Safety performance of oxide and metallic fuels in SFRs

Youpeng Zhang

Royal Institute of Technology (KTH)

Contents

- Simulation tools
- Implementation of the BN600 and IFR models
- Reactivity coefficients and core performance data
- Definition of transients and failure mechanisms
- Transient simulation results
- Conclusions

Simulation tools

SERPENT Monte Carlo code

- ✓ Continuous energy Monte Carlo burnup code
- ✓ Solving Bateman equations with Transmutation Trajectory Method (TTM) for burnup calculation
- ✓ JEFF-3.1 data library
- ✓ 5 to 15 times faster than traditional Monte Carlo code due to evenly subdividing cross section energy grid

Simulation tools

SAS4A/SASSYS code (ver. 3.1)

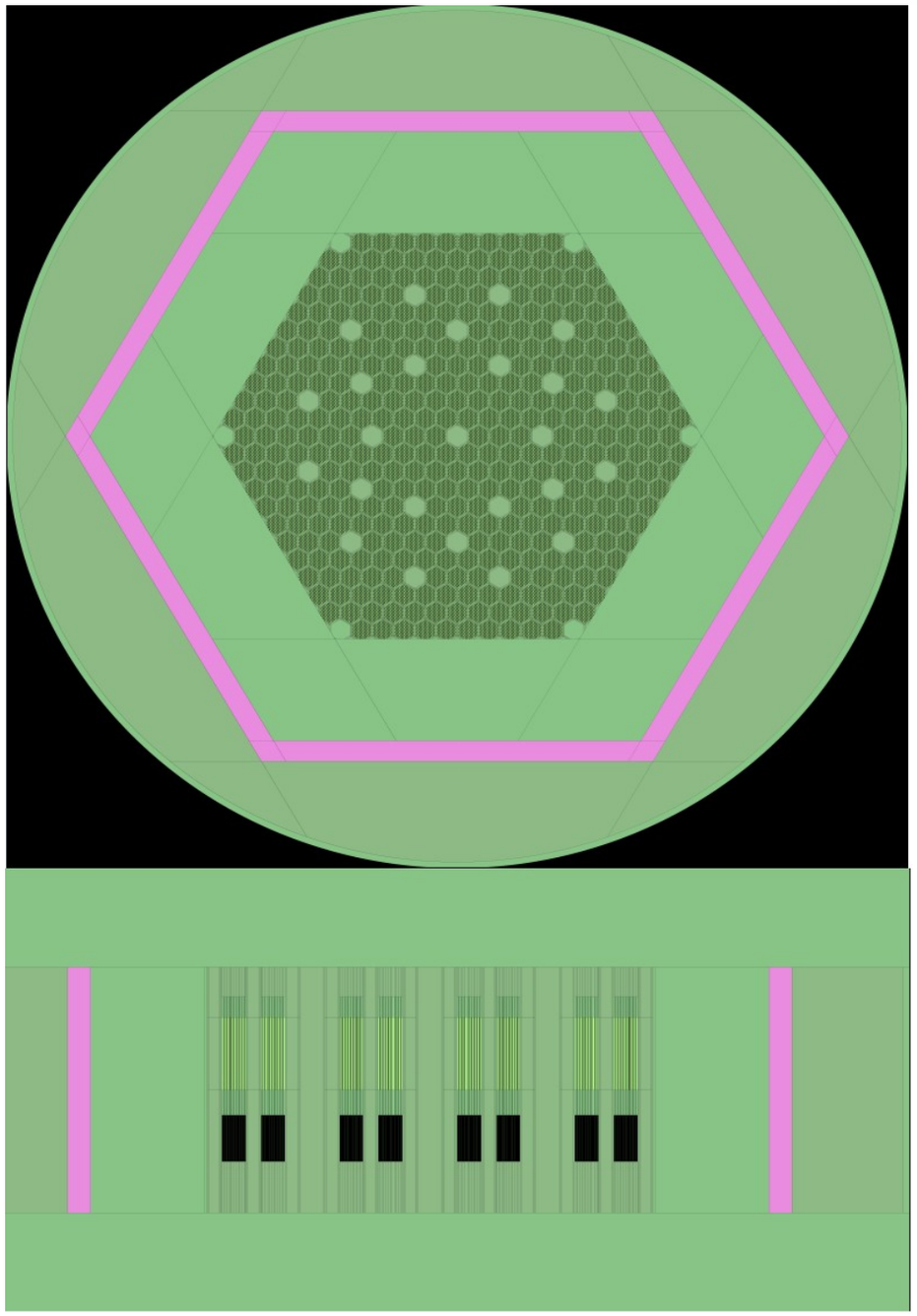
- ✓ Point kinetic model
- ✓ Two-dimensional (r/z) heat conduction equation
- ✓ One-dimensional non-equilibrium, homogenous coolant flow model
- ✓ Qualified for licensing liquid Na, liquid Pb and LBE cooled reactors loaded with oxide or metallic fuels, by means of LOF, TOP, LOHS and BT

