Institute for Neutron Physics and Reactor Technology
Plant Development,System Dynamic and Safety

Experimental Investigation of heat transfer enhancement for innovative gas cooled systems

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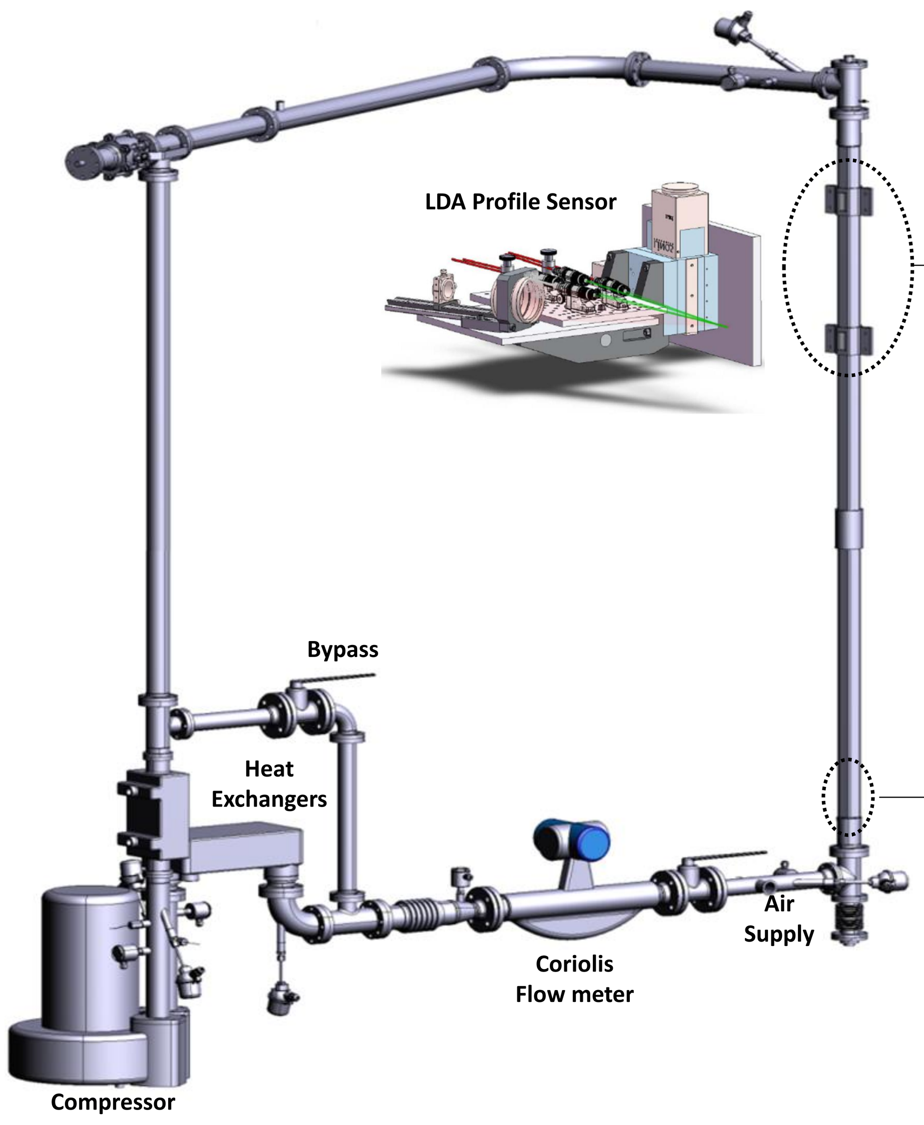
MOTIVATION

In the 7th European Framework program a innovative gas cooled accelerator driven system is foreseen as an alternative concept to liquid metal cooled systems. Therefore, the design of new gas innovative energy systems a high overall efficiency is envisaged, leading to operate at higher temperatures between the 700 and 1000°C. In such temperature regimes gas cooled systems are favorable; however, their design is limited by the physical properties of the fluid and the wall heat transfer. For this purpose, the heat transfer and pressure penalties have to be optimized to ensure the desired design and safety functionality.

