FUEL PIN
PRELIMINARY DESIGN

Nuclear Engineering – Politecnico di Milano

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ABSTRACT: This report presents the preliminary design and verification of a fuel pin for a sodium-cooled fast reactor. The analysis focuses on determining cladding thickness, the size of the fuel-cladding gap, and the plenum height while ensuring compliance with design limits and safety margins. The main assumptions, approximations, and conclusions are discussed.

Key-words: Fuel Pin, Lead Cooled, Plenum, Cladding Thickness

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1 INTRODUCTION

The fuel pin design process involves:

- Determining the cladding thickness, the fuel-cladding gap size, and the plenum height.
- Verifying the design against limits for fuel melting, cladding temperature, yielding, and thermal creep.
- Identifying critical aspects if the irradiation time is doubled.

Most design specifications were provided. Missing data were sourced from relevant literature or handouts.

2 ASSUMPTIONS AND METHODOLOGY

Material and Thermal Assumptions:

- Material properties were treated as temperature-dependent, modeled using empirical correlations.
- Axial profiles for power and neutron flux were assumed constant.
- Initial helium pressure and temperature in the fuel-cladding gap were as specified.

Key Approximations:

- The fuel-cladding gap was treated as uniform, neglecting axial deformation.
- Fission rate calculations assumed uniform flux and macroscopic cross sections derived from the JANIS database.
- Plutonium redistribution and void swelling were modeled using analytical correlations.

3 DESIGN RESULTS AND VERIFICATION

3.1 Preliminary Sizing

The genetic algorithm was used to optimize the cladding thickness and plenum height while maintaining performance and safety:

- **Cladding Thickness:** 80–120 μm.
- **Plenum Height:** 80–100 cm.

3.2 Verification

Thermal Performance:

- The margin to melting of the fuel was validated under steady-state conditions.
- Axial and radial temperature profiles confirmed acceptable temperature gradients in the cladding and fuel.

Mechanical Analysis:

- Stresses in the cladding were calculated using Mariotte and Lamé criteria.
- The time to rupture due to thermal creep was evaluated using the Larson-Miller parameter.

Key Findings:

- The fuel-cladding gap remained within the design range throughout operation.
- Cladding stresses remained below yielding limits.
- The design provided sufficient safety margins for thermal creep and mechanical integrity.

4 CRITICAL ISSUES FOR EXTENDED OPERATION

If the irradiation time is doubled:

- Increased fission gas release (FGR) will elevate internal pressure and reduce thermal conductivity in the gap.
- Cladding thickness constraints must be re-evaluated to prevent long-term creep failure.
- The redistribution of Plutonium could lead to localized power peaking, necessitating further analysis.

Conservative limits on cladding thickness and plenum height were implemented to address these issues.

5 CONCLUSIONS

The finalized design meets all specified requirements, ensuring safety and reliability for up to a four-year fuel cycle. Conservative assumptions and thorough validation steps provided additional safety margins. The design demonstrates robustness under normal and extended operational conditions.

APPENDIX

All supporting code is available in the following repository: NDT-Homeworks Repository.