SIMULATION OF IRRADIATION OF A BUNDLE OF MOX FUEL RODS IN THE OMICO EXPERIMENT IN BR2

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Belgian High Flux Materials Testing Reactor BR2

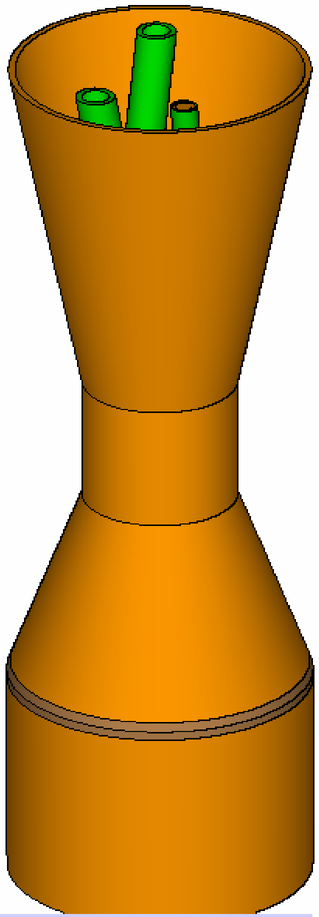
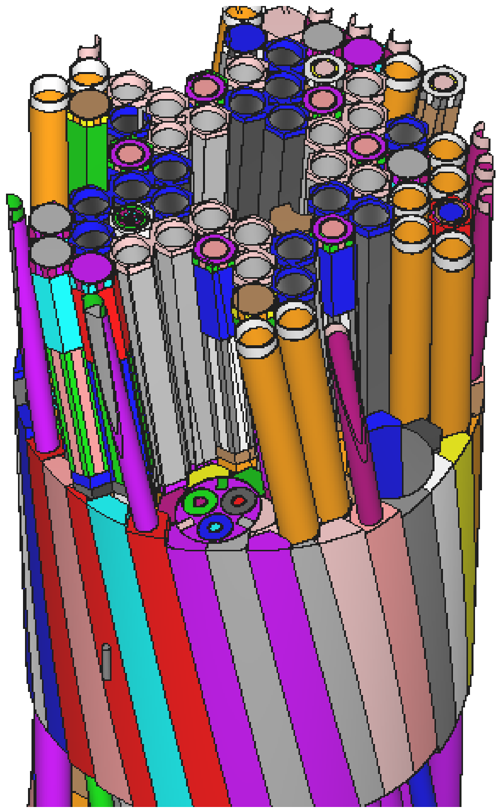


Fig.1 3-D MCNP simulation model of the BR2 reactor with inclined channels



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On-line Data Acquisition System

Data acquisition system BIDASSE in BR2 :

- On-line measurement of the total deposited energy in the in-pile channels using the thermal balance method.
- On-line measurement of the thermal neutron flux density in self-powered neutron dosimeters inside channel (implemented by L.Vermeeren)

Detailed distributions of the power and of heat fluxes in fuel rods and in assembly are not available

Objective of the Study

Accurate prediction of irradiation conditions in BR2 :

- Detailed distribution of power in different structural elements and fuel elements inside the IPS channels
- Spatial distributions of fission events and the fuel burn-up in fuel bundles including fuel elements of different type under long history of irradiation
- Validation of calculations by comparing with the available on-line measurements .

Calculation Model of the OMICO Experiment

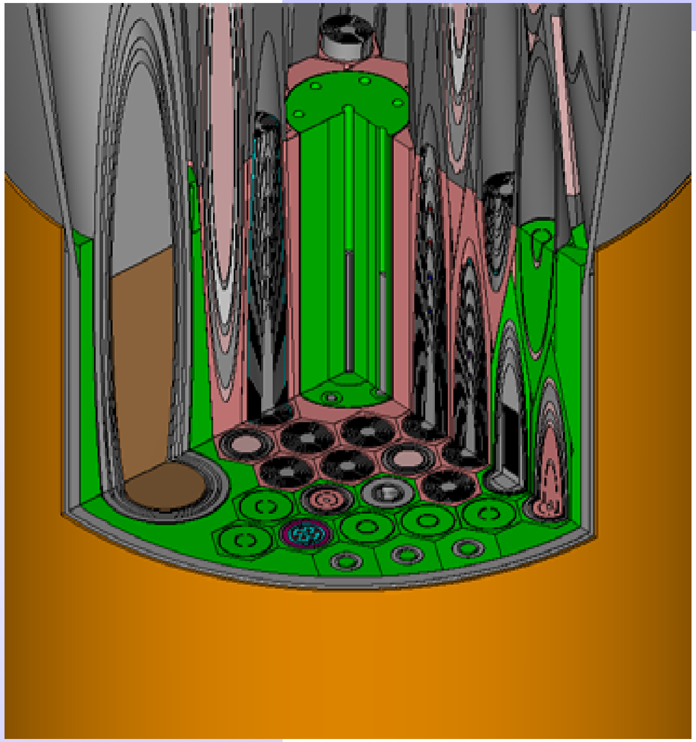

Fig.3 A reactor core cut in 3-D model of the BR2.