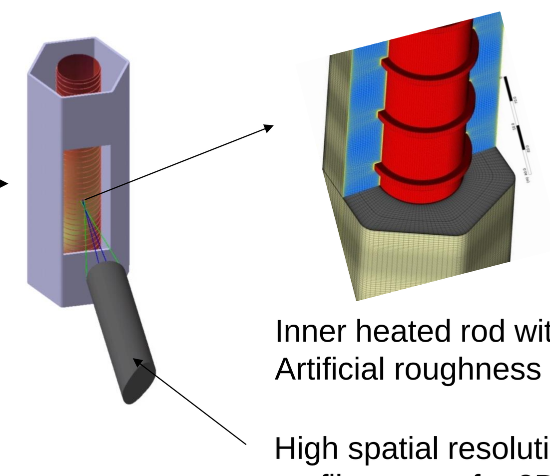
EXPERIMENTAL FACILITY

The experimental facility L-STAR which has been erected at KIT consist of a gas loop with a hexagonal annular cross-section channel containing an inner electrical heater rod (smooth or roughened) placed concentrically within the test section, designed and scaled to conduct research on the thermohydraulic issues of a sub channel with a single pin core of innovative gas cooled system.



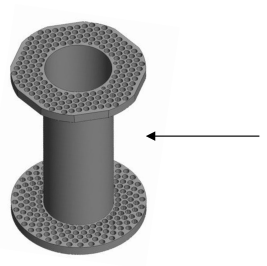
3D schematic representation of the L-STAR gas close loop facility with main components.

Hexagonal channel with inner heater rod with two optical LDA window access.



Inner heated rod with Artificial roughness

High spatial resolution profile sensor for 2D-LDA

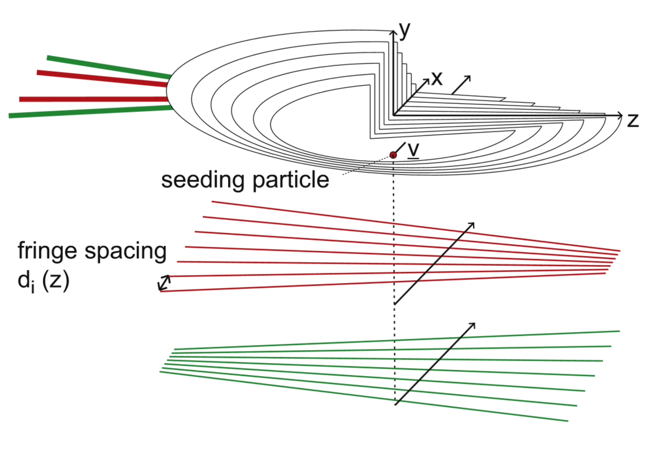


Flow straightener with 2 metallic plates use to enhance the flow entrance.

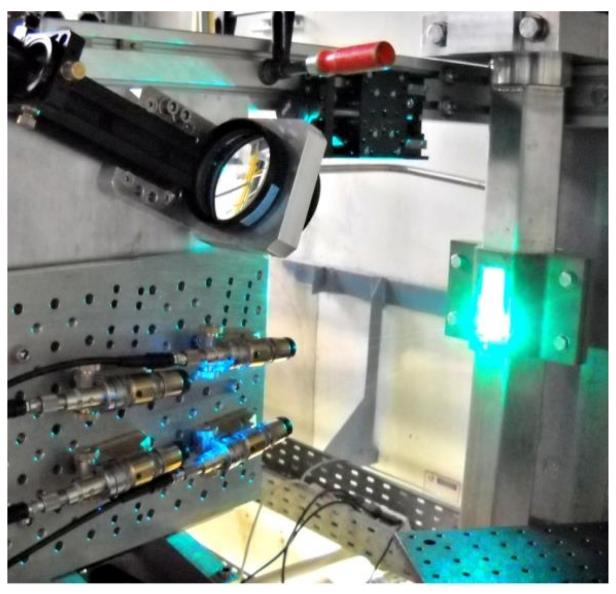
Test section length	3.7 m
Design heating power	24 kW
Gas Temperature range	RT - 250°C
Max. Operating pressure	3 Bar (abs)
Max. Mass flow rate	0.33 kg/s

