CANDU-SCWR Coupling Toolset (DONJON5 - CATHENA3)

Technical presentation

Ulysse Le Tennier

Génie énergétique et nucléaire
Polytechnique Montréal

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Summary

Introduction

Coupling Inputs

Coupling manuals

Coupling archives

CANDU-SCWR

The canadian proposition for SCWR reactors (Generation IV)

- Coolant : subcritical light water that crosses the supercritical point along its course
- Several design adjustments proposed since 2015
- Coupled calculations between CATHENA3 and DONJON5 for the CANDU-SCWR safety analysis never performed before

Neutronic thermalhydraulic coupling necessity

The transition from subcritical to supercritical happens in the fuel channels.

The location of the density drop in each channel must be accurately located.

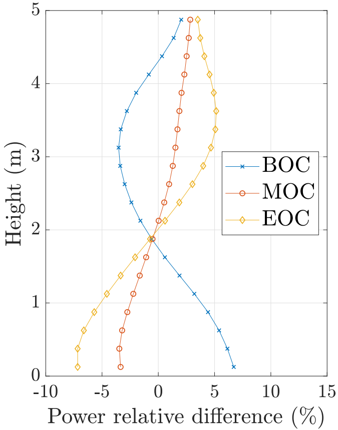

Figure: Axial power for BOC, MOC and EOC when coupling takes place

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Coupling Inputs
- CATHENA input
- Coupling main and procedures
- Data treatment

Coupling manuals
- IGE-379
- CSCT-D5C3 User's Manual

Coupling archives

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Geometry : hydraulic network

- Only 84 fuel channels declared
- Each channel accounts for 4 (symmetries)
- 20 nodes for flow tube and fuel channel

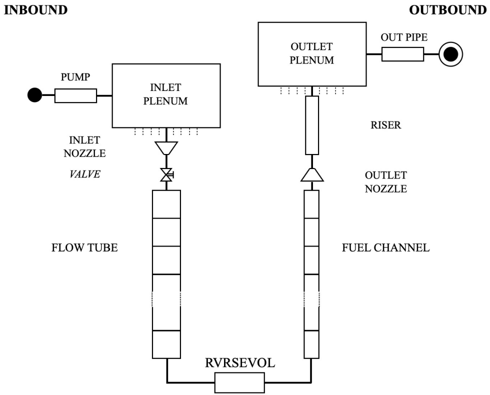

Figure: CATHENA hydraulic network

Geometry : thermal models

- Four thermal models
- 0.8 MPa total pressure drop
- An arbitrary share of power between inner (48.1%) and outer rods (51.9%)

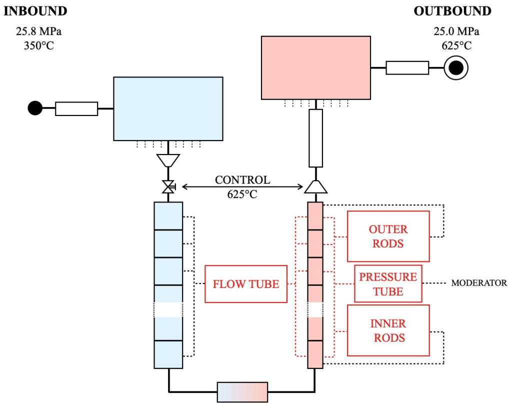

Figure: CATHENA thermal models

Coupling marks

Two constraints on the CATHENA input :

- Coupling marks to be replaced
- Consistent set of outputs

```
'*------------------------------------------------------------------------'/
'SOLUTION CONTROL'/
0.00,HERE00, , 1.00E-06, 1.00E-06, 1.00E-01/
```

```
'* CHANNEL1' /
'INNOZ1', 'BY-ENDS', 'HG-BY-SAT', 'HF-BY-TEMP'/
2.580E+07, , 350.00, 0.00, HEREMFL1/
2.580E+07, , 350.00, 0.00, HEREMFL1/
'*------------------------------------------------------------------------'/
'FLOWTB1', 'BY-ENDS', 'HG-BY-SAT', 'HF-BY-TEMP'/
2.580E+07, , 350.00, 0.00, HEREMFL1/
2.580E+07, , 350.00, 0.00, HEREMFL1/
'*------------------------------------------------------------------------'/
'RVVOL1', 'BY-ENDS', 'HG-BY-SAT', 'HF-BY-TEMP'/
2.580E+07, , 350.00, 0.00, HEREMFL1/
2.580E+07, , 350.00, 0.00, HEREMFL1/
```

```
'STAINLESS STEEL'/
HERE1IN
'HQ-NIL'/
'HQ-NIL'/
'TEMP-2D-RAD-AXI'/
687.0, 687.0, 687.0, 687.0, 687.0, 687.0/
687.0, 687.0, 687.0, 687.0, 687.0, 687.0/
```

Figure: CATHENA input coupling marks

Input generation

Seven python functions are provided :

- One aggregating function
- Six group functions

The aggregating function relies on the group functions

The group functions declare the groups required by CATHENA
They cope with the coupling constraints

Equilibrium calculation

Before coupling, an initial burnup distribution which is independent of the cycle is needed.

