Boron dilution benchmark using COBAYA3/FLICA4 coupled codes within the NURISP European Project

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1 Introduction

Within the subproject 3 of the NURISP project three neutron kinetic codes have been implemented into the NURESIM platform. For all three codes (CRONOS2, COBAYA3 and DYN3D) the coupling with the thermal hydraulic code FLICA4 was accomplished using the features of the NURESIM platform.

This paper contains the results obtained with COBAYA3/FLICA4 coupled codes for the PWR boron dilution benchmark defined within the sub project 3 of the NURISP project. Results are provided for all the scenarios.

2 Transient calculation

The boron slug transient calculation has been an extremely demanding and difficult exercise from the point of view of the tools used. The fact that FLICA4 works only for 32 bits has limited greatly the perform of the transients, a vast number of them have been crashed due to memory problems (it is was not possible to use more than 4 Gb of RAM, even in virtual machines, due to the 32 bit restriction).

There have been performed many sensitivities regarding the timestep, the axial levels and the boron model options (method, CFL, boron timestep). From all these experience it has been extracted the best estimate options that fits all three boron slugs: the global timestep has to be less than 0.005 s to perform correctly the neutron kinetics and the boron timestep needs to be less than 0.02 s to perform adequately the boron transport behaviour.

2.1 Initial steady state

Next are presented the results for the steady state calculation. The initial K_{eff} is 0.955988. In figure 3.3 the 2D radial power distribution and in figure 3.4 the axial power distribution are shown.

				0.332	0.381	0.476	0.341	0.476	0.381	0.332				
		0.312	0.324	0.836	0.590	0.898	0.528	0.898	0.590	0.836	0.324	0.312		
	0.312	1.046	1.121	0.795	1.495	0.646	1.013	0.646	1.495	0.795	1.121	1.046	0.312	
	0.324	1.121	0.695	2.275	2.588	2.454	0.957	2.454	2.588	2.275	0.695	1.121	0.324	
0.332	0.836	0.795	2.275	2.506	3.221	2.800	2.780	2.800	3.221	2.506	2.275	0.795	0.836	0.332
0.381	0.590	1.495	2.588	3.221	1.393	1.895	1.256	1.895	1.393	3.221	2.588	1.495	0.590	0.381
0.476	0.898	0.646	2.454	2.800	1.895	2.263	2.328	2.263	1.895	2.800	2.454	0.646	0.898	0.476
0.341	0.528	1.013	0.957	2.780	1.256	2.328	1.057	2.328	1.256	2.780	0.957	1.013	0.528	0.341
0.476	0.898	0.646	2.454	2.800	1.895	2.263	2.328	2.263	1.895	2.800	2.454	0.646	0.898	0.476
0.381	0.590	1.495	2.588	3.221	1.393	1.895	1.256	1.895	1.393	3.221	2.588	1.495	0.590	0.381
0.332	0.836	0.795	2.275	2.506	3.221	2.800	2.780	2.800	3.221	2.506	2.275	0.795	0.836	0.332
	0.324	1.121	0.695	2.275	2.588	2.454	0.957	2.454	2.588	2.275	0.695	1.121	0.324	
	0.312	1.046	1.121	0.795	1.495	0.646	1.013	0.646	1.495	0.795	1.121	1.046	0.312	
		0.312	0.324	0.836	0.590	0.898	0.528	0.898	0.590	0.836	0.324	0.312		
				0.332	0.381	0.476	0.341	0.476	0.381	0.332				

Fig. 3.3 2D Radial power distribution

Fig. 3.4 1D axial normalized power distribution (radially averaged)
for the whole core and in central assembly

2.2 Transient calculation for Boron slug 1

The first Boron slug has 18 m^3 size. Regarding to instabilities with the boron transport numerical model, the chosen timestep for the thermal hydraulics and the neutronics is 0.001 s and 0.01 s for the boron transport model. The result presented are referred to the neutronic part as it has not been possible to extract the thermal hydraulic variables form the FLICA4 outputs.

For the boron slug 1 there has been calculated the theoretical boron concentration for the first 5.5 seconds, to make sure that the average trend is kept during the transient, Figure 3.6. As it can be seen in Figure 3.5, the power peak is very small, less than 0.1 MW. It is consistent with the reactivity behaviour, as the reactivity insertion due to the boron dilution is less than 1 $, Figure 3.7

Therefore, it can be concluded that, although the reactor becomes supercritical during the transient, it is not enough to create a big power peak, due to the low reactivity insertion. The dilution is smooth and slow enough to avoid it. **3**

Data	**COBAYA3/FLICA 19 AL**	COBAYA3/FLICA 38 AL
Max. core power [MW]	4.39E-02	1.41E+04
Time of maximum [s]	6.688	5.708
Full width at half maximum [ms]	1004.7	25
Max. 3D power peaking factor [-]	13.1771	13.3599
Position of maximum1	-	-
Time of maximum [s]	5.9704	5.671

Figur 3.5 Slug 1 Neutronic Power (MW)

Figure 3.6 Slug 1 average boron concentration evolution, simulated vs theoretical

Figure 3.7 Slug 1 reactivity evolution

2.3 Transient calculation for Boron slug 2

The second Boron slug has 20 m^3 size. Regarding to instabilities with the boron transport numerical model, the chosen timestep for the thermal hydraulics and the neutronics is 0.0025 s and 0.01 s for the boron transport model. The result presented are referred to the neutronic part as it has not been possible to extract the thermal hydraulic variables form the FLICA4 outputs.

In the second boron dilution, the reactivity peak is quite different, Figure 3.10, the insertion is almost 2 $, and that lead to a power peak of more than 40000 MW before 6 seconds, Figure 3.8. In this case the dilution is quicker, as the boron slug is bigger, Figure 3.8.

Data	**COBAYA3/FLICA**
Max. core power [MW]	4.10E+04
Time of maximum [s]	5.463
Full width at half maximum [ms]	14.75
Max. 3D power peaking factor [-]	13.0304
Position of maximum[1]	-
Time of maximum [s]	5.441

Figure 3.8 Slug 2 Neutronic Power (MW)

Figure 3.9 Slug 2 average boron concentration evolution

Figure 3.10 Slug 2 reactivity evolution

2.4 Transient calculation for Boron slug 3

The third Boron slug has 26 m^3 size. Regarding to instabilities with the boron transport numerical model, the chosen timestep for the thermal hydraulics and the neutronics is 0.0025 s and 0.01 s for the boron transport model. The results presented are referred to the neutronic part as it has not been possible to extract the thermal hydraulic variables form the FLICA4 outputs.

In the third boron dilution transient, the behaviour is quite similar to the second transient, although the difference is bigger that between slug 1 and two. The reactivity insertion is a little bit bigger than in the previous case, and that fact results in a 30% greater power peak, close to 60000 MW.

Data	**COBAYA3/FLICA**
Max. core power [MW]	5.56E+04
Time of maximum [s]	5.757
Full width at half maximum [ms]	12.72
Max. 3D power peaking factor [-]	16.1302
Position of maximum[1]	-
Time of maximum [s]	6.042

Figure 3.11 Neutronic Power (MW)

Figure 3.12 Slug 2 average boron concentration evolution

Figure 3.13 Slug 3 reactivity evolution

3 References

- Jimenez, J., Cuervo D., Kliem S., Mittag, S. (2009), Report specifying the necessary cross sections libraries for the nodal and pin scales by diffusion and transport (SPn) approximations, NURISP deliverable D3.1.2.1, 29p.
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