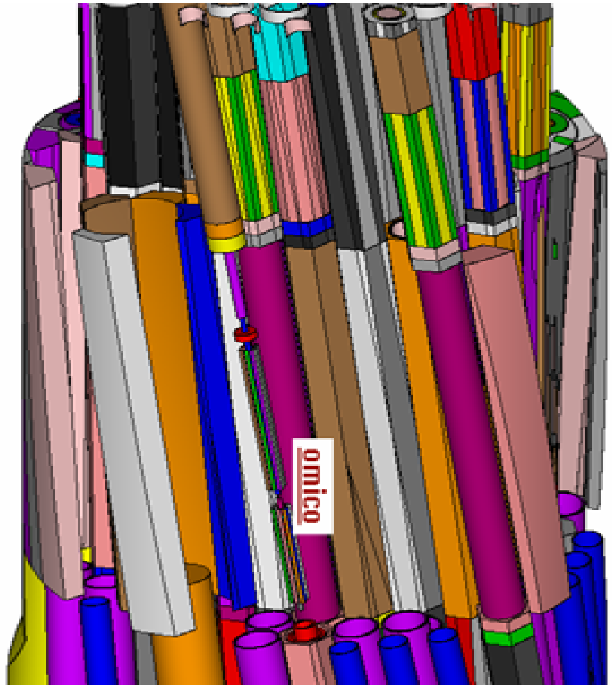

Fig.4 Position of the OMICO fuel bundles grouping of 8 MOX fuel rods each

OMICO in Different Irradiation Cycles

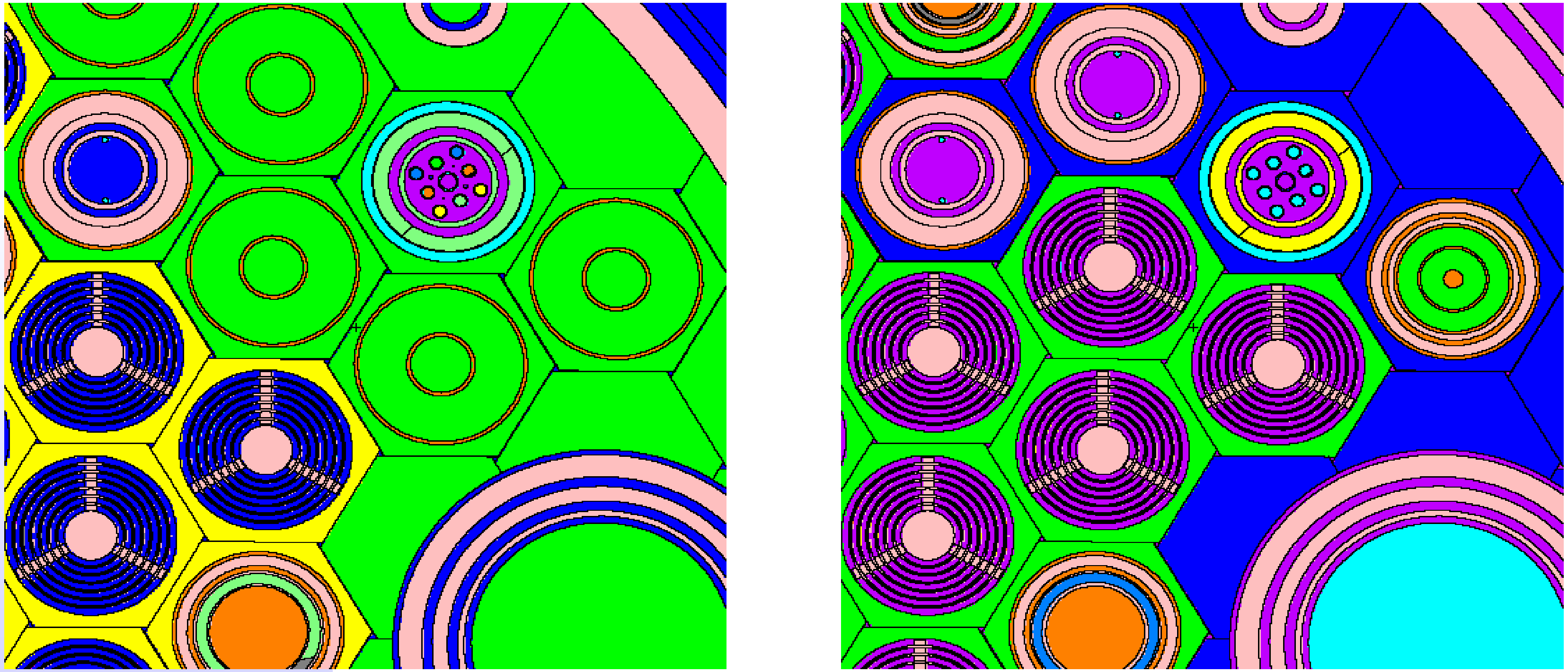

Fig.4 Changing an environment around the site of OMICO in different irradiation cycles

Radiation Heating in the In-pile Section

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Nuclear heating induced by photons is about 20% of the total heating energy

Calculation of radiation heating in the in-pile section

- Prompt gammas
  - BR2 model for MCNP code
- Intensity of delayed gammas generated in fuel elements in the reactor core
  - BR2 model for SCALE-4.4a & MCNP

$$E_\gamma^{SCALE} = n_\gamma \bar{E}_\gamma = \frac{I_\gamma \bar{E}_\gamma E_{fiss} 1.6\times10^{-19}}{P_{FE}} MeV / fiss$$

Calculations 20,4 - 22.1 kW
Later on measurements 20.7 - 21.2 kW

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3D Distributions of the Fuel Burn-up in Complex Assemblies

Choice of calculation method

- Multiple steps of the fuel burn-up calculation for fuel assembly:
  - ***Solution of the BATEMAN equation in each registration zone for a burn-up step***
    - ♣ Determination of the nuclide concentrations in the fuel zone using the data for the power or for neutron flux densities