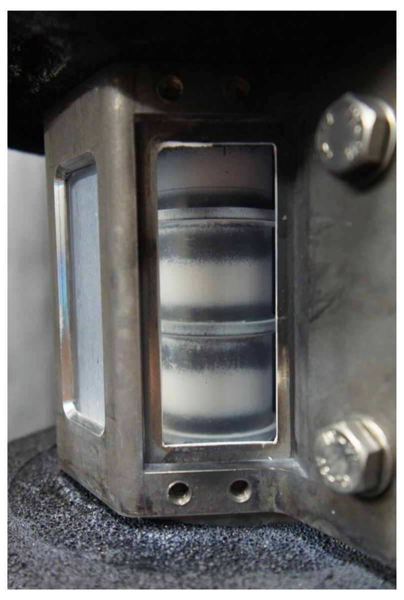
HIGH RESOLUTION LDA PROFILE SENSOR

The Laser Doppler Velocity Profile Sensor with two superposed interference fringe systems enables to resolve the both axial position, as well as, transverse velocities inside the measurement volume with a **spatial resolution of 20 µm**. The implementation of such high resolution system is advantageous for the investigation of fine scale turbulence structures.



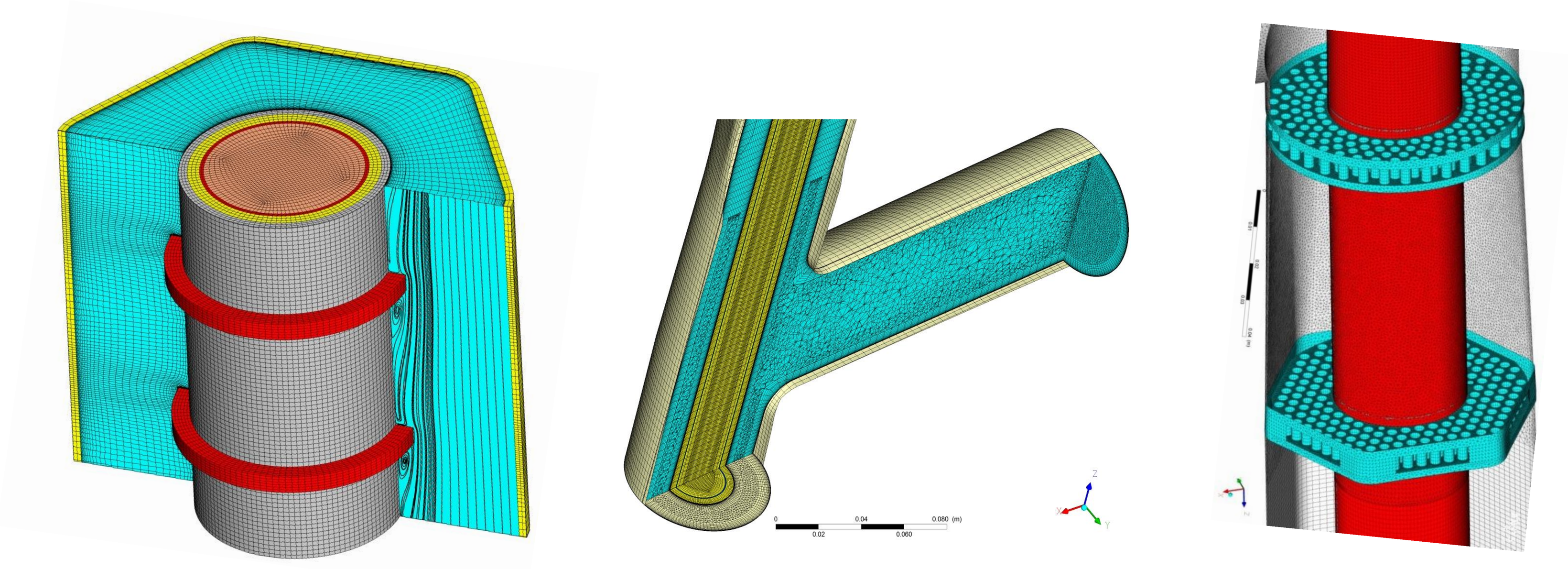
Schematic of the Profile sensor measurement. Two interference fringe systems with common fringe spacing *d1(z)*. (J. Czarske, TU Dresden)





