Czech Technical University in Prague
Faculty of Mechanical Engineering

COOLANT MIXING IN THE VVER-440 FUEL ASSEMBLY HEAD

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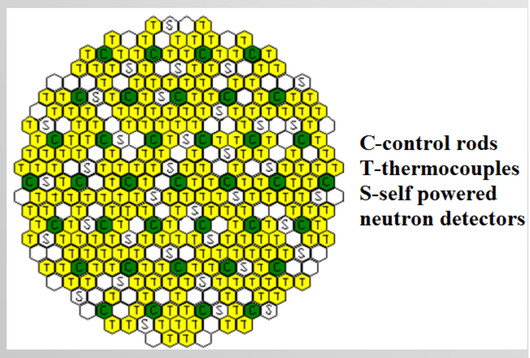
Introduction

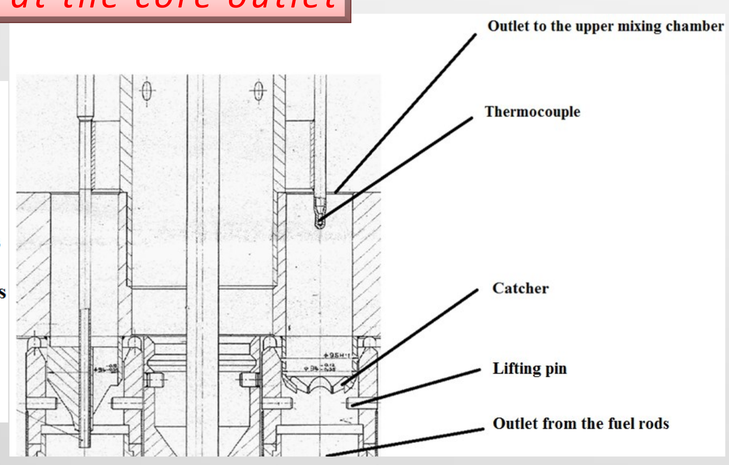
- Studying behavior of coolant flow in the fuel assembly head
- Possible occurrence of deviations between the signal from the thermocouple and the actual average temperature at the outlet of the assembly head (imperfect mixing of coolant)
- Creating computational grid of the fuel assembly outlet
- Thermohydraulic CFD calculation focused on field of coolant temperature
- Comparison of the calculated, measured values and values calculated from previously performed simulations

Temperatures measuring at the core outlet

•210 thermocouples



Pic.: *Cut of the core*



Pic.: *Distributions of components*

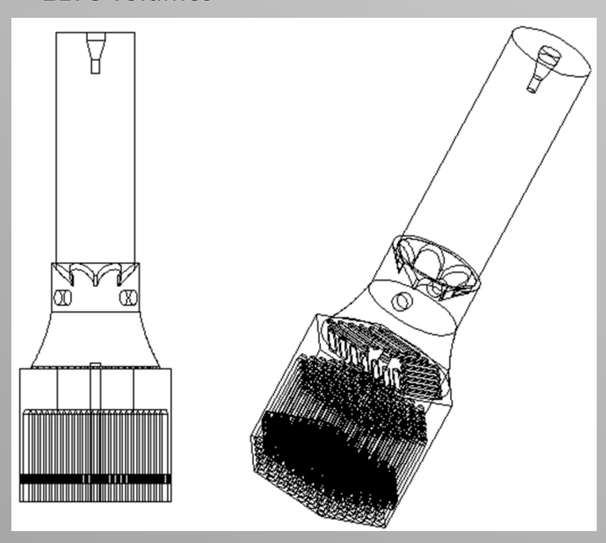
Simulation focused on mixing flow in the assembly head

- Atomic Energy Research International Symposium in Bulgaria 2009

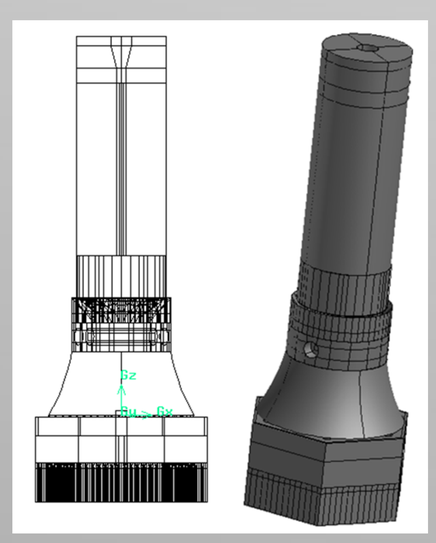
-7 institutions (BME, ÚJV Řež, VUJE, FORTUM, AEKI, GIDROPRES, ŠKODA JS)
-Comparison of the calculated data and prove imperfect mixing of coolant
-Source geometry (step file) and input data for all participants were identical
- Construction of computational models and calculation settings were different
- Consideration of effects from the central flow tube

