UNIVERSITY OF TWENTE.

"Supercritical Gasification of Wet Biomass"

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Introduction

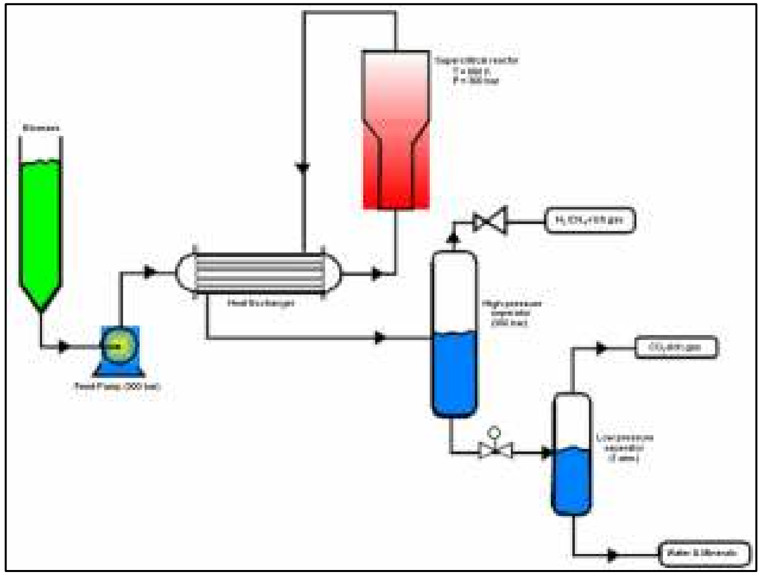
- Problem Statement
  - Super Critical Water Gasification (SCWG) converts wet biomass/waste streams (more than 70 wt.% water) into medium calorific gas.
    - Rich in either Methane or Hydrogen
  - **Availability of wet biomass** in the Netherlands is approximately **15*10^6 tonnes/year**
  - **Energy potential** of approximately **500 PJ** [Koppejan 2005]

Project

SenterNovem

- Biomass handling and feed preparation → QPQP
- Chemistry of supercritical gasification → TCCB
- Reactor design → ThW &
- Product gas upgrading → btg biomass technology group