SERPENT models

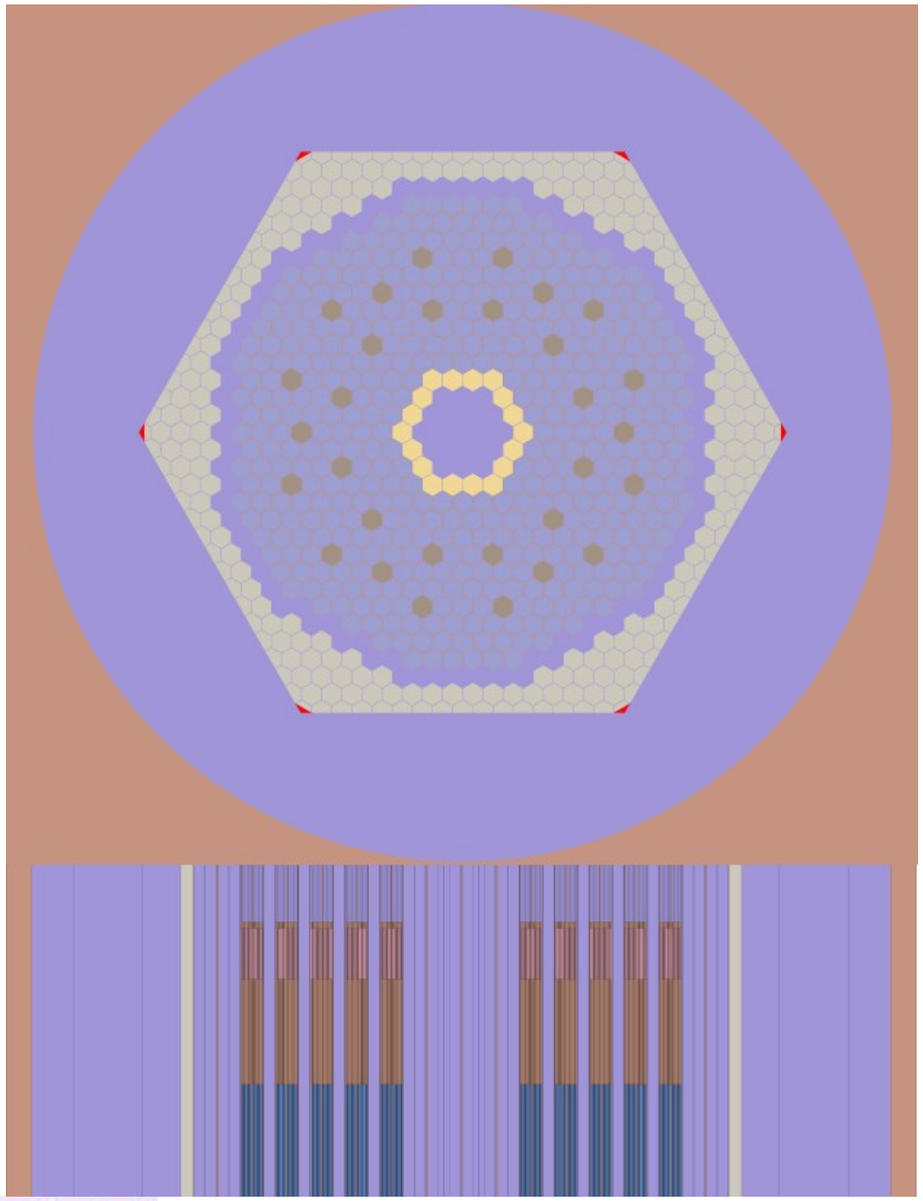
BN600

- 369 driver SA
- 127 pins per SA
- 8 mm pin pitch
- 99 mm SA pitch
- 20 at.% Pu + 0~10 at.% Am

Isotope	at.%	Isotope	at.%
Pu-238	3.50	Pu-239	52.88
Pu-240	23.82	Pu-241	12.90
Pu-242	7.90		
Am-241	57.58	Am-243	42.42



SERPENT models



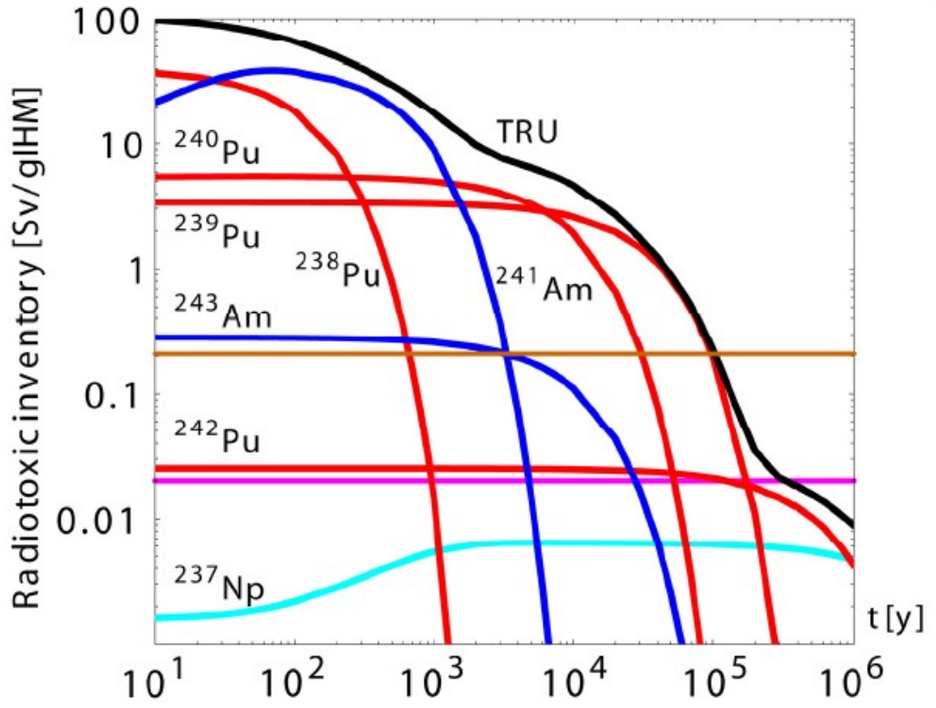
IFR

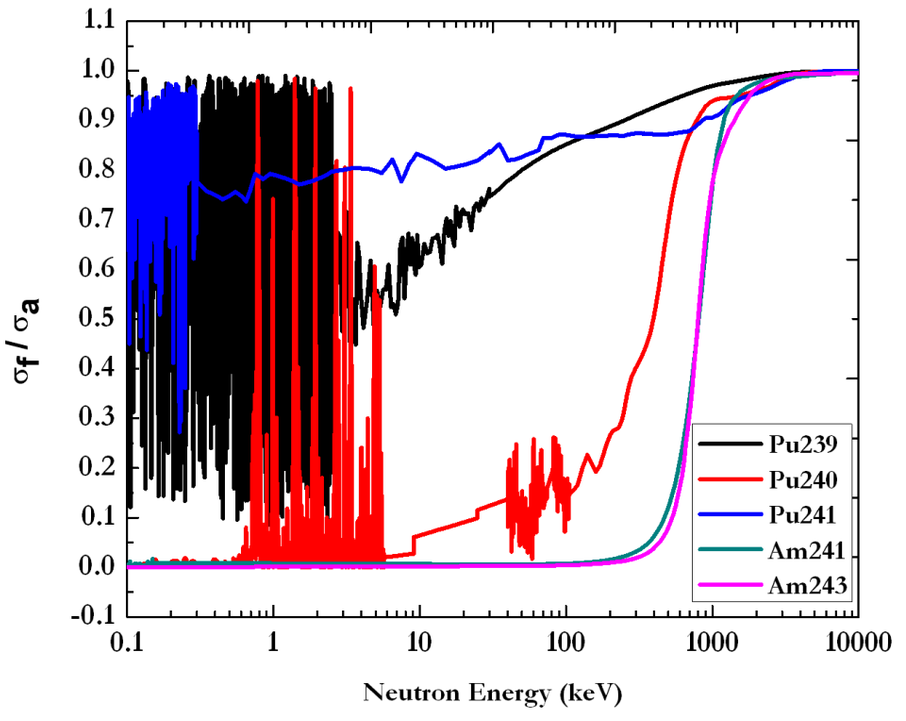
- 456 driver SA
- 271 pins per SA
- 8.4 mm pin pitch
- 162 mm SA pitch
- 10.8 at.% Pu + 0~10 at.% Am

Isotope	at.%	Isotope	at.%
Pu-238	3.50	Pu-239	52.88
Pu-240	23.82	Pu-241	12.90
Pu-242	7.90		
Am-241	57.58	Am-243	42.42

Troublesome americium

- **Neutron emitter due to spontaneous fission reactions**
- **He release from alfa-decay reactions**
- **Could not be transmuted by multi-recycling in LWRs**
- **Deterioration effects on core safety parameters**