Two solutions :

- Provide the good distribution (6720 values)
- Perform enough consecutive cycles to reach equilibrium

Equilibrium functions find the burnup distribution and create DONJON inputs required by the coupling program

Coupling directories architecture

The coupling program requires a strict directories architecture

- Stores
- Executables

The subdirectories CA, DJ and PY contain templates, data or procedures. They are referred as stores. Detailed information is available in IGE-379

```
EXEC_DIRECTORY
  ├─ CA
  ├─ DJ
  ├─ PY
  ├─ DISTRIBUTION
  ├─ donjon.exe
  ├─ cat3_6_1_1-b01.exe
  └─ rdonjon5.bat
```

Figure: Directories architecture

Coupling general principles

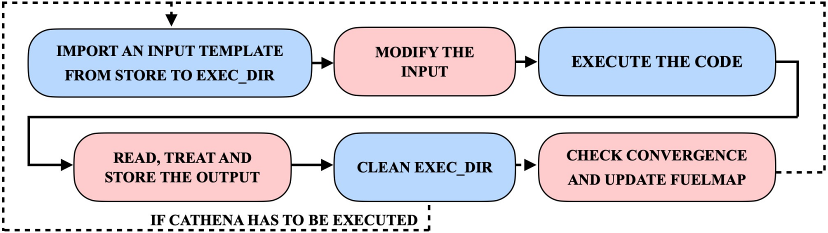

Figure: Coupling program's way to operate

Coupling data structures

	Cpl. thermalhydraulic parameters	Non-cpl. thermalhydraulic parameters	Power/Burnup distribution	Critical boron	Execution variables
numpy array	X (two latest solutions)	X (two latest solutions)			
FUELMAP			X		
HISTORY				X	X
.txt file (DISTRIBUTION)	X (latest cycle's solutions)	X (latest cycle's solutions)			
Python output string	X	X			

Figure: Data dispatching among data structures

Cpl thermalhydraulic parameters :
coolant densities, temperature, fuel temperature and mass flow

HISTORY structure

DONJON uses specific variables to manage reloading, to burn fuel... Those are stored in HISTORY

- Python main program reads Step variable
- Passes it to DONJON input
- DONJON reads variables in HISTORY at Step

  - Few variables to pass from python to DONJON
  - One fundamental variable, Step
  - All the variables are saved in a file, not in python variables

Restart coupling

To restart the coupling after the program stopped :

- Correct potential errors
- Clean the execution directory from inputs/outputs
- Retrieve the latest value of Step in HISTORY (DJ dir.)
- Call the main program at the latest Step value

When stopped, python output strings are lost

The latest cycle's solution is available in DISTRIBUTION dir.

Data treatment principles

Data treatment :

- Recovers 3D data
- Unfolds data
- Builds a 3D matrix consistent with the physical geometry
- Plot heatmaps (if necessary)

It is assumed that, from this basis, additional data treatment programs are easy to create.

Data treatment functions

Two files are provided TreatMaps.py and TreatMapMFlw.py :

TreatMaps.py contains one function to read power distribution (FMAP), one to read python output strings other than mass flow and one to plot heatmaps

TreatMapMFlw.py contains a function to read mass flow distributions and one to plot heatmaps

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IGE-379 overview

IGE-379 is available on GitHub (click), it introduces :

- Core geometries
- General principles to use the coupling program
- Data treatment principles
- CATHENA input generation functions

IGE-379 most valuable informations

This manual should be used :

- To get familiar with the core geometries
- To get familiar with the main program algorithm
- To have insights on convergence feature
- To modify CATHENA input

CATHENA and DONJON user's manual are cited. They are a valuable support to modify the input of each code.

CSCT-D5C3 User's Manual overview

CSCT-D5C3 User's Manual is available at GitHub (click), for each function, it provides :

- A general and technical description
- Input and output
- Websites for eventual support (seaborn heatmaps)

The way the functions are chained is not explicitly described

CSCT-D5C3 User's Manual most valuable informations

This manual should be used :

- To understand technical aspects of the main program
- To modify accurately the coupling program
- To modify CATHENA input generation functions

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Databases

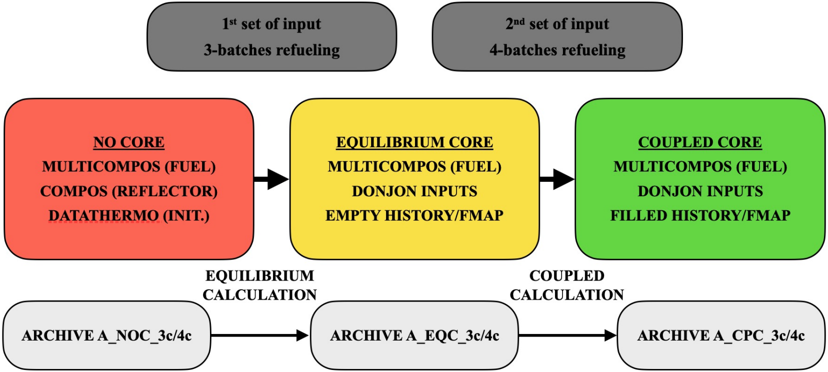

Figure: Different archives available, if asked, at letennier.u@gmail.com