Validation of STAR-CCM+ with the OECD/NEA T-Junction Blind Benchmark

Santhosh Jayaraju
Ed Komen
Emilio Baglietto

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Introduction

What is thermal fatigue?

» Degradation mechanism induced on primary piping system of a NPP.

How important is this problem?

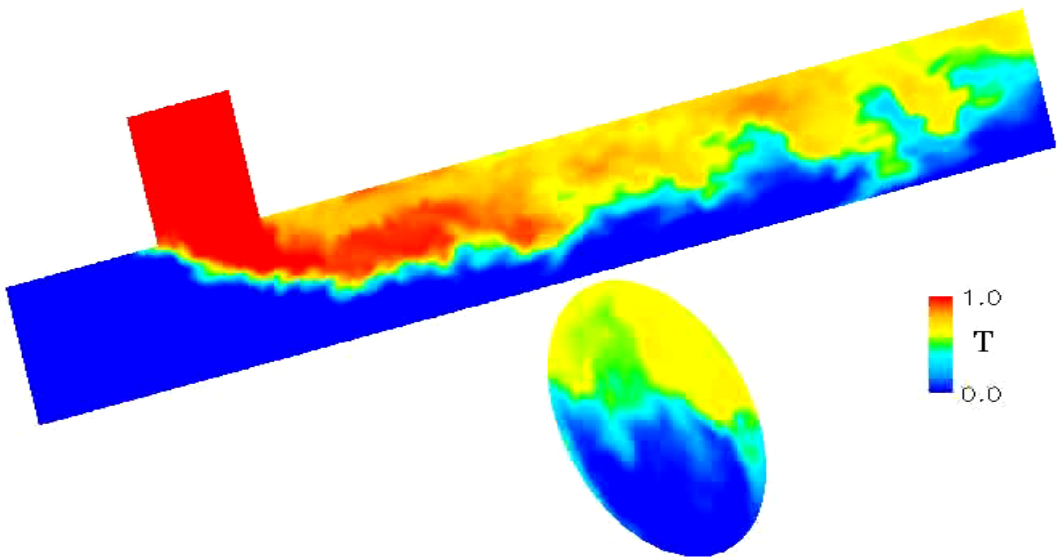
» Complete shut-down of French PWR Civaux in 1998.

» Occured in Japanese PWR Tsuruga-2 in 1999 & Tomari-3 in 2003.

Thermal Fatigue is seen as one of the most influential parameter affecting ageing and life management of NPP's.

Introduction

What causes thermal fatigue?



Mixing of hot & cold streams causes temperatature fluctuations next to piping walls resulting in thermal fatigue.

OECD/NEA BLIND BENCHMARK

OBJECTIVE

Test the capabilities of state of the art CFD codes in accurately predicting important parameters affecting thermal fatigue