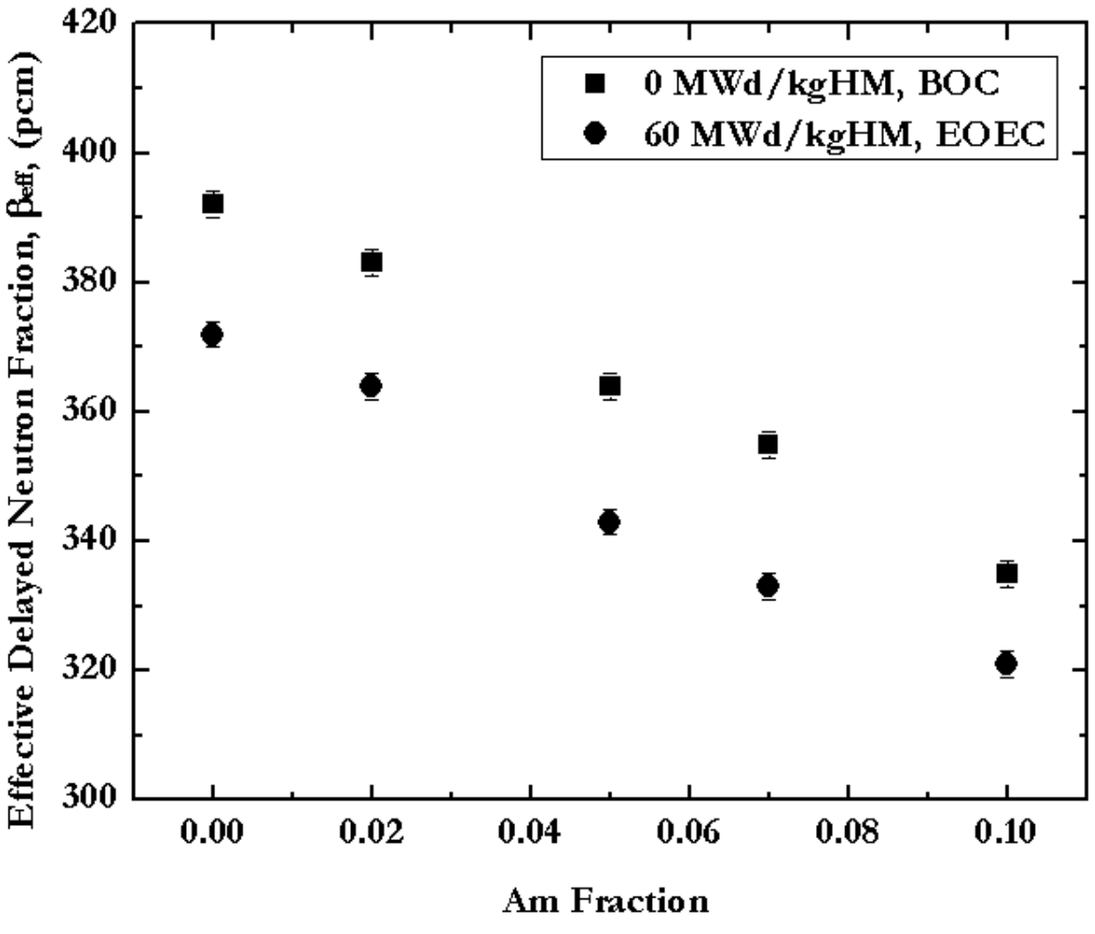




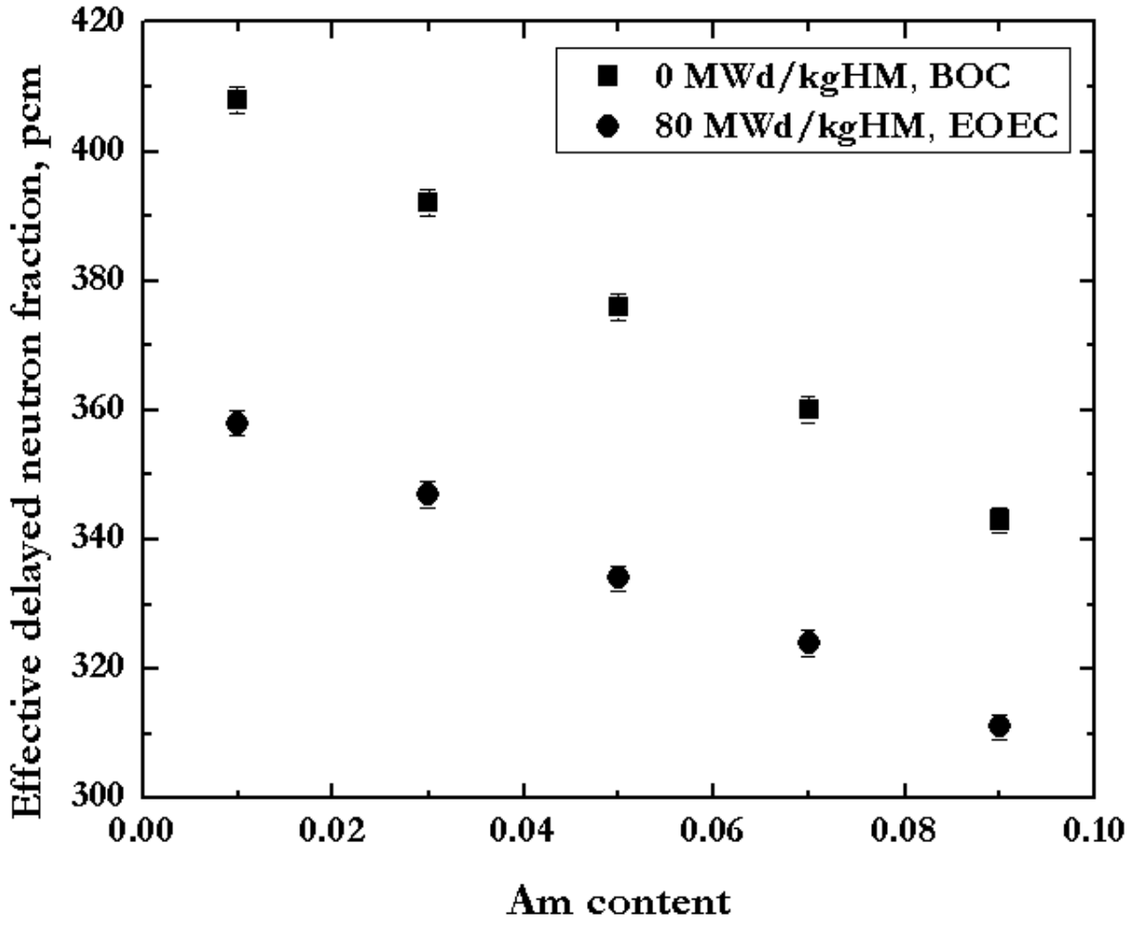
Reactivity coefficients and core performance data

