TWO-WAY-COUPLING USING DYN3D-SP3 AND SUBCHANFLOW

Francisco Javier Chaparro

Nuclear Engineering
School of Physics and Mathematics
National Polytechnic Institute

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PIN LEVEL NEUTRONIC – THERMALHYDRAULIC TWO-WAY-COUPLING USING DYN3D-SP3 AND SUBCHANFLOW

Armando Gómez Torres*, Victor Sánchez Espinoza, and Uwe Imke
Karlsruhe Institute of Technology
Institute for Neutron Physics and Reactor Technology
Hermann-von-Helmholtz-Platz 1, D – 76344 Eggenstein – Leopoldshafen
armando.gomez@kit.edu; uwe.imke@kit.edu

Rafael Macián Juan
Department of Nuclear Engineering
Technical University München
Boltzmannstr. 15, D – 85748 Garching
Rafael.Macian@ntech.mw.tum.de

Aim

- Presenting a new coupled program system DYNSUB developed by coupling DYN3D-SP3 and SUBCHANFLOW codes at pin level.
- The paper summarizes the codes update for the new program.
- DYNSUB was used to analyse stationary PWR mini core problems at the pin-level neutronic-thermalhydraulic.

Overview

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- Computational Tools

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  - DYN3D

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  - Case B

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  - Case B
  - Case C

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  - Case B
  - Case C
- Conclusions

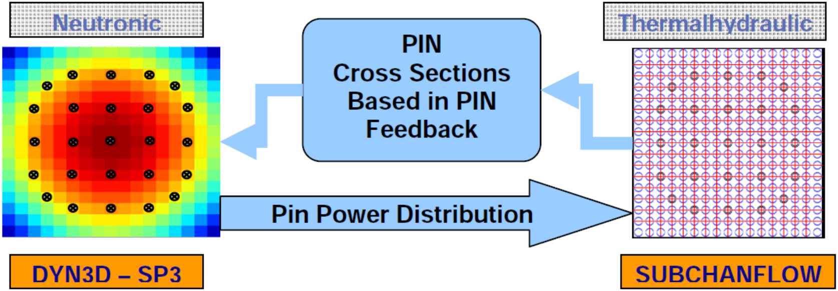
Computational Tools

- DYN3D
  Includes a 3-dimensional neutron kinetics models based on a nodal expansion method for solving the two-group neutron diffusion equation in hex-z or rectangular x,y,z-geometry.
- DYN3D-SP3
  It has a one dimensional thermal hydraulic model to describe the two phase flow and thermal behaviour of fuel rods.
  This code is already validated for stand alone version.

Computational Tools

- SUBCHANFLOW
  The code consist of a three equation two phase flow model a mixture equation for mass, momentum and energy balance.

In DYNSUB, the module DYN3D-SP3 is the master and the slave is SUBCHANFLOW



The radial mapping is: 4 subchannels corresponds to one neutronic node.

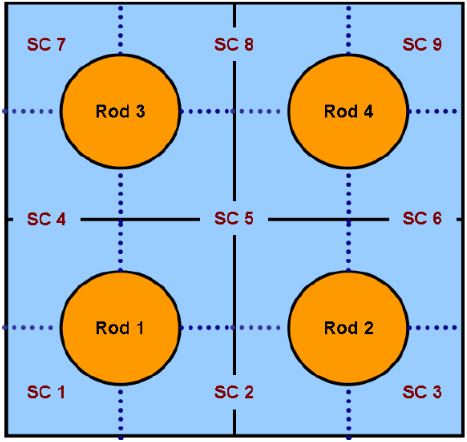


Figure 3. Bundle of 4 fuel rods with 9 subchannels.

Definition of the Test

The cases were based in the "OECD/NEA and U.S. NRC PWR MOX/UO2 core transient Benchmark"