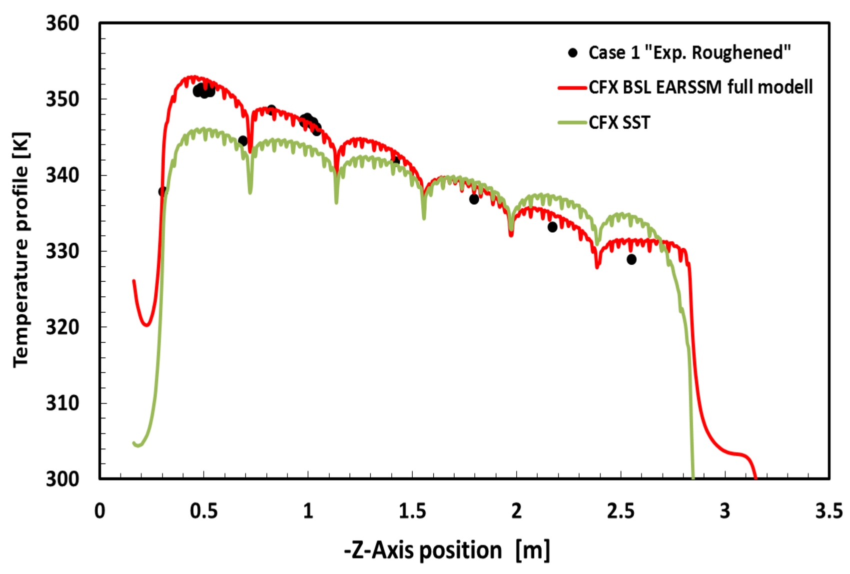
Setup configuration of the velocity profile measurement system in the structured L-STAR test section through the optic LDA window access.