KUNGL TEKNISKA HÖGSKOLAN — KTH Syd, Campus Haninge, Campus Telge

BN600



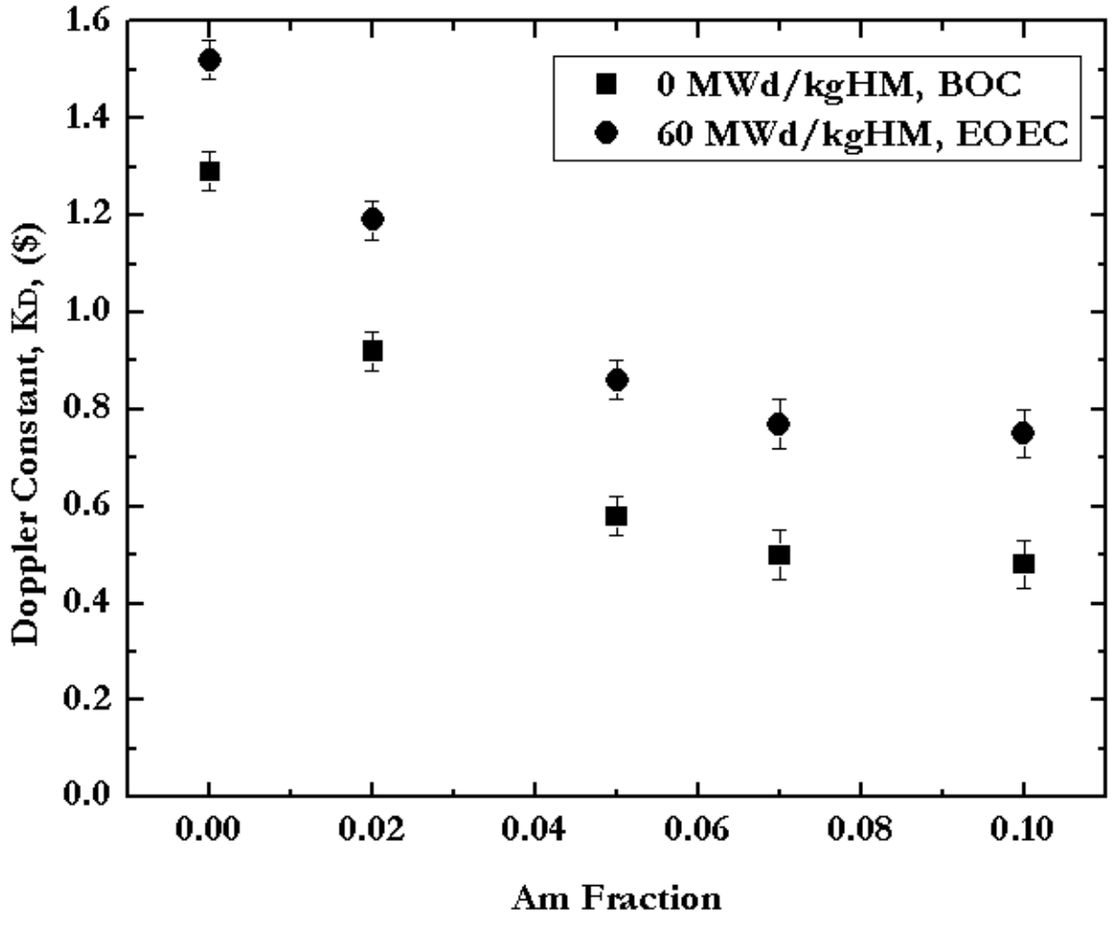
IFR



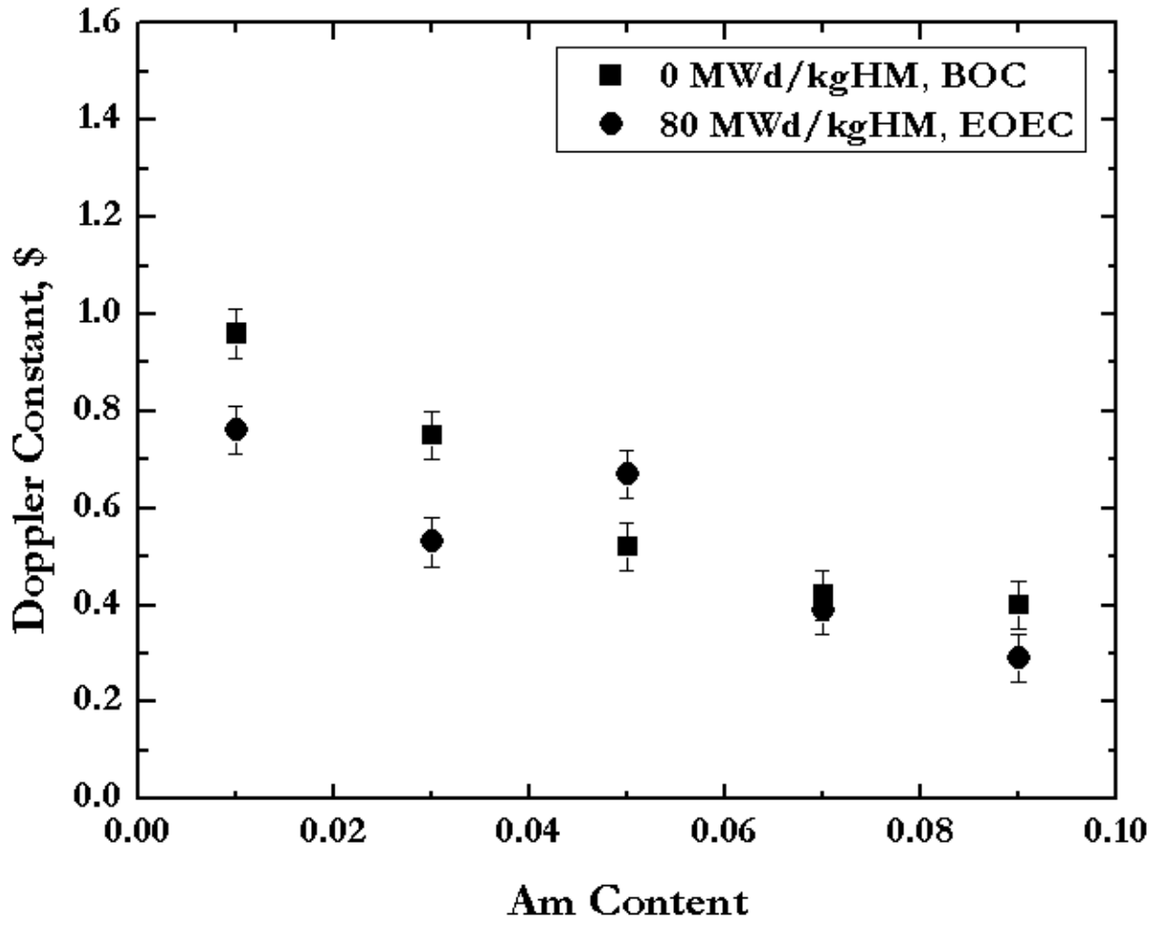
Reactivity coefficients and core performance data