OECD/NEA BLIND BENCHMARK

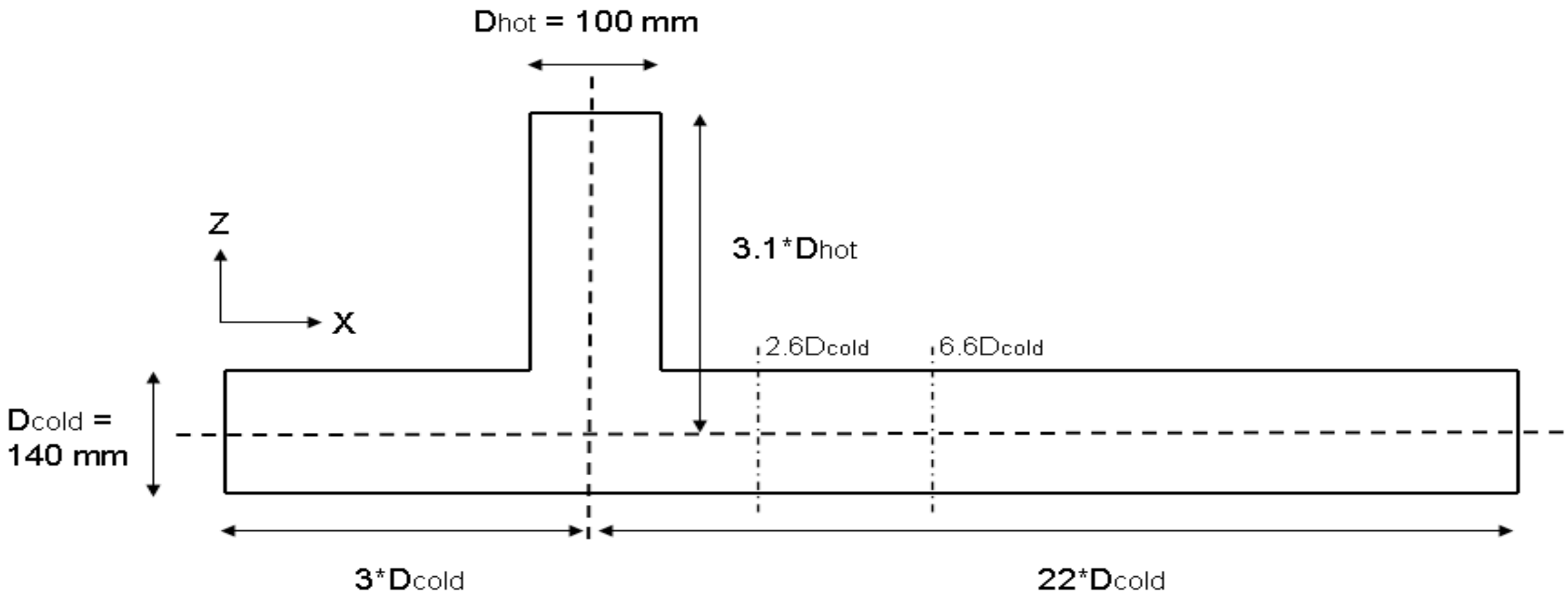
29 International participants

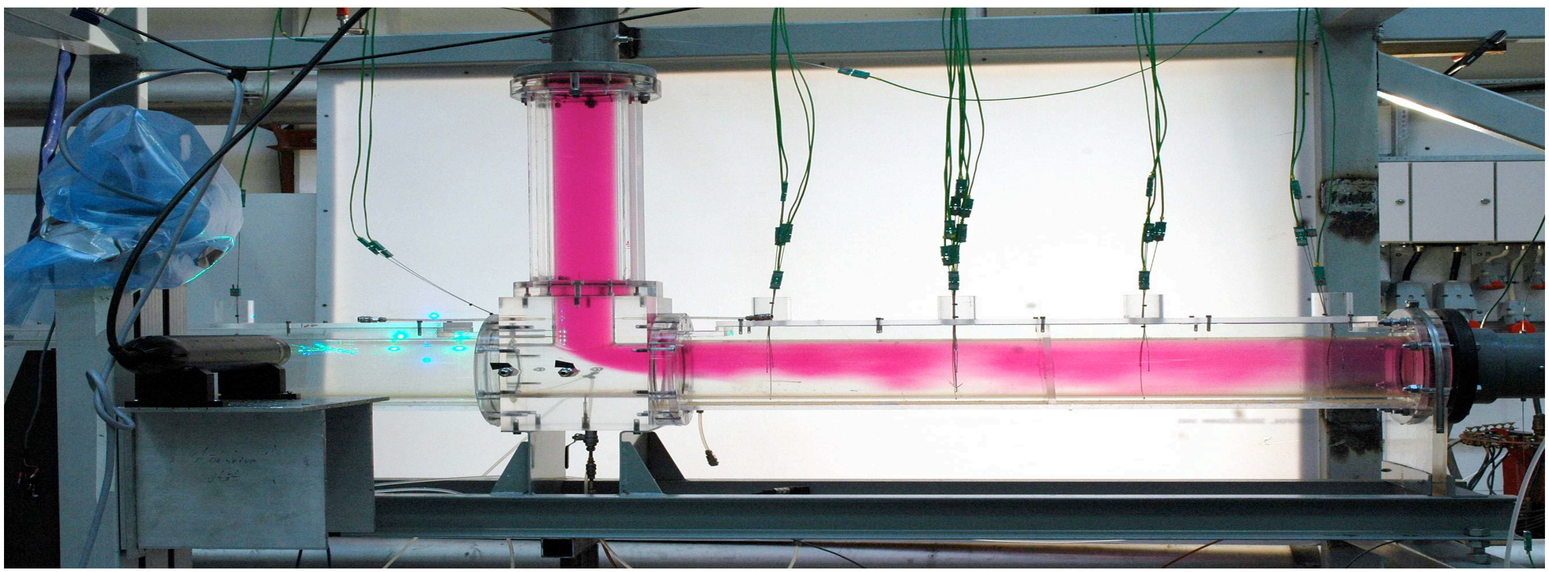
Belgium	1	Germany	4	Netherlands	1	Sweden	6
Canada	2	Greece	1	Nigeria	1	Switzerland	7
Czech Republic	1	Hungary	2	Russia	4	Turkey	1
Egypt	1	Italy	3	Slovakia	1	USA	6
Finland	3	Japan	6	South Africa	1		
France	8	S. Korea	2	Spain	3		