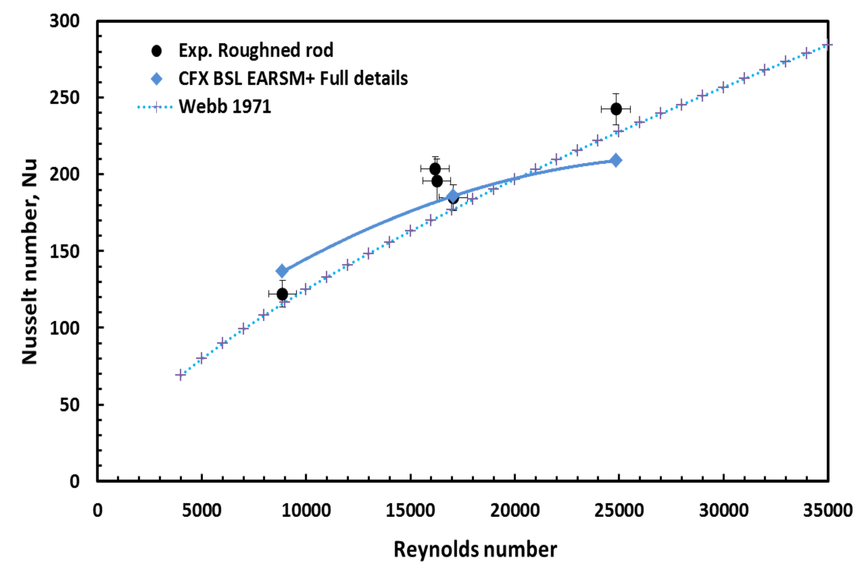
CFD ANALYSES

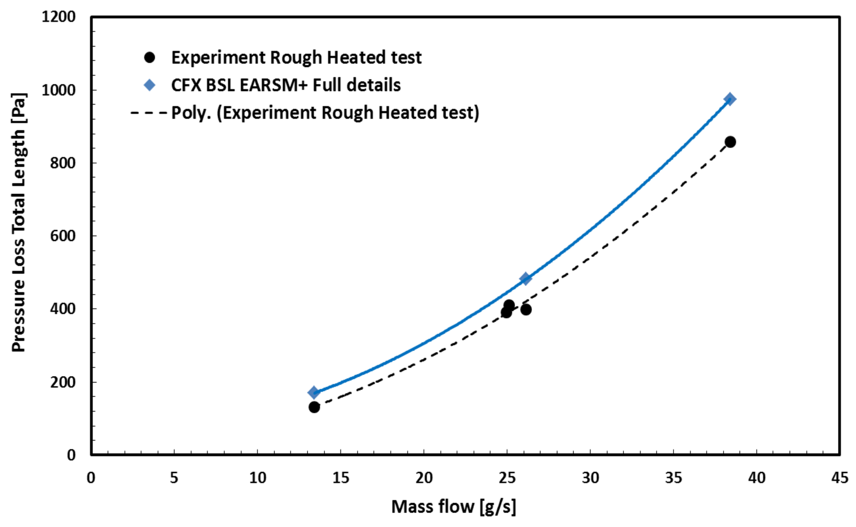


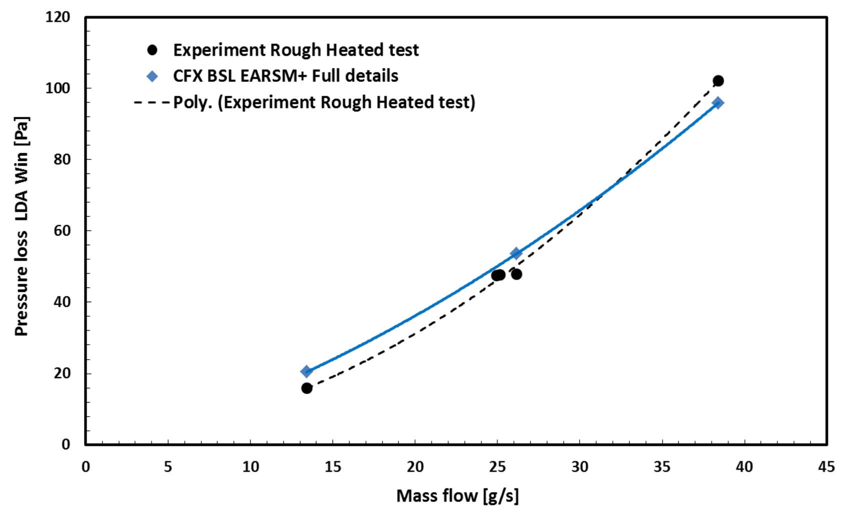
- ❑ ANSYS CFX 14.0 is used for the numerical calculation including bends.
- ❑ Mesh of the CFD model was constructed with Gridgen V15
- ❑ Test section
  - ✓ 72 Mio Cells Detailed model of Heater rod $y^+<1$
- ❑ Flow Straightener
  - ✓ Coarse model with a Wall resolution y+ 30 to 80
- ❑ BSL EARSM turbulent model (Explicit Algebraic Reynolds Stress Models)
- ❑ Monte Carlo radiation model
- ❑ Heat conduction in Hexa wall, flow straightener plates and inlet/outlet bends.