KUNGL TEKNISKA HÖGSKOLAN
KTH Syd
Campus Haninge
Campus Telge

BN600



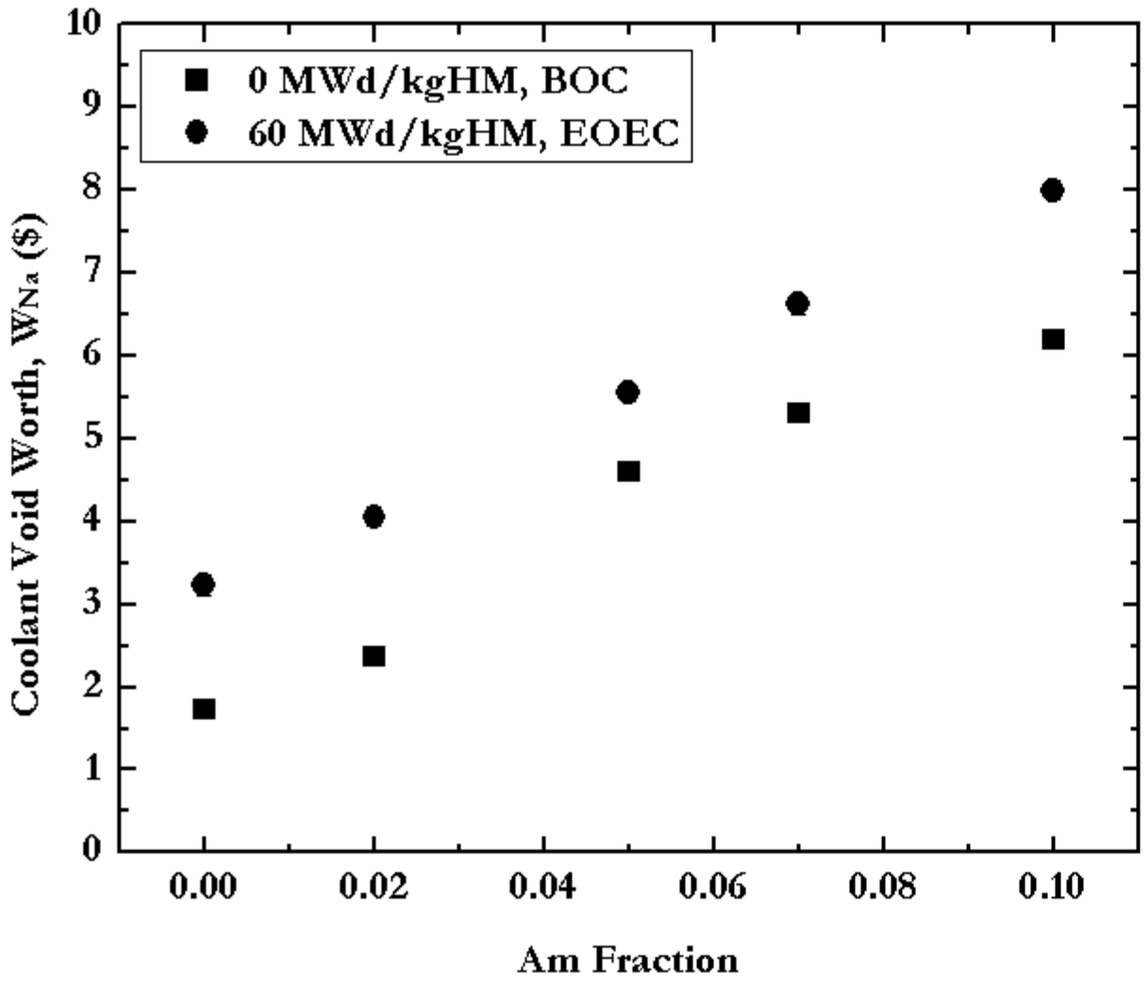
IFR



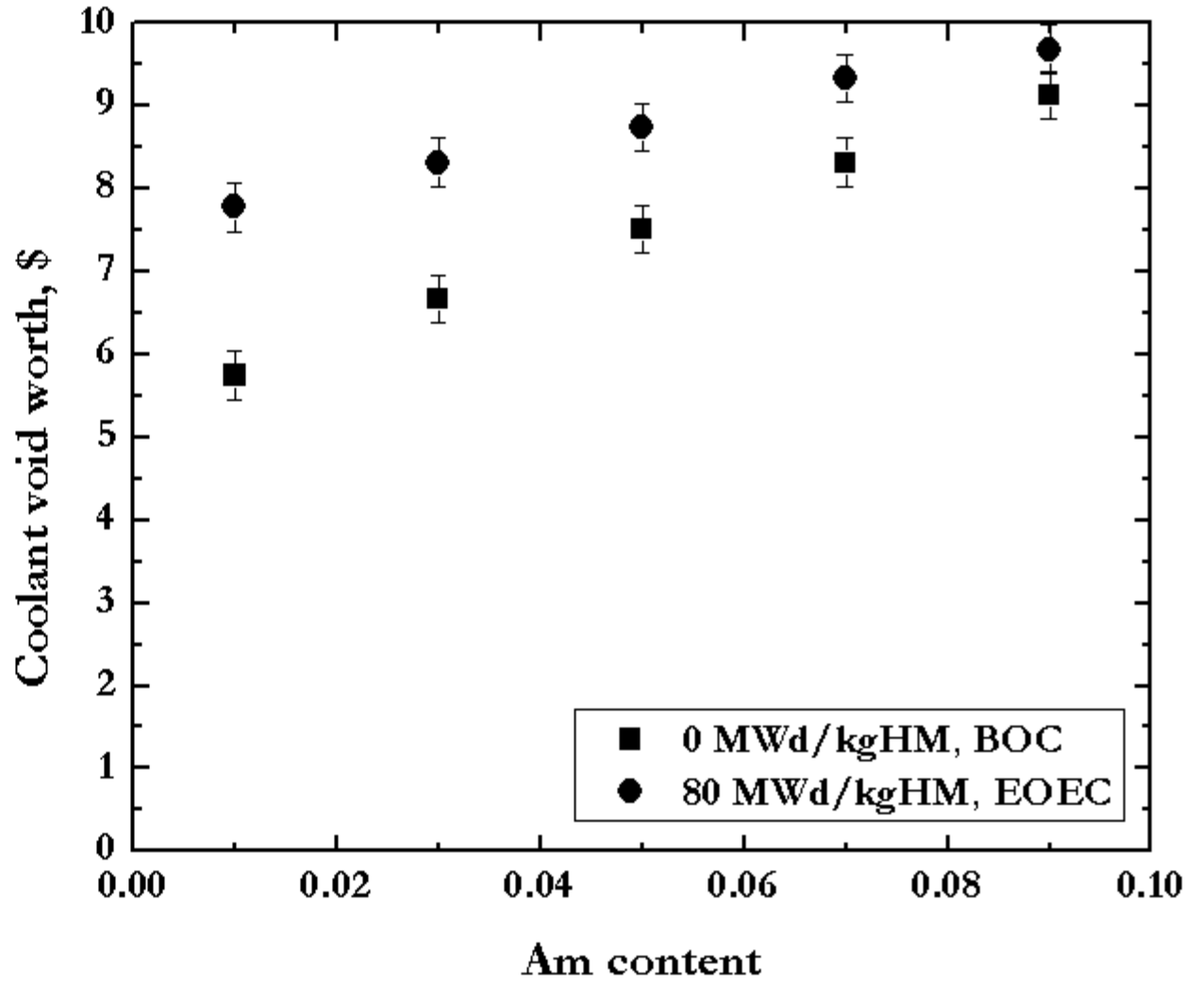
Reactivity coefficients and core performance data