Creation of the model geometry and computational grid

- Source geometry: step file from AER symposium
- Used preprocessor code: GAMBIT 2.4.6
- Segmentation model to six parts: inlet, above inlet, mixing grid and the surrounding parts, the area around the lifting pins, catcher, outlet
- Segmentation parts to volumes (application of hexahedral cells and grid quality)
- 2178 volumes



Pic.: *Step file*



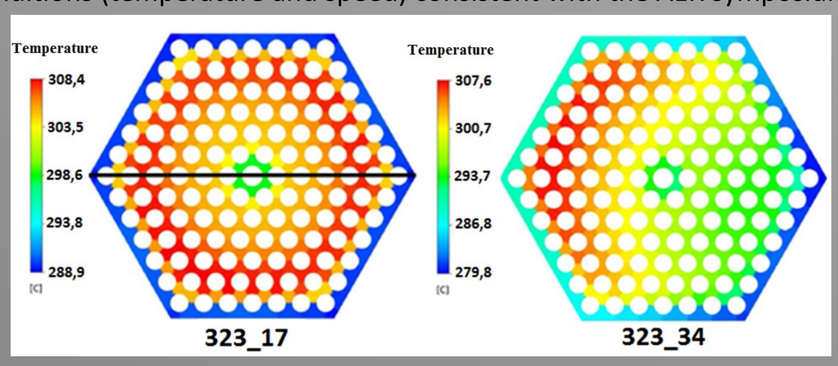
Pic.: *Computational model*

- Modifications:
  - –Reducing lenght of the input section (neglecting the influence of spacer grids)
  - –Excesion of cather solid geometry
- Mesh summary:
  - 13 214 013 hexahedral cells
  - controlled mesch quality using a set of boundary layers and setting on the edges of volumes
  - 520 cells Equi-size skew (0,75 - 0,819) = 0,004% of the total number

Thermohydraulical CFD calculation

- Used CFD code: ANSYS FLUENT 14.5
- Stationary calculation
- Solved two cases
  - 323_17 = internal assembly
  - 323_34 = peripheral assembly

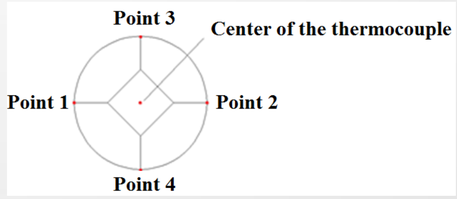
The initial conditions (temperature and speed) consistent with the AER symposium



Pic.: *Inlet temperature field*

- Consideration of flow from the the central tube
- Realizable k-ε turbulent model, standart wall function, set discretization schemes for second-order accuracy
- Every case that had been solved had approximately 10 000 iterations and was solved by eight processors INTEL XEON SGI ALTIX 320, RAM 24 GB over 300 hours.

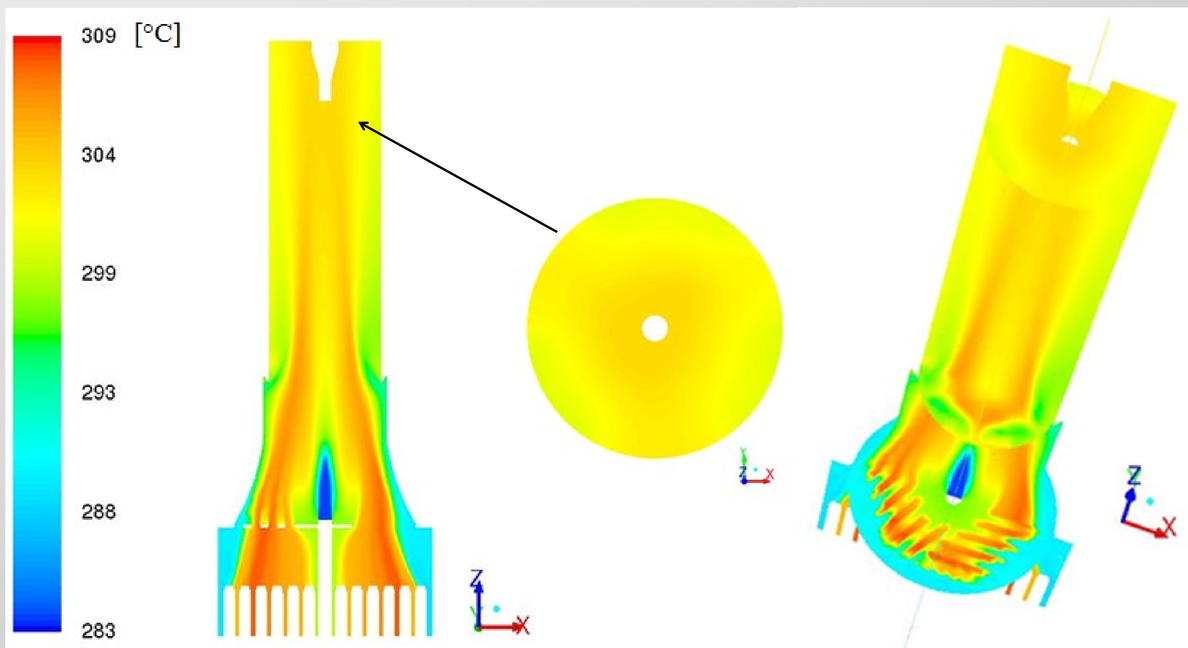
- For both cases selected reference iterations (closest to the average of 10 selected iterations):
  - 323_17 - iteration 9500 , 323_34 – iteration 10850
- Monitoring the average temperature of the thermocouple from 5 points