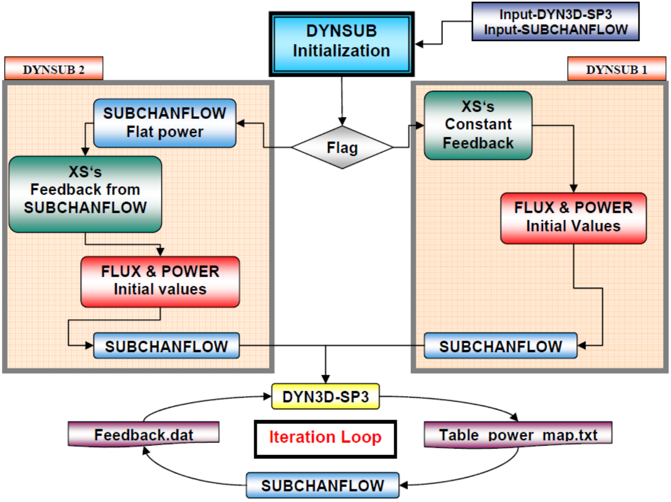
- One assembly UO_2 at 4.50%,
- A minicore 3 x 3, with a central UO_2 - 4.5% assembly and surrounded by 8 MOX - 4.3% assemblies,
- A minicore 5 x 5, based the quarter of the central section of the core.

Definition of the Test

Table II. Operational conditions for the three cases considered.

	Case A	Case B	Case C
Number assemblies	1	9	25
Power level (MWth)	18.47	166.24	461.79
Inlet Temperature (°C)	287	287	287
Core Outlet Pressure (MPa)	15.375	15.375	15.375
Active flow (kg/sec)	82.12124	739.09116	2053.031
Fuel lattice, fuel rods per assembly	17 x 17, 264	17 x 17, 264	17 x 17, 264
Heated length (cm)	3657.6	3657.6	3657.6
Assembly pitch (cm)	21.41	21.41	21.41
Pin pitch (cm)	1.26	1.26	1.26
Radial boundary conditions	$\alpha = 1.0$	$\alpha = 1.0$	$\alpha = 1.0$
Axial boundary conditions	$\alpha = 0.5$	$\alpha = 0.5$	$\alpha = 0.5$
Number of axial nodes	17	17	17

Definition of the Test



Results Case A

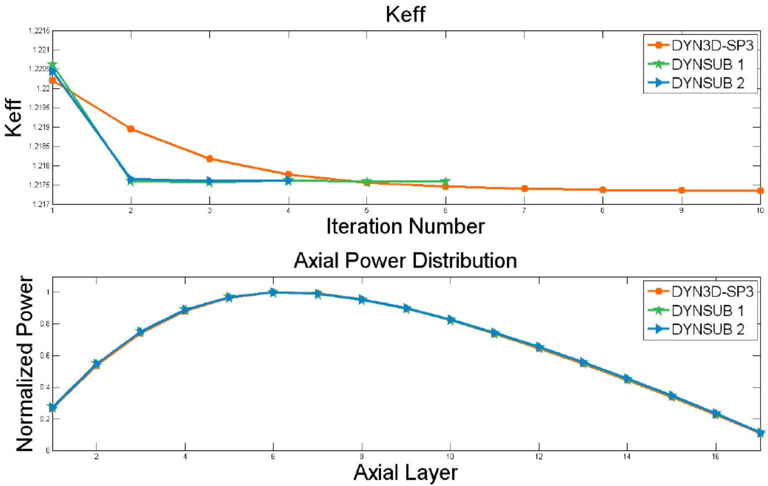


Figure 6. Results for "Case A", upper: Convergence of Keff, lower: Axial Power Profile.

Results Case B

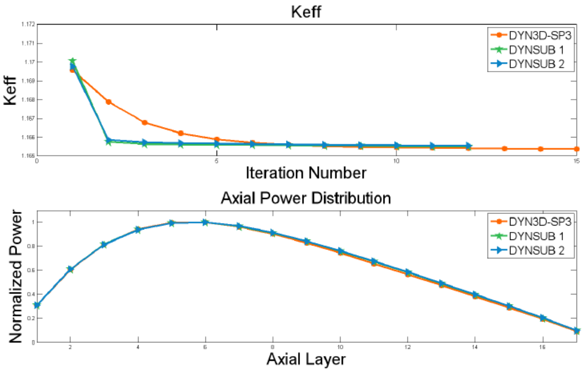
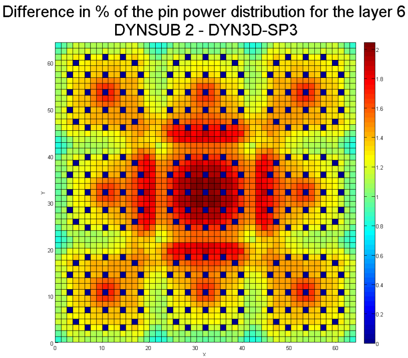


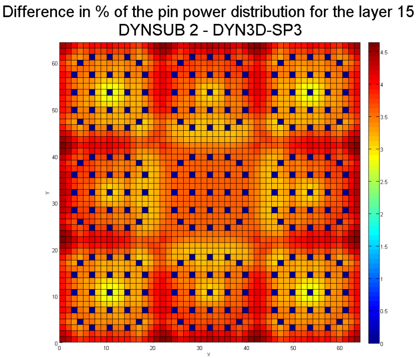
Figure 7. Results for "Case B", upper: Convergence of Keff, lower: Axial Power Profile.