KUNGL TEKNISKA HÖGSKOLAN
KTH Syd
Campus Haninge
Campus Telge

BN600



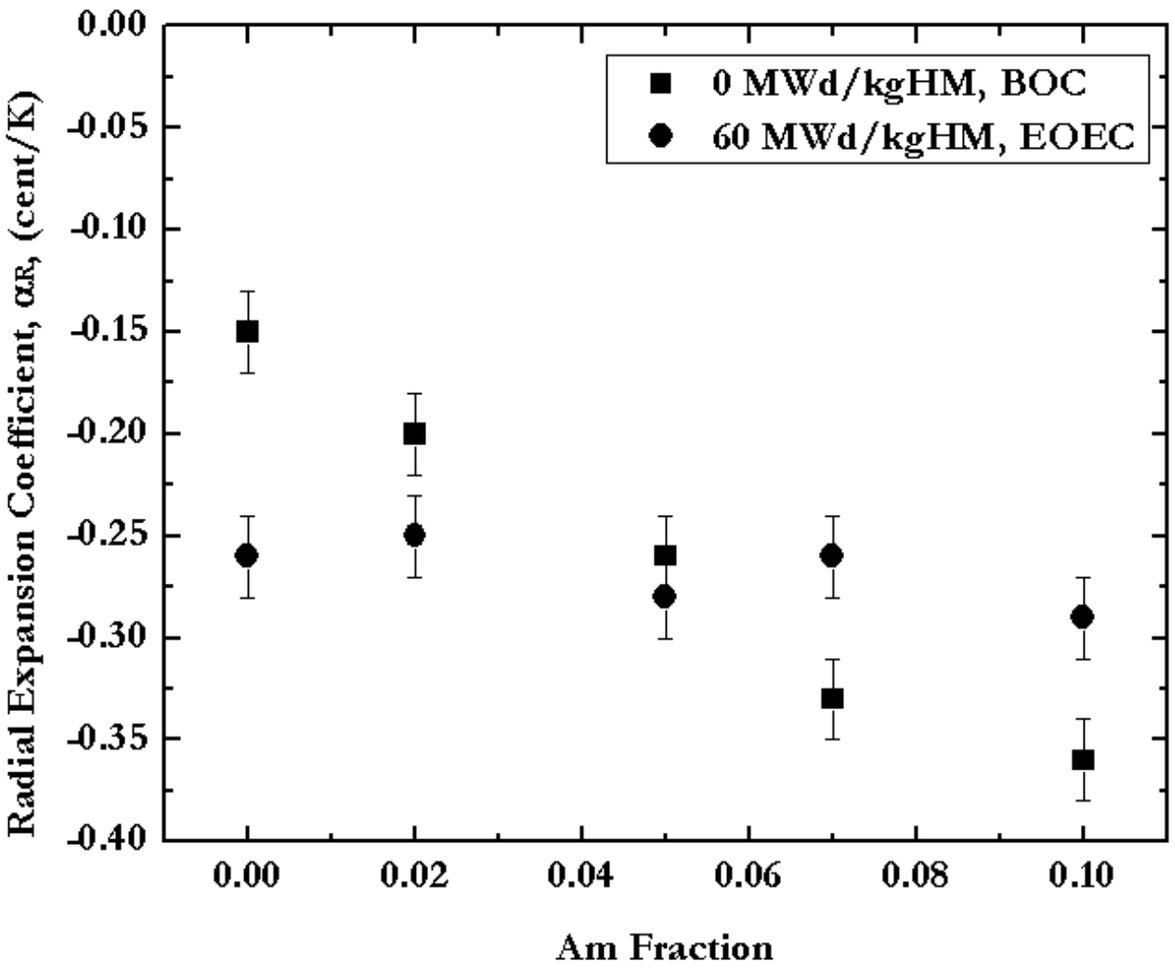
IFR



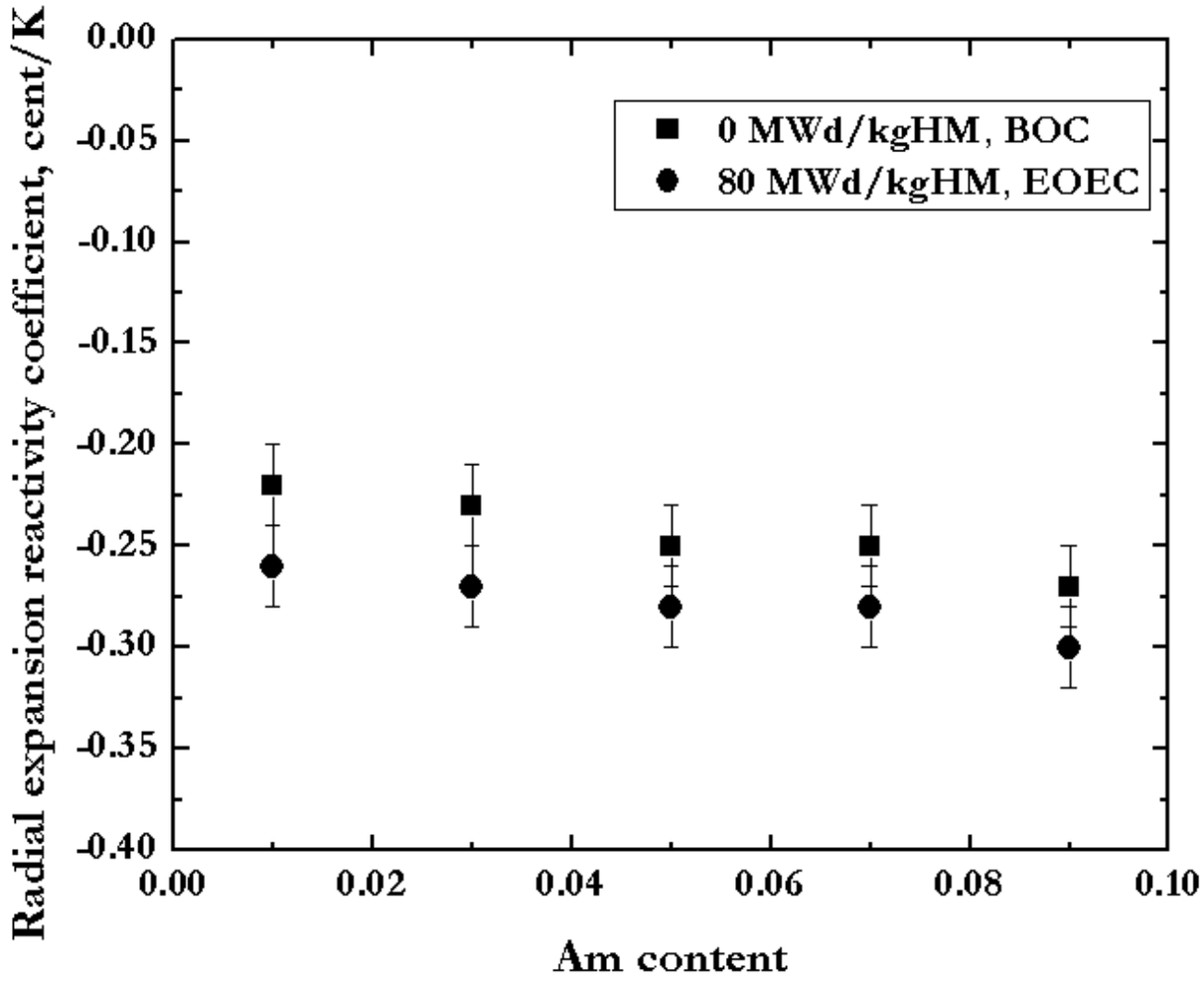
Reactivity coefficients and core performance data

