EVALUATION OF A ZIRCONIUM-MATRIX CERMET FOR THE STORAGE AND TRANSMUTATION OF TRANSURANIC ISOTOPES

A Thesis

Submitted to the Faculty

of

Purdue University

by

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In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science Nuclear Engineering

August 2006

Purdue University

West Lafayette, Indiana

This thesis is decidated to my mother and father, Debbie and John Totemeier.
Without their unwavering love and support, none of this would have been achieved.
Thank you both.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the U.S. Department of Energy under contract number: DE-FC07-05ID14656. Also, many thanks go to Edward Merrit and David Regan for their help with the electronic and hydraulic systems and to Paul Mews and Adam Parkison for their assistance with the experimentation. I would like to thank Dr. Dayanada and Dr. Revankar for being on my committee and Dr. McDeavitt for advising me through this work.

PREFACE

This research was born from the U.S. DOE Advanced Fuel Cycle Initiative (AFCI) and the desire to reduce the waste volume load on a geologic repository such as Yucca Mountain. In no way does it remove the current and future need for such a repository, instead the intention is to extend the life and storage capabilities by removing some of the "bad-actors".

The overall concept is to remove transuranic elements from spent nuclear fuel through the UREX/TRUEX process and separate the zirconium from fuel cladding through a zirconium hydride-dehydride process currently under development. This recycled Zr will then be used as the matrix of a cermet storage form for transuranic oxides with the possibility of conversion to a transmutation target or fast reactor burner pin. Within this larger project design, the focus of this thesis is an evaluation of the necessary concepts and theories for fabricating and utilizing such a storage form.

TABLE OF CONTENTS

ABSTRACT

Totemeier, Aaron R. M.S.N.E., Purdue University, August, 2006. Evaluation of a Zirconium-Matrix Cermet for the Storage and Transmutation of Transuranic Isotopes. Major Professor: Sean M. McDeavitt.

Reduction of the radiotoxic inventory of spent nuclear fuel (SNF) in the United States has lead to an interest in the development of a zirconium matrix cermet storage form for transuranic (TRU) isotopes. A hot extrusion process has been developed for fabrication of the proposed cermet.

A 90 thydraulic press has been outfitted with ceramic fiber heaters to heat the extrusion tooling and billet. Eight extrusion development tests have been performed to determine the initial response of the hot extrusion process to temperature, billet green density, and particle loading. Zirconium powder (-325 mesh) is used as the matrix phase and YSZ (400 μm diameter) as the TRU oxide simulant. It has been confirmed that below temperatures of 700 °C the extrusion of powder zirconium will not proceed. Low green density of the pre-extruded billet is believed to have caused fracture of the extruded rod. A large amount of particle damage has been observed for a reduction ratio (A_o/A_f) of 9 and 2.6, though less damage is seen in the smaller reduction. High particle loading causes particle fracture by impact during deformation. A lower particle loading and method to maintain interparticle spacing during extrusion are suggested to relieve this contact fracture.

The SRIM code package has been used to determine He ion ranges in Zr and UO_2 as a TRU oxide simulant. From this information the amount of undamaged Zr matrix as a function of particle size and volume loading has been calculated, suggesting a smaller particle size may be used in future work.

Metallography of the extruded cermet samples has been performed to visualize particle distribution and damage. Detailed microscopic analysis on porosity and oxygen gettering in the matrix has not been performed at this time.

This work is the beginning of an ongoing project to perform a parametric study of the hot extrusion process for Zr cermet fabrication. Future work will include analysis of reduction ratio, particle loading, and matrix density.