATR

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OBJECTIVE

The objective of this task is to reduce the vanadium to chromium transmutation rate to acceptable levels during irradiation at the A-10 position of the ATR fission reactor and to estimate the nuclear heating deposition on the specimens and structure of the capsule within the narrowest possible band of uncertainty.

SUMMARY

The transmutation rate of vanadium to chromium was controlled with the use of thermal neutron absorber (gadolinium) which was incorporated, by design, within the drop-in experimental capsule. Gadolinium was selected as the filtering material due to several reasons, among those one can mention, high cross section for thermal neutrons, required thickness to survive 5 dpa's irradiation of less than 2 mm, good neutronics data base, easy handling, and overall cost.

The nuclear heat deposition, accounting for gamma-ray and neutron heating from the surroundings (core and reflector region) and gamma-ray heating produced by the capture of thermal neutrons at the thermal neutron filter, was estimated at each region of the capsule. The temperature distribution inside the capsule was analyzed as a function of the gas gap between the sub-capsule and the holder (maintained at the coolant temperature 60^{o}). The results presented here are considered preliminary, and a more precise estimation of the values is underway.

PROGRESS AND STATUS

Introduction

The ATR (Advanced Test Reactor) is an irradiation testing reactor with several positions for irradiation. The outer A positions of ATR are the most suitable, among the drop-in positions, to perform irradiation testing of fusion materials because of the characteristics of the neutron energy spectrum. The A1 experiment is to be performed at the A-10 position of ATR. The test matrix for the A1 experiment is composed primarily of vanadium with a few specimens of ferritic steel. It's well known that vanadium irradiation in fission reactors has to be carefully designed to avoid excessive transmutation of vanadium to chromium. The A1 experiment is a drop-in experiment in which the temperature of the specimens is controlled by the design of the capsule. The use of the thermal neutron filter to reduce the transmutation rates of vanadium to acceptable levels further complicates the control of the temperature due to the additional gamma-ray source produce by the filter itself due the neutron capture.

This paper describes the neutronics calculations and the design approach to accommodate the requirement of the experiment within the narrowest possible band of uncertainty concerning temperature and transmutation rate during the experiment.

Procedure

The transmutation and the expected lifetime of the filtering material were estimated based on an experimental neutron flux spectrum for the A-10 channel of ATR measured by JW Rogers [1]. The transmutation rate of vanadium to chromium was calculated based on the spectrum obtained from the transport of the above mentioned neutron flux spectrum through the absorber's wall. The REAC3 [2] code was used to quantify the transmutation rate and the ONEDANT [3] and MCNP [4] codes to transport the neutrons though the filtering region.

The nuclear heating deposition estimation was based on the nominal gamma-ray heating deposition provided by ATR for the A-10 position [5] (calculations are underway to provide gamma-ray and neutron heating deposition for the actual configuration of the capsule design for each region) and the estimated gamma-ray flux generated by the capture of neutrons. This part of the calculation is still underway and only preliminary estimations are available at the time of this writing.

Results and Discussion

The thickness of gadolinium required to survive up to 5 dpa's was estimated to be 1.7 mm based on the spectrum at the midplane of the reactor. This thickness could be reduced if alternative materials such as dysprosium or europium were used. The option of not using these materials is due mainly to the lack of information about the gamma-ray generation for the dysprosium and cost, handling, and fabrication for the europium. The required thickness for the filtering material, despite being considerably large (3.4 mm on the diameter, compared with the 15.8 mm OD of the holder), could be accommodated within the sub-capsule and still provide enough room for irradiating a significant number of samples.

The preliminary estimate of the nuclear heating deposition is 11 to 15 W/g (SS-316) for the different positions within the capsule. Preliminary estimation of the temperature profile [5] within the capsule indicated that it is possible to perform the irradiation at two different temperatures, 200°C and 300°C, for different sub-capsules by controlling the gas mixture into the gas gap.

CONCLUSION

It was shown that the use of the outer A positions of the ATR reactor are suitable for fusion materials irradiation testing, and that an acceptable volume of samples can be irradiated up to 5 dpa's using gadolinium as thermal filtering material. The gadolinium filter will reduce the vanadium to chromium transmutation rate to acceptable levels.

FUTURE WORK

The final values for the expected nuclear heating deposition and temperature distribution inside the capsule are to be determined.

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