Pic.: *Five monitoring points at the thermocouple*

Results

323_17

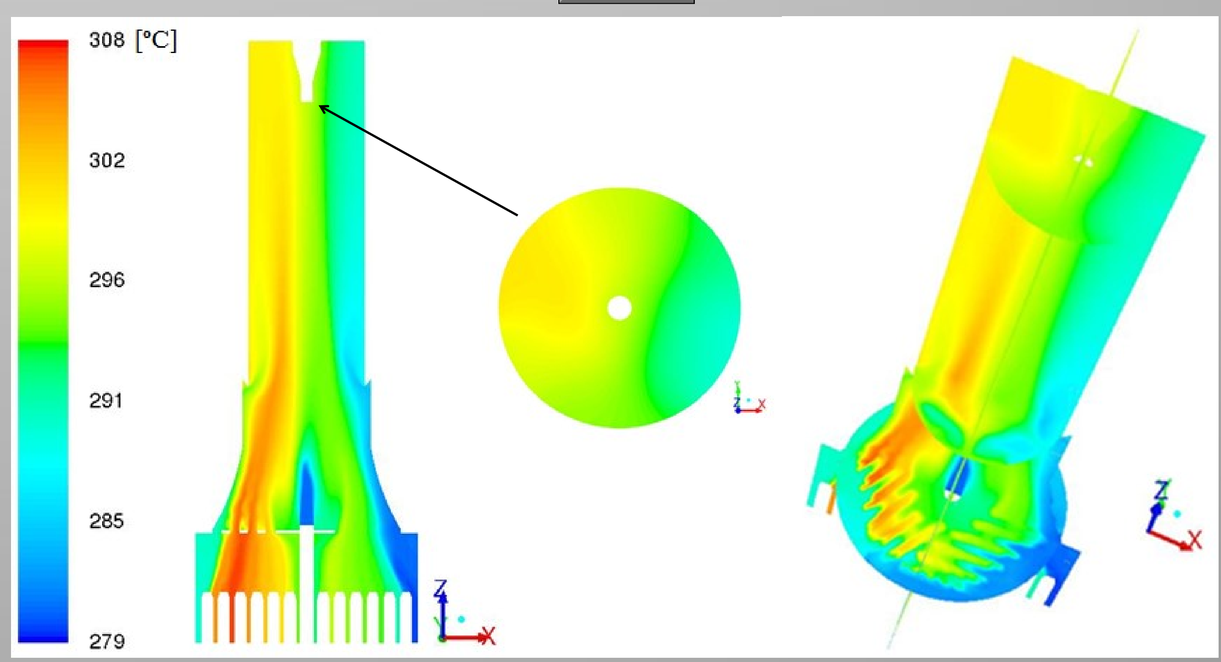


Pic.: *Distribution of temperature field, case 323_17*

	T_{OUT} [°C]	T_{TC}[°C]	T_{TC}-$T_{TC\ M}$[°C]	T_{TC}-T_{OUT}[°C]
Calculation	301,69	303,13	-0,17	1,44
Measuring	-	303,3	-	-

T_{OUT} … average temperature of the coolant at the outlet
T_{TC} … calculated signal at the thermocouple
$T_{TC\ M}$ … measured signal at the thermocouple

323_34



Pic.: *Distribution of temperature field, case 323_34*

	T_{OUT} [°C]	T_{TC}[°C]	T_{TC}-$T_{TC\ M}$[°C]	T_{TC}-T_{OUT}[°C]
Calculation	295,88	296,66	-0,14	0,78
Measuring	-	296,8	-	-

Conclusion

- Unsteady effects over mixing grid , but insignificant effect on the thermocouple measuring
- Coolant mixing in the fuel assembly head is imperfect, diverse temperature profile at outlet

Comparison table of results

323_17			323_34		
	T_{TC}[°C]	T_{TC}-$T_{TC\ M}$[°C]		T_{TC}[°C]	T_{TC}-$T_{TC\ M}$[°C]
Measuring	303,3	-	Measuring	296,8	-
BME	303,3	0	BME	296,9	0,1
Calculation	303,13	-0,17	Calculation	296,66	-0,14
VUJE	303,5	0,2	ÚJV Řež	297	0,2
ÚJV Řež	302,9	-0,4	FORTUM	296,6	-0,2
FORTUM	303,9	0,6	AEKI	296,5	-0,3
AEKI	302,4	-0,9	VUJE	297,5	0,7
GIDROPRES	301,9	-1,4	GIDROPRES	295,8	-1
ŠKODA JS	300,3	-3	ŠKODA JS	294,2	-2,6

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