OECD/NEA BLIND BENCHMARK

- *Only inlet boundary conditions were provided*
- *Data at various measuring stations downstream of mixing t-junction were requested*
- *FLUENT - 8; CFX - 7; STAR-CCM - 4; OpenFoam - 2*
- *LES – 19; DES – 3; RANS - Rest*
- *Mesh sizes ranged from 0.28M to 70.5M*

Computational domain



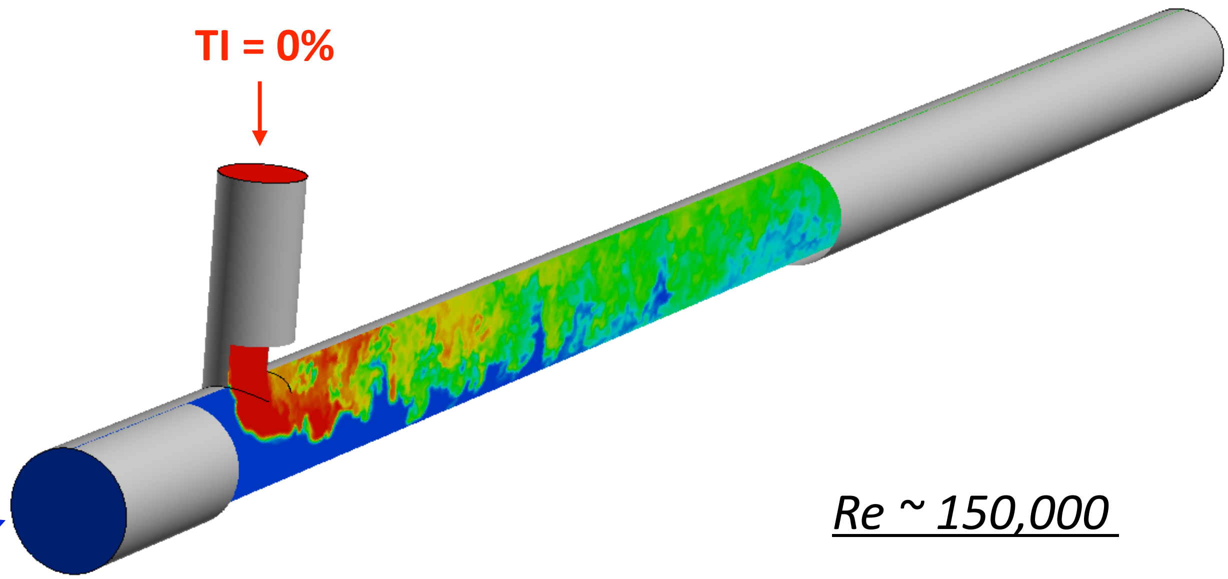


BOUNDARY CONDITIONS

Q_{hot} = 6 l/s

T_{hot} = 36 C

TI = 0%



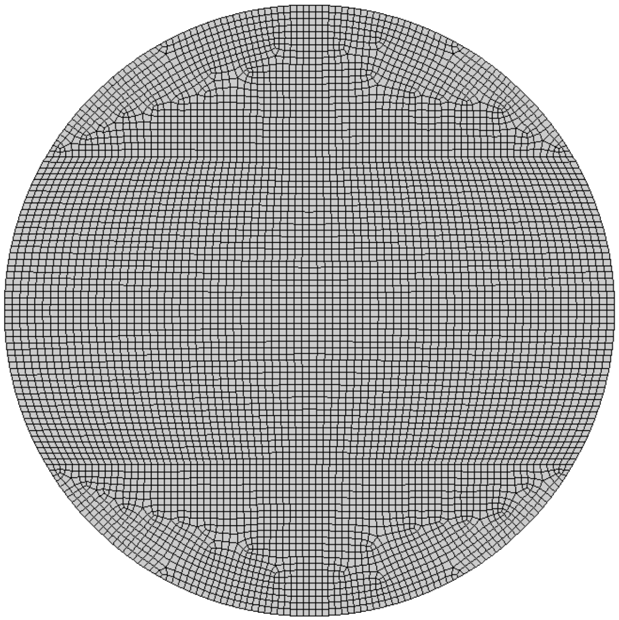
Q_{cold} = 9 l/s

T_{cold} = 19 C