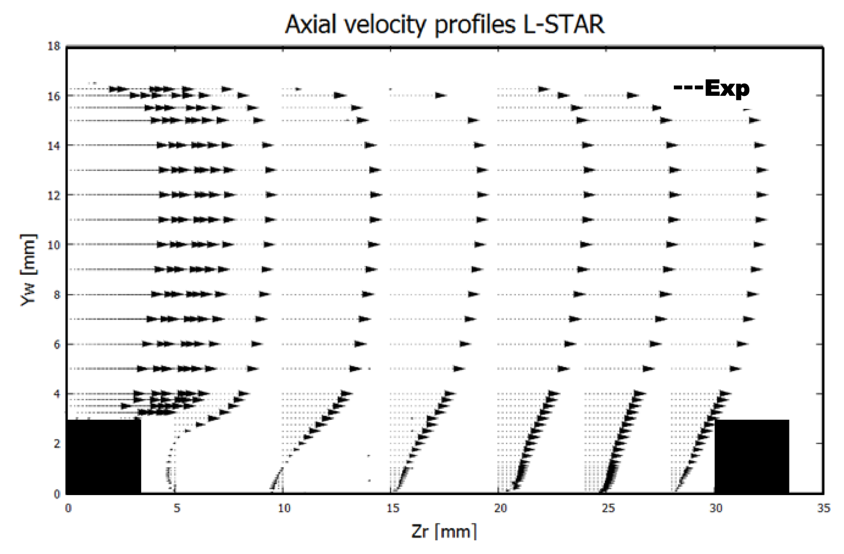
RESULTS

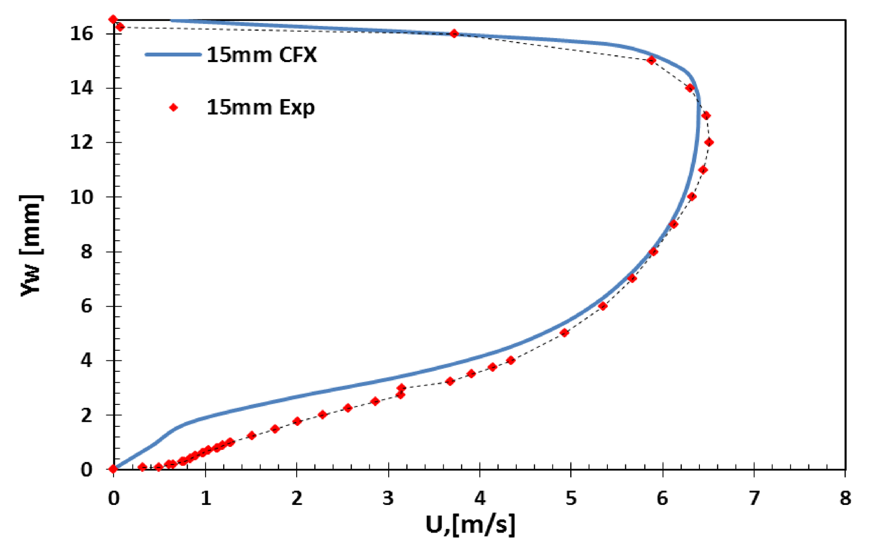












SPECIFIC OBJECTIVES

- ❑ Experimental optimization of heat transfer and overall pressure losses using artificial surface structures "Ribs" to reduce thermal loads on the cladding material surface.
- ❑ Improve the understanding of complex turbulent gas flows and its enhancement mechanism specially near the wall.
- ❑ Support the forward qualification and validation of CFD codes relevant for innovative gas cooled systems.
- ❑ Generation of friction and heat transfer correlations suitable to be used in system codes.

CONCLUSIONS

- ❑ Good reproducibility of all experimental curves, pressure drop, temperature distribution and velocity profiles have been achieved.
- ❑ The CFX 14 numerical model results captured very well the thermohydraulic behavior of the hexagonal test section.
- ❑ Temperature profile a deviation of less than <5°C is obtained in the total length of the heated section compared to the experiment.
- ❑ The deviations of pressure differences for the test section are below 10%, while for the overall model 16% are reached based on the rougher discretization of the flow straightener components.