KUNGL TEKNISKA HÖGSKOLAN — KTH Syd, Campus Haninge, Campus Telge

BN600



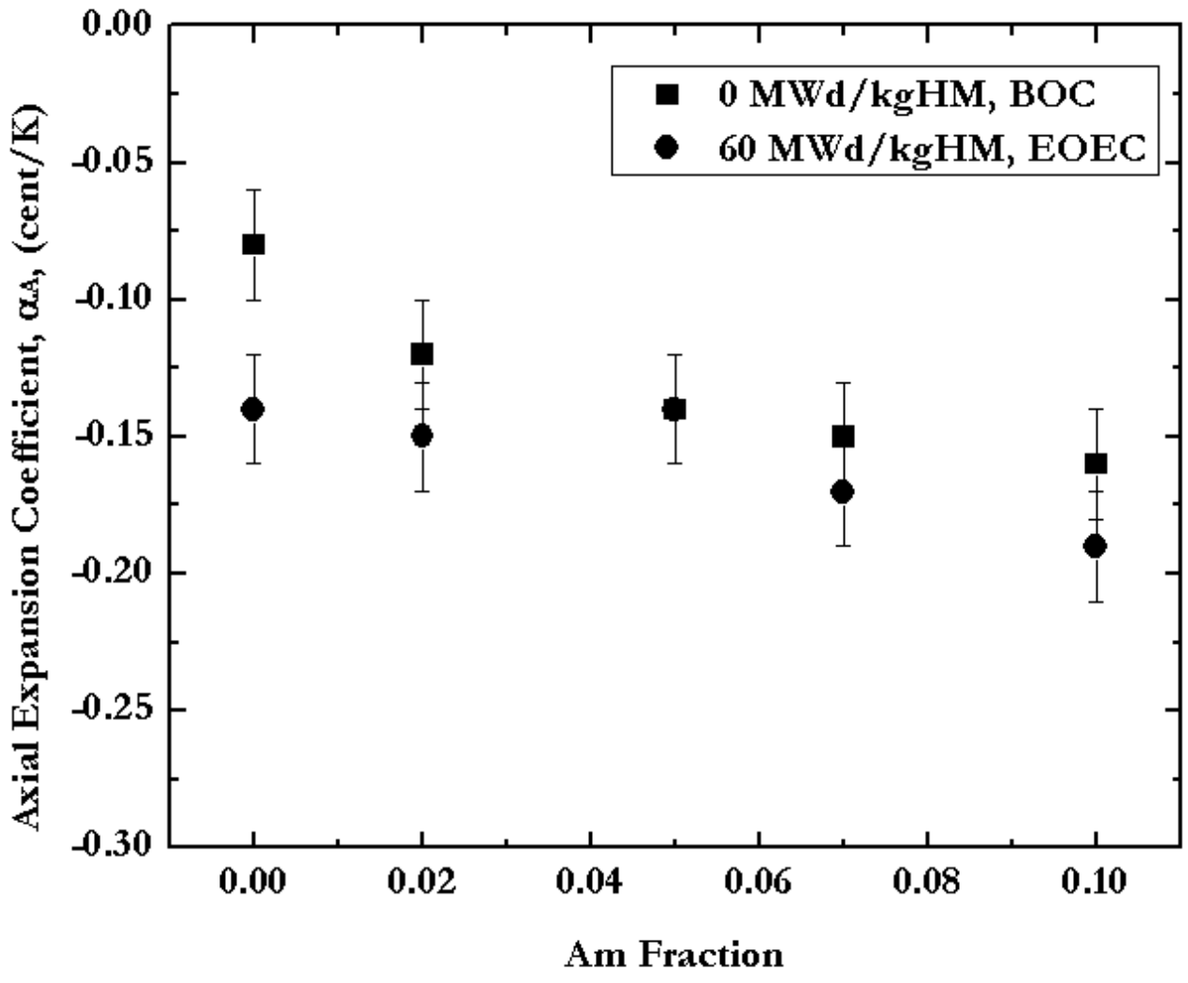
IFR



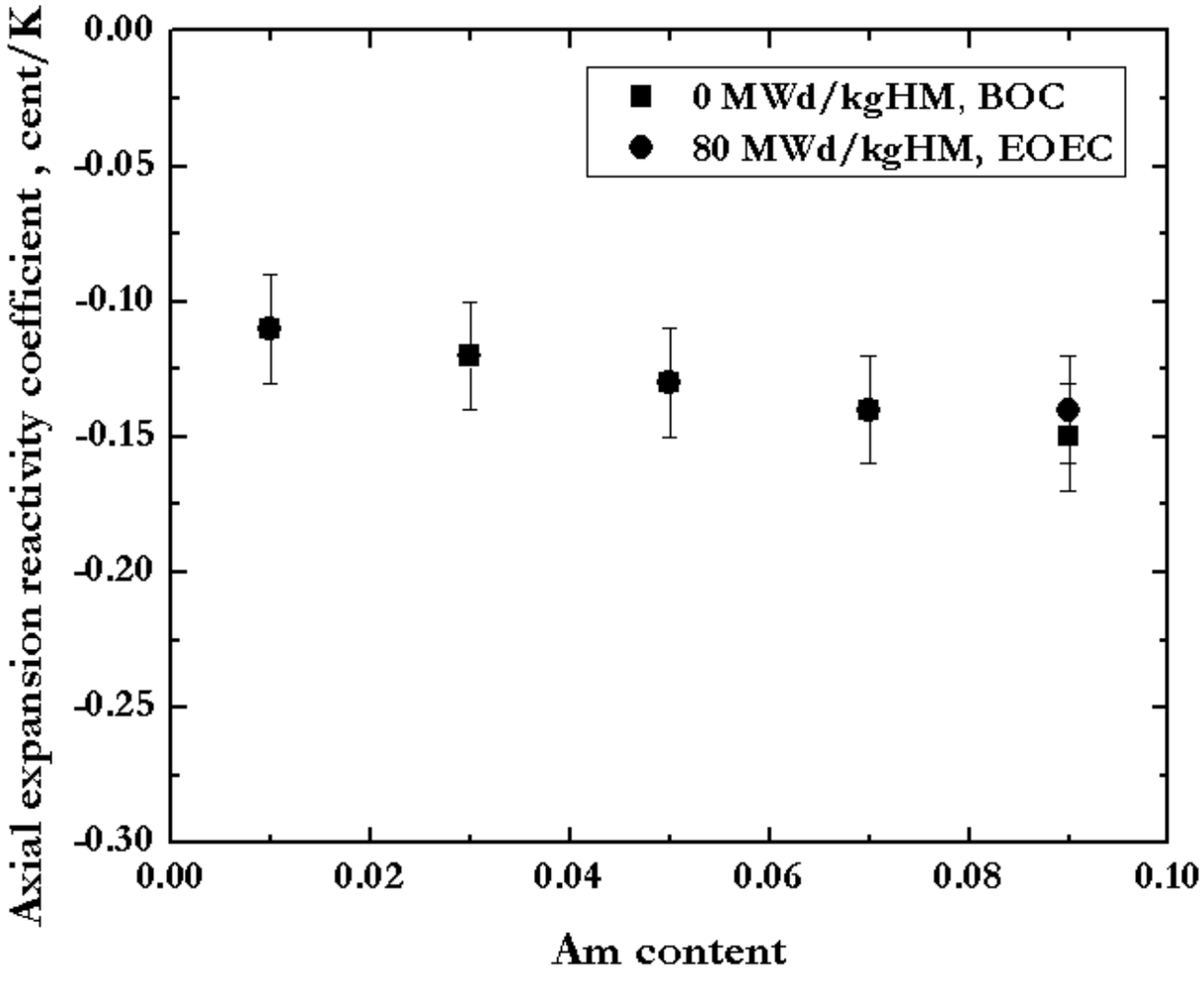
Reactivity coefficients and core performance data