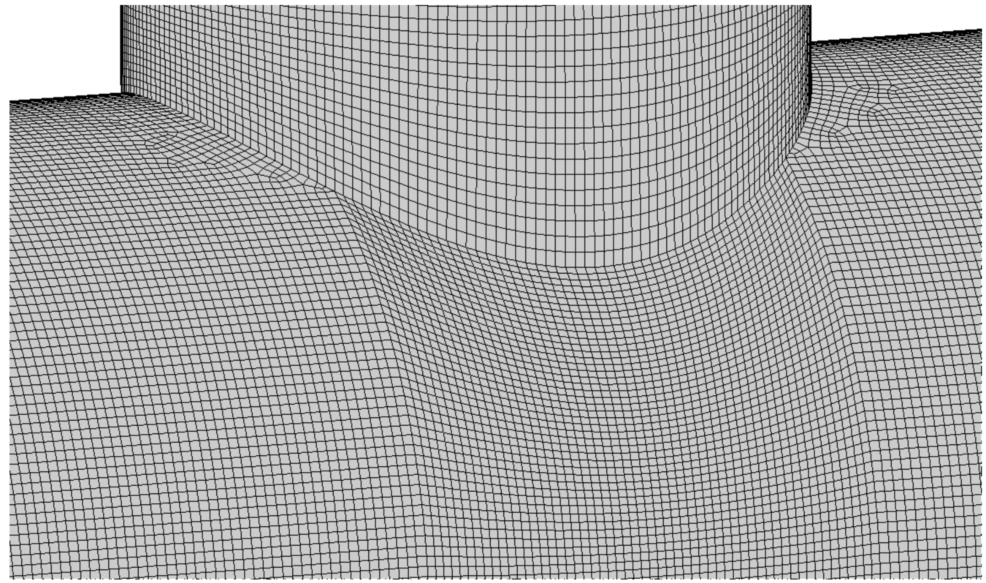
TI = 0%

Re ~ 150,000

Computational Grid



Inlet



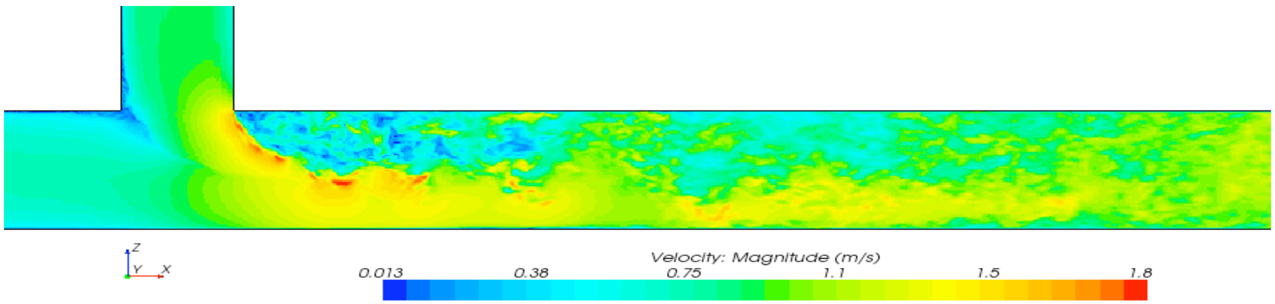
T-Junction

- *Mesh type:* Hex
- *Mesh size:* 13.22 million

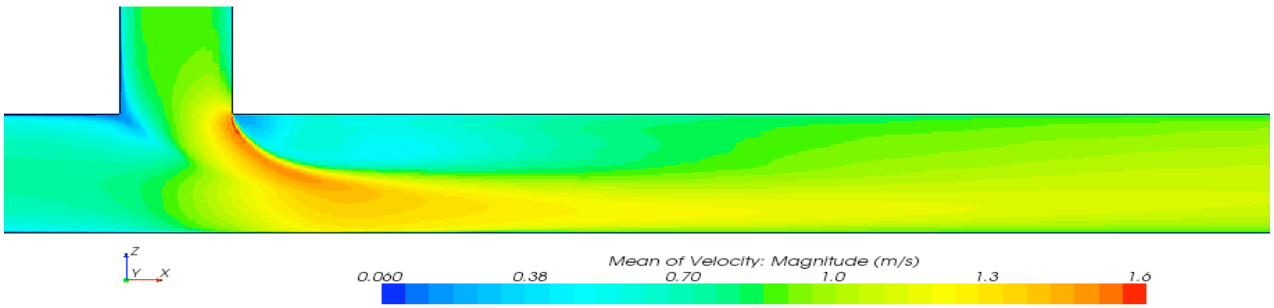
Numerical Approach

- *Turbulence model:* Large Eddy Simulation
- *SGS model:* WALE
- *Wall treatment:* Wall-function approach
- *Spatial discretization:* Bounded central (upwind blending factor: 0.1)
- *Temporal discretization:* 2nd order implicit