    - ♣ Recalculation of the neutron fluxes and the power using new nuclide composition in the zone

- One step calculation of the fuel burn-up distribution in the assembly :
  - ***Preparing a dependence of fuel nuclides composition versus the fuel burn-up***
  - ***Calculation of the detailed power distribution and the mean fuel burn-up in the whole fuel assembly or in the rod in the burn-up step***
    - ♣ Reconstruction of the detailed fuel burn-up distribution in the whole fuel assembly using the power peaking factors in registration zones

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Local Burn-up vs Mean Burn-up

Local fuel burn-up in the registration cell {υ}n

$$\beta(\nu,T)=C_\nu \frac{\int_0^T P(\nu,t)\,dt}{M(\nu)}100\%,\qquad C_\nu=\frac{A_U}{N_A E_{eff}}\alpha_\nu,\qquad \alpha_\nu=\frac{\left\langle \sigma_f+\sigma_c\right\rangle_\nu}{\left\langle \sigma_f\right\rangle_\nu}$$

Dependence of the local burn-up on the mean burn-up and on the peaking factors

$$\beta_\nu(T_N)=\beta_\nu(T_1)+\sum_{i=2}^{N}\left(\bar{\beta}(T_i)-\bar{\beta}(T_{i-1})\right)\times k_\nu(T_i)=$$

$$\sum_{i=1}^{N-1}\bar{\beta}(T_i)\left[k_\nu(T_i)-k_\nu(T_{i+1})\right]+\bar{\beta}(T_N)\,k_\nu(T_N),$$