KUNGL TEKNISKA HÖGSKOLAN — KTH Syd, Campus Haninge, Campus Telge

BN600



IFR



Transient definitions and failure mechanisms

KUNGL TEKNISKA HÖGSKOLAN
KTH Syd
Campus Haninge
Campus Telge

- **ULOF**

  70% coolant flowrate decrease within 10.0 sec.

- **UTOP**

  1.0 $ external reactivity insertion with a ramp rate of 0.05$/s

- **Cladding**

  Creep rupture – Larson-Miller Parameter – 1170 K (150 Mpa Hoop stress)

- **Coolant boiling**

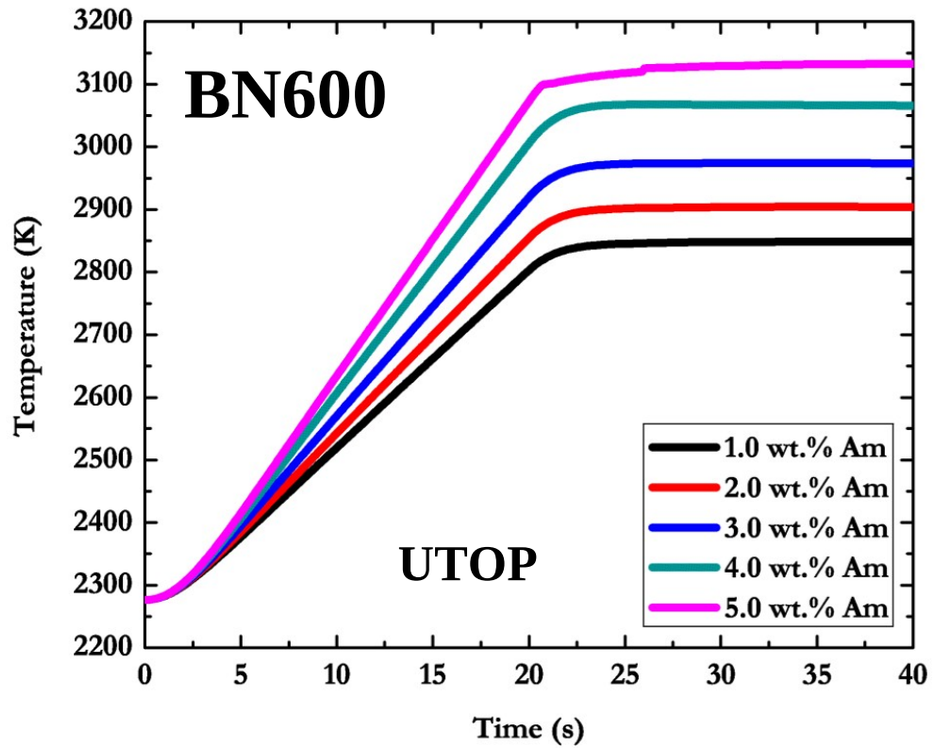
  Boiling point offset

- **Fuel failure**

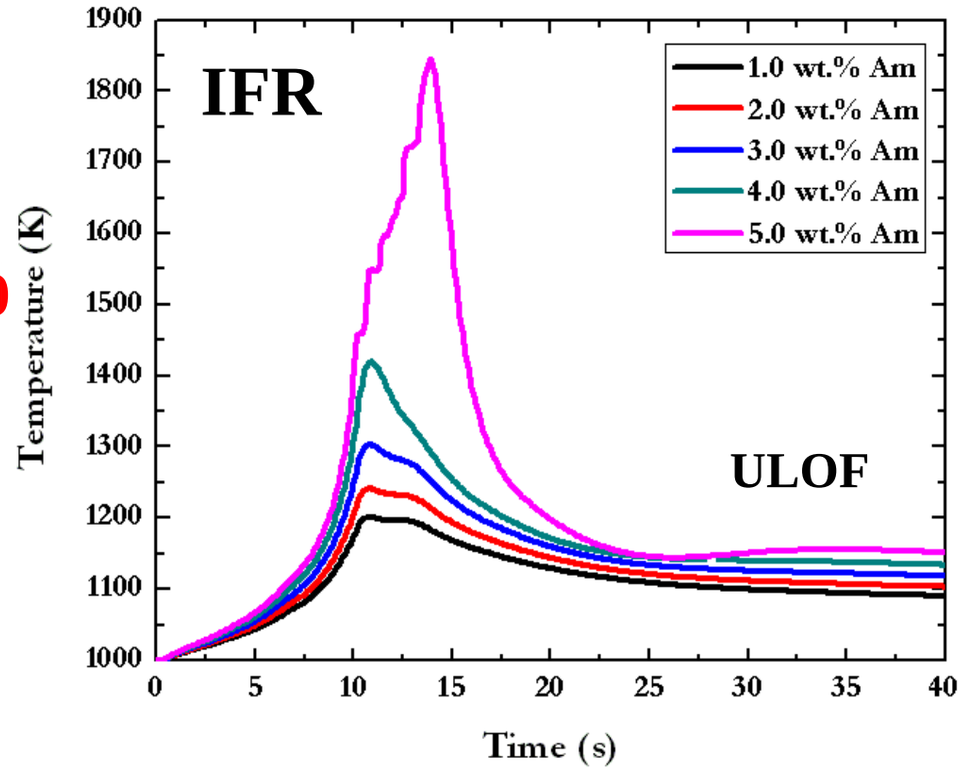
  Solidus temperatures offset

  - ✓ **2930~2951 K for oxide fuel**
  - ✓ **1379 K for metallic fuel (U-Pu-Zr) due to lack of information**

Transient simulation results



- **Fuel temperature at hot spot increases by 300 K when Am content increases from 1.0 wt.% to 5.0 wt.% during UTOP.**
- **1.0 wt.% additional Am leads to 6 % power penalty, preserving 100 K margin to fuel melting.**



- **Fuel temperature at hot spot increases by 700 K when Am content increases from 1.0 wt.% to 5.0 wt.% during ULOF.**
- **1.0 wt.% additional Am leads to 10 % power penalty, preserving 100 K margin to fuel melting.**

Conclusions

- Transmutation of Am in SFRs loaded with oxide and metallic fuel may be possible but leads to significant power penalty.

- Fuels with high thermal conductivity (e.g., nitride fuel) and coolant with high boiling point (e.g., liquid Pb) could be considered.

- ADS is more efficient and suitable for Am transmutation.

Thanks for listening !

Questions are welcomed!