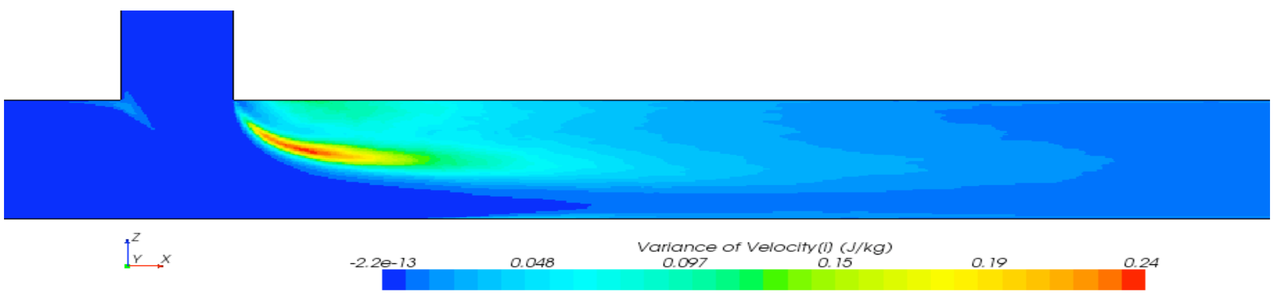
Results



Instantaneous velocity

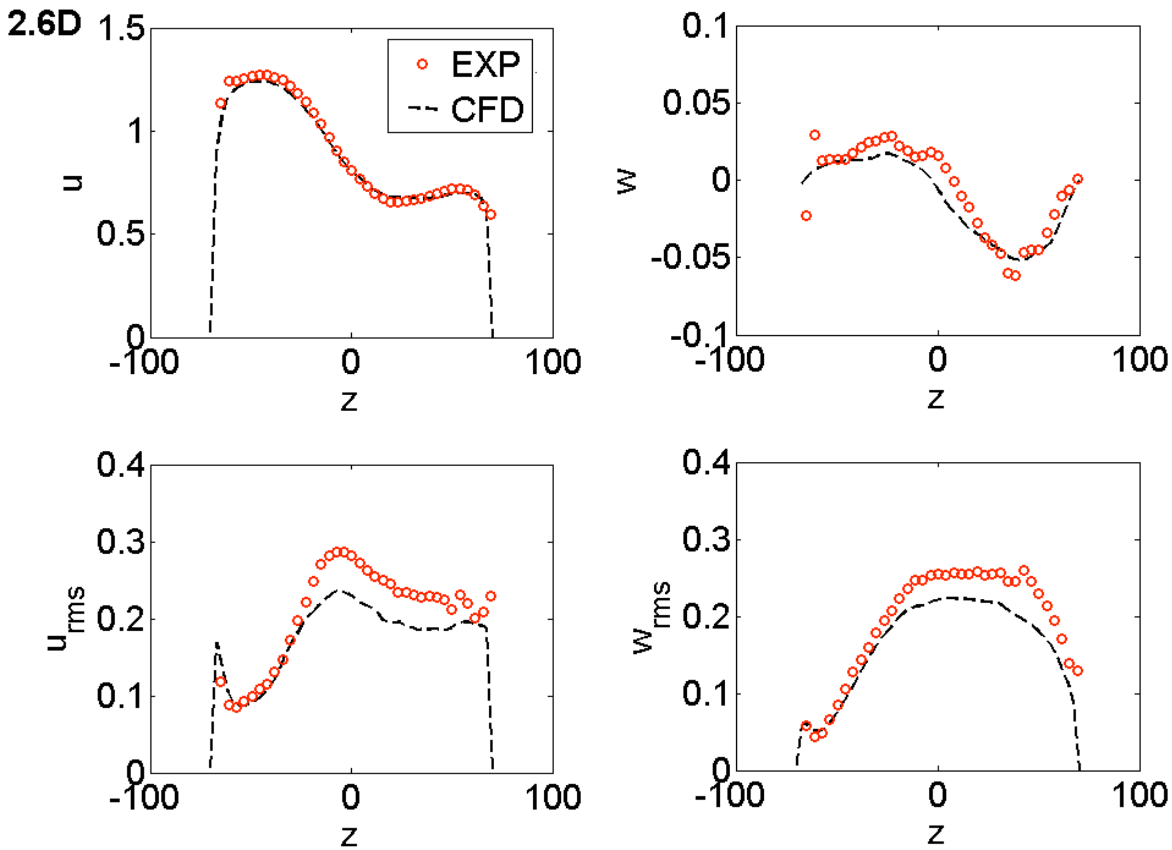


Time averaged velocity



RMS velocity

Results



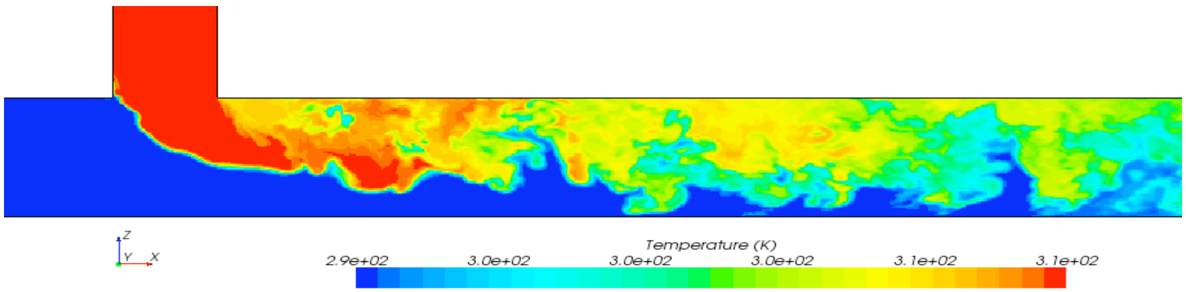
Mean & RMS velocities at 2.6 diameters downstream of mixing zone