Table IV. Keff, Number of Iterations and Calculation Time for "Case B".

	Keff	pcm	No. Iteration	Relative CPU time
DYN3D-SP3	1.165381	----	15	1.000
DYNSUB 1	1.165520	13.9	12	1.406
DYNSUB 2	1.165552	17.1	12	1.312

Results Case B





Results Case C

	1	2	3	4	5	6	7	8
A	U 4.2% (CR-D) 35.0	U 4.2% 0.15	U 4.2% (CR-A) 22.5	U 4.5% 0.15	U 4.5% (CR-SD) 37.5	M 4.3% 17.5	U 4.5% (CR-C) 0.15	U 4.2% 32.5
B	U 4.2% 0.15	U 4.2% 17.5	U 4.5% 32.5	M 4.0% 22.5	U 4.2% 0.15	U 4.2% (CR-SB) 32.5	M 4.0% 0.15	U 4.5% 17.5
C	U 4.2% (CR-A) 22.5	U 4.5% 32.5	U 4.2% (CR-C) 22.5	U 4.2% 0.15	U 4.2% 22.5	M 4.3% 17.5	U 4.5% (CR-B) 0.15	M 4.3% 35.0
D	U 4.5% 0.15	M 4.0% 22.5	U 4.2% 0.15	M 4.0% 37.5	U 4.2% 0.15	U 4.5% (CR-SC) 20.0	M 4.3% 0.15	U 4.5% 20.0
E	U 4.5% (CR-SD) 37.5	U 4.2% 0.15	U 4.2% 22.5	U 4.2% 0.15	U 4.2% (CR-D) 37.5	U 4.5% 0.15	U 4.2% (CR-SA) 17.5	
F	M 4.3% 17.5	U 4.2% (CR-SB) 32.5	M 4.3% 17.5	U 4.5% (CR-SC) 20.0	U 4.5% 0.15	M 4.3% 0.15	U 4.5% 32.5	
G	U 4.5% (CR-C) 0.15	M 4.0% 0.15	U 4.5% (CR-B) 0.15	M 4.3% 0.15	U 4.2% (CR-SA) 17.5	U 4.5% 32.5		
H	U 4.2% 32.5	U 4.5% 17.5	M 4.3% 35.0	U 4.5% 20.0				

Assembly Type
CR Position
Burnup [GWd/t]

Fresh
Once Burn
Twice Burn

Results Case C

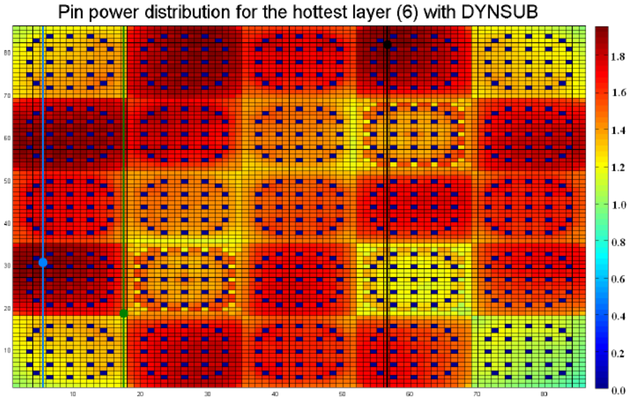


Figure 11. Normalized Pin Power Distribution for the hottest layer with DYNSUB 1 for "Case C".

Conclusions

- DYNSUB is a new tool with a two-way-coupling methodology ready for steady state calculations.
- For the three cases, the behaviour of DYNSUB in steady state is in agreement with the results coming from the already validated stand alone version of DYN3D-SP3.
- Larger deviations emerged when comparing the temperature profiles of particular pins against the averaged values coming from DYN3D-SP3.
- The differences in axial temperature profile may be significant when a transient is investigated.
- At least in the steady state, the effect of cross flow implies not too much deviation.