Evolution of the Spatial Distribution of the Burn-up in Irradiated rods

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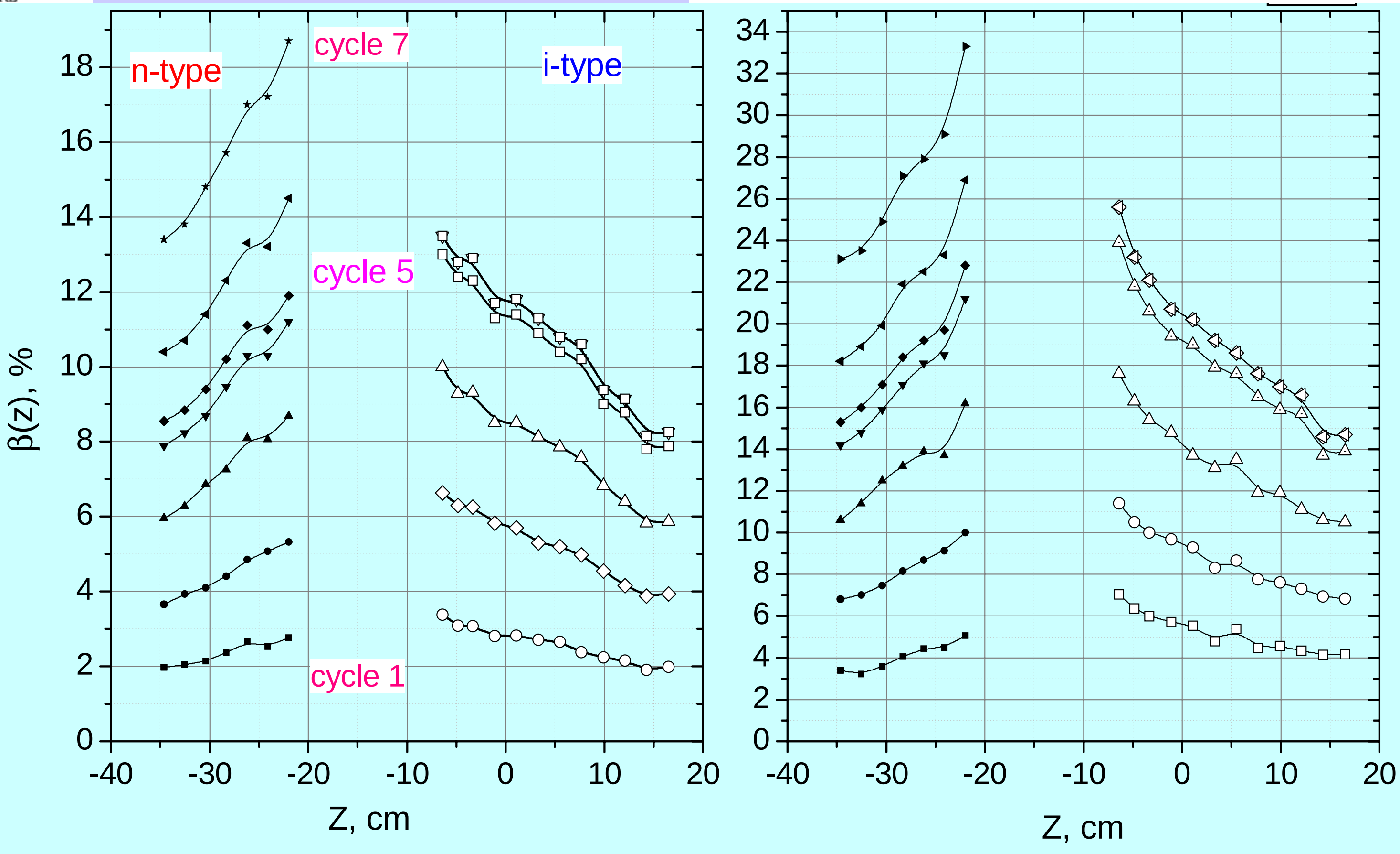

Fig.5 Example of the evolution of spatial distributions of the fuel burn-up in different rods in the fuel bundle

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Comparison of the Calculated Thermal Power in the In-pile Section

cycle	Time	BR2 reactor	IPS1 channel		
		Power, MW	Calculated power (C), kW	Measured power (M), thermal balance, kW	Difference (1-C/M), %
1	BOC	46	80	91	-12
	EOC	52	90	103	-13
2	BOC	61	80	86	-7
	EOC	60	89	89	+0
3	BOC	56	73	77	-5
	EOC	56	82	81	+2
4	BOC	57	72	74	-3
	EOC	57	77	82	-6
5	BOC	60	71	70	+2
	EOC	60	76	73	+4
6	BOC	58	36	38	-4
	EOC	58	37	35	+6
7	BOC	58	50	52	-4
	EOC	58	47	53	-11
mean					-4

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Conclusion

- A simple approach for calculation of the 3D detailed fuel burn-up distributions in the bundle of fuel rods are applied for the OMICO experiment using realistic 3D model of BR2 reactor
- The difference between the calculated power and on-line measurements in different irradiation cycles in most cases is less than 10%, and in average is about -4%