Results

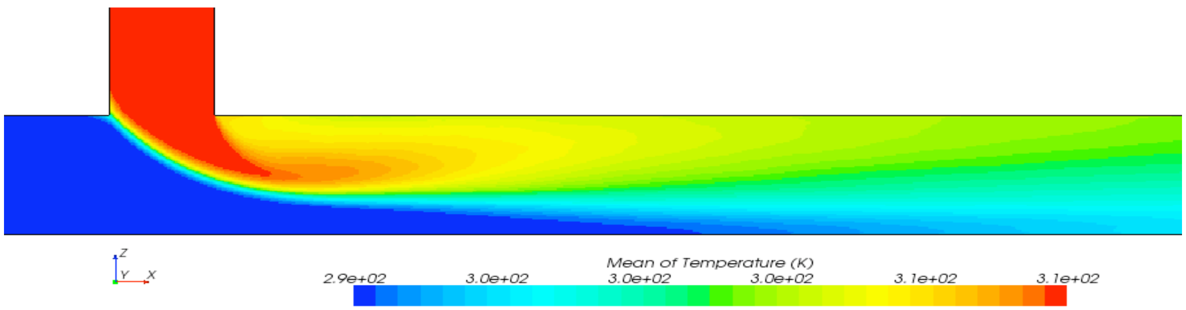
Mean & RMS Velocity Ranking

Ranking	***Code***	***Turb model***	***Mesh size***
1	FLUENT	LES, Dynamic Smagornisky	70.5M
2	FLUENT	LES, Dynamic Smagornisky	34M
3	STAR-CCM+	LES, WALE	13.2M
4	FLUENT	LES, Dynamic Smagornisky	5.8M
5	OpenFoam	LES, Dynamic Smagornisky	8M