Goal

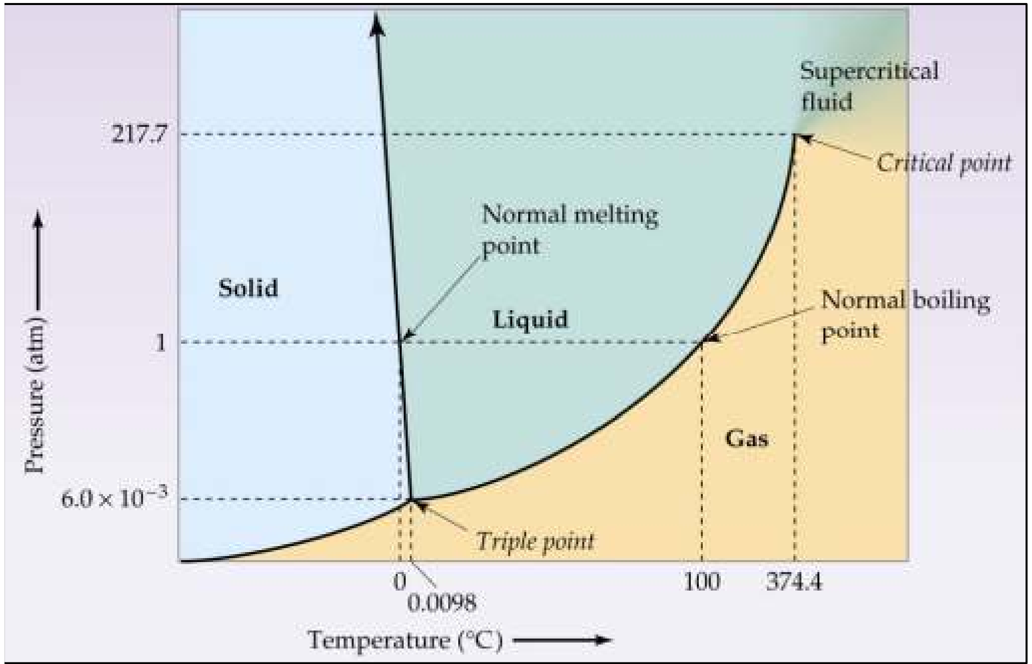


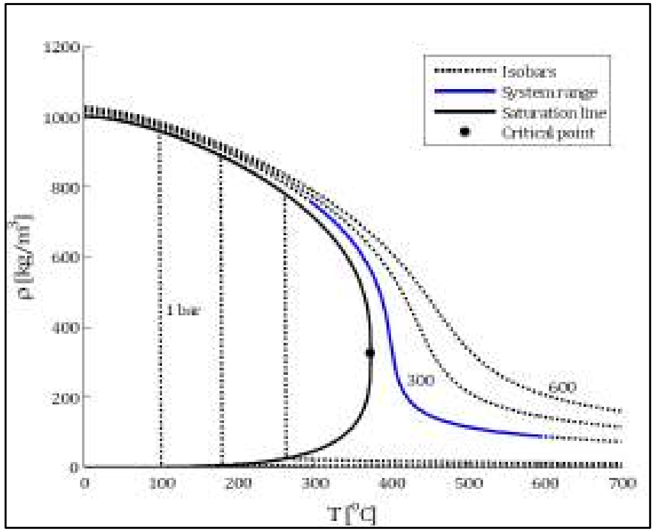
- Development of the process of Supercritical Gasification of Wet Biomass
  - Look at chemical kinetics
  - Heat transfer
  - CO_2 capture
  - Come up with design rules for a continuous reactor design for Supercritical Gasification of Wet Biomass

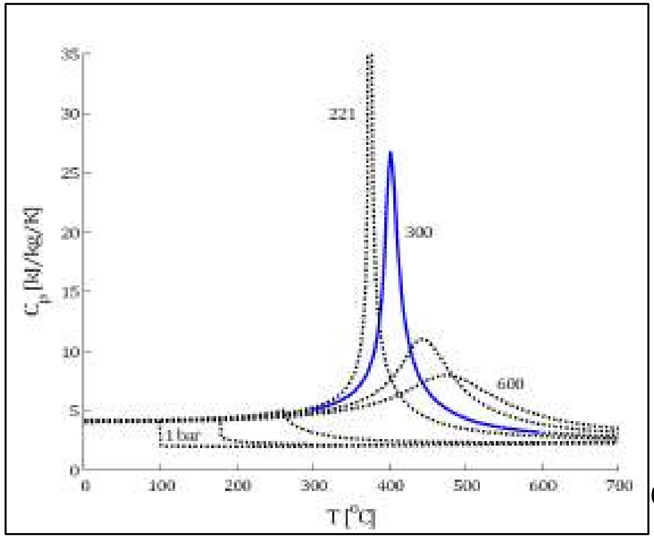
Supercritical water

- **The benefits**
  - No drying of the wet biomass is necessary
  - Complete miscibility of gases and organics
  - Water acts both as solvent and as a reactant
  - High hydrogen yield

Supercritical water

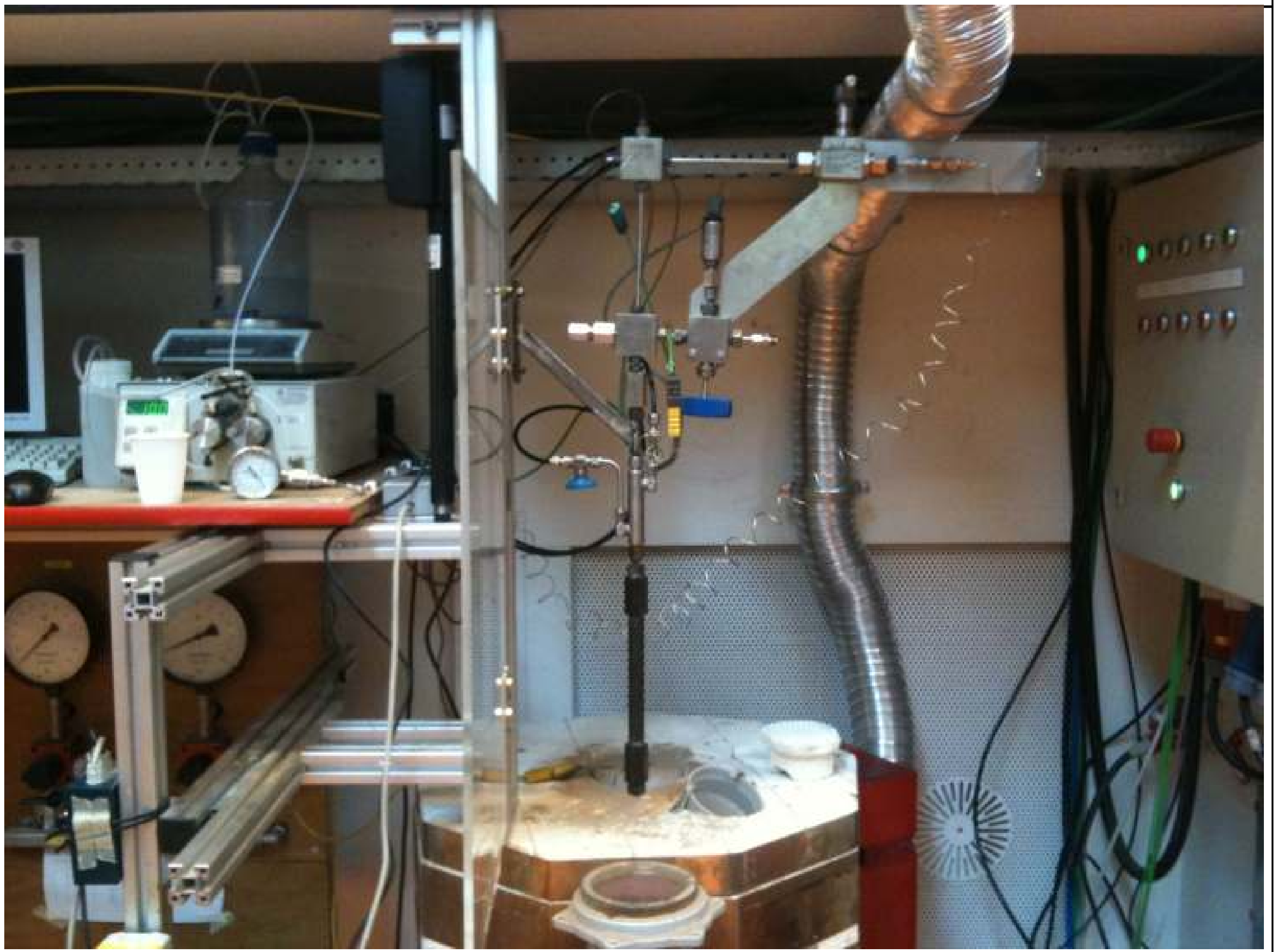


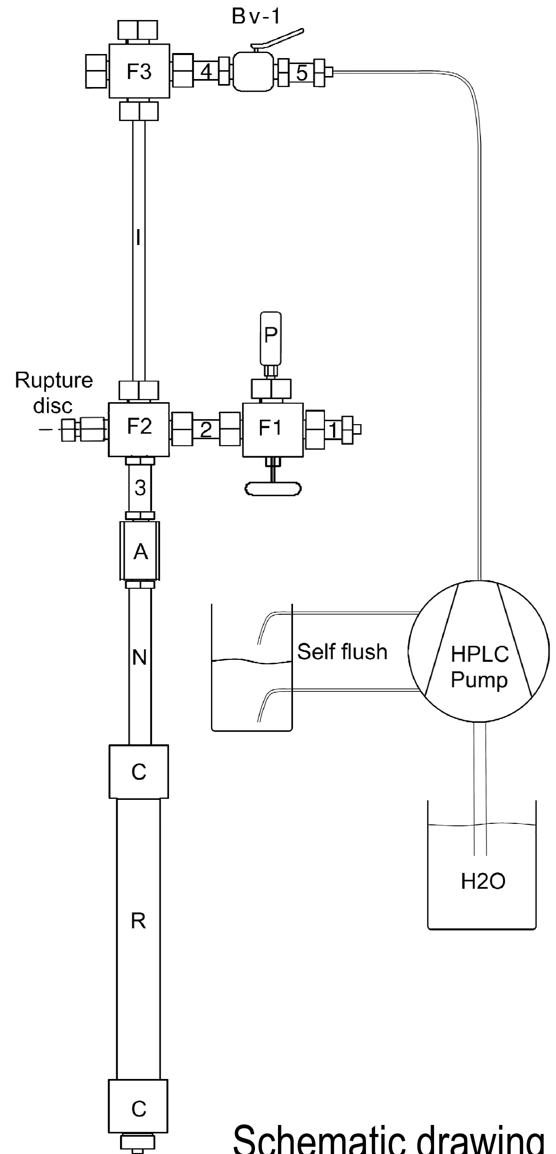




REACTOR

Batch reactor with injection system

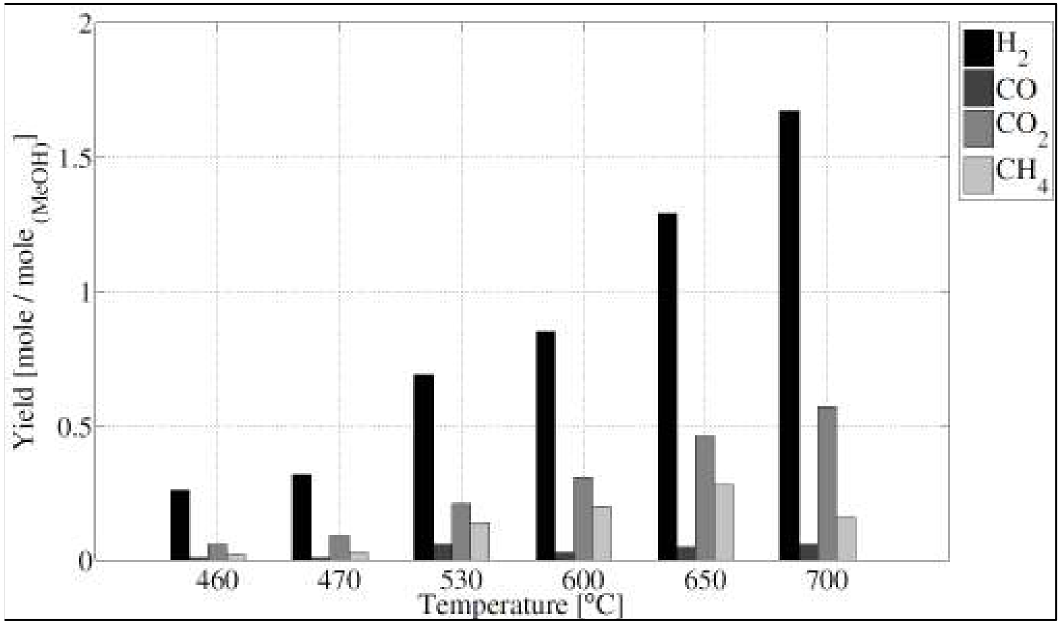


