Thermomechanical Model developed for the Pebble Bed Assembly applied to other Pebble Bed Mock-Up Tests

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Contents

• thermomechanical pebble bed model
• application to HCPB in-pile test element
• results HELICA analyses
• next steps
Thermomechanical Pebble Bed Model (1)

- reliable temperature prediction
  - feasibility in-pile test module
  - determination test matrix

- engineering tool
  - lay-out in-pile test module
  - determination of gas gap dimensions
  - determination of pre-compaction procedure
  - safety evaluation
• describe observed behaviour
  - *non-linear elasticity*
  - *initial compaction behaviour*
  - *creep compaction behaviour*
  - *strain dependent thermal conductivity of pebble bed*

• based on available test data
  - *oedometer experiments*
Thermomechnical Pebble Bed Model (3)
HCPB In-Pile Test Element

Cooling water

#1: OSi - 650°C
#2: MTi - 850°C
#3: MTi - 850°C
#4: OSi - 850°C

Eurofer containment

Beryllium #1

Beryllium #2

Breeder

Pressure lid

Gas tight lid

Thermal barrier

Pressure ring

AISI 316L containment
HCPB In-Pile Test Element
HELICA Geometry and FE-model

- T91
- Stainless steel
- Orthosilicate pebbles
- Inconel
- Kanthal
- Soft gasket

3277 elements
3144 nodal points
HELICA Thermal boundary conditions (1)

$h = 10 \text{ W/m}^2\text{K} \quad T_{\text{sink}} = 20^\circ\text{C}$

$h = 145 \text{ W/m}^2\text{K} \quad T_{\text{sink}} = 250^\circ\text{C}$
HELICA Thermal boundary condition (2)

$h = 84 \text{ W/m}^2\text{K}$  \hspace{1cm} $T_{\text{sink}} = 250^\circ\text{C}$
HELICA Mechanical boundary conditions
HELICA Loading conditions

Schnorr springs (p = 0.09 MPa)
HELICA Summary of analysis

- thermomechanical model for pebble bed
  - non-linear elasticity
  - initial compaction
  - creep compaction

- generalized plane strain

- MSC.Marc Version 2005

- gap development at interfaces pebble bed - solids

- heat transfer through gaps by purge gas conduction

- analysis of complete loading cycles
HELICA TC-positions (1)
HELICA Results (1)

HELICA (tc 155 mm)

HELICA (tc 105 mm)

HELICA (tc 060 mm)
HELICA Results (2)
HELICA Results (3)
HELICA Results (4)

HELICA (tc 155 mm)

HELICA (tc 105 mm)

HELICA (tc 060 mm)
HELICA Results (5)

mean initial compaction strain
HELICA Results (6)
HELICA Results (7)

mean creep compaction strain
HELICA Results (8)
HELICA Results (9)

mean total compaction strain

Inc:    76250
Time:   5.760e+04
HELICA Results (10)

gap development after cooldown
HELICA Results (11)
HELICA Next steps

- comparison calculated results with TC measurements
- comparison calculated results with deformation measurements
- optimisation of boundary conditions
- improvement of thermomechanical pebble bed model