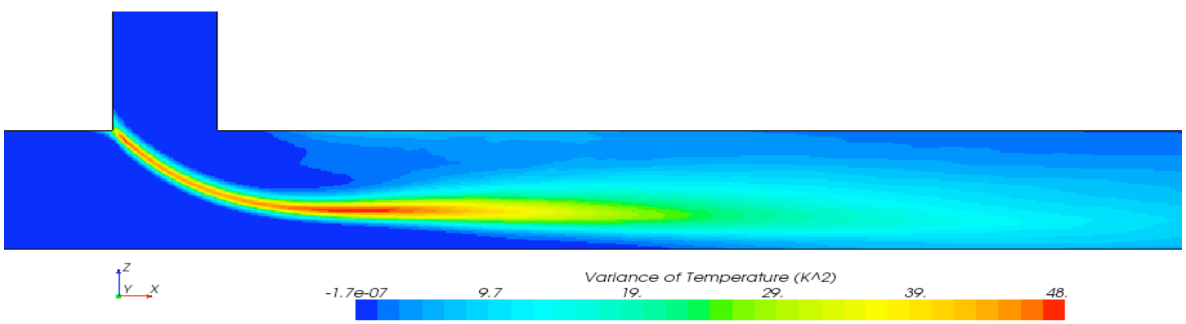
Results



Instantaneous temperature

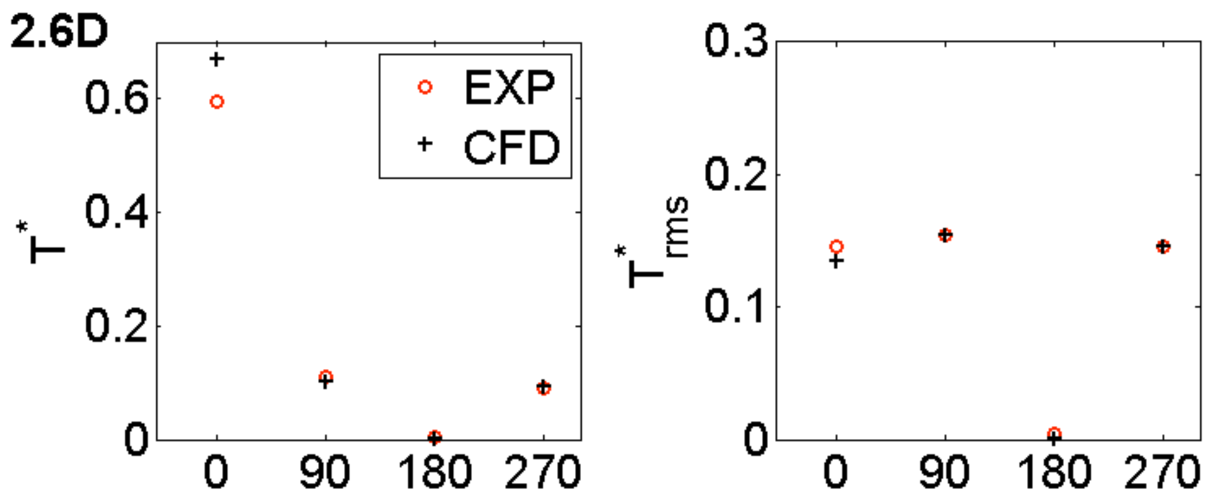


Time averaged temperature

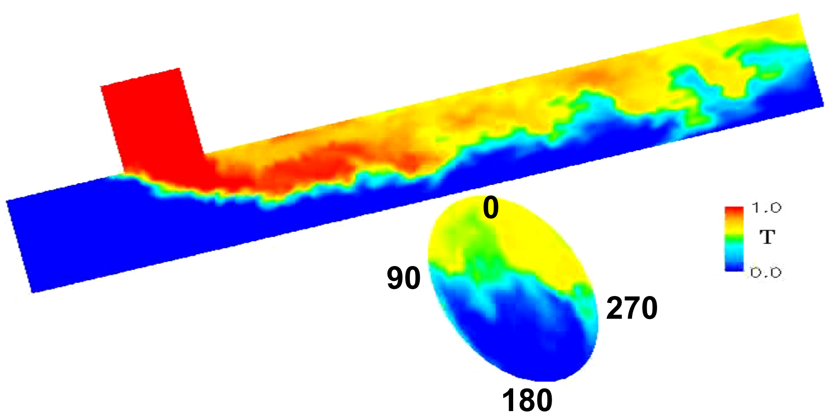


RMS temperature

Results



Mean & RMS temperatures at 2.6 diameters downstream of mixing zone



Results

Mean & RMS Temperature Ranking

Points	***Code***	***Turb model***	***Mesh size***
1	NEK5000	LES, Spectral Damping	21M
2	FLUENT	LES, WALE	7.7M
3	STAR-CCM+	LES, WALE	13.2M
4	FLUENT	LES, Dynamic Smagornisky	5.8M
5	STAR-CCM+	LES	4.4M

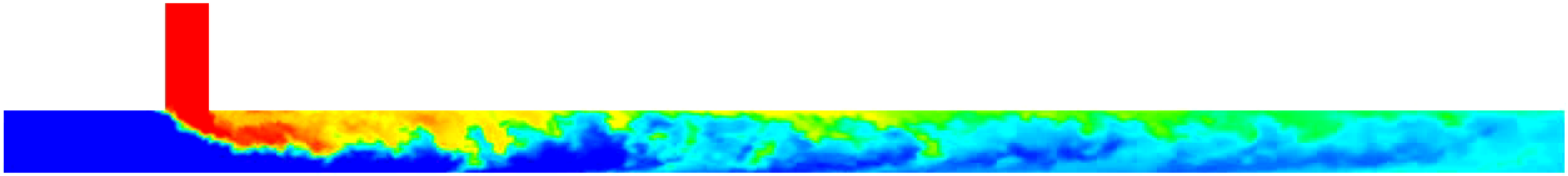
Results

Total Ranking

Ranking	*Code*	*Turb model*	*Mesh size*
1	FLUENT	LES, Dynamic Smagornisky	70.5M
2	STAR-CCM+	LES, WALE	13.2M
3	FLUENT	LES, Dynamic Smagornisky	5.8M
4	FLUENT	LES, Dynamic Smagornisky	34M
5	NEK5000	LES, Spectra damping	21M

Conclusions

- Generally good agreement between experiments and LES predictions.
- LES is very much suitable for thermal fatigue predictions.
- For the overall velocity and temperature predictions, STAR-CCM+ was ranked 2nd among 29 international participants.
- Given the mesh size difference between 1st and 2nd ranked participants, we as a user of STAR-CCM+ are very pleased with its capabilities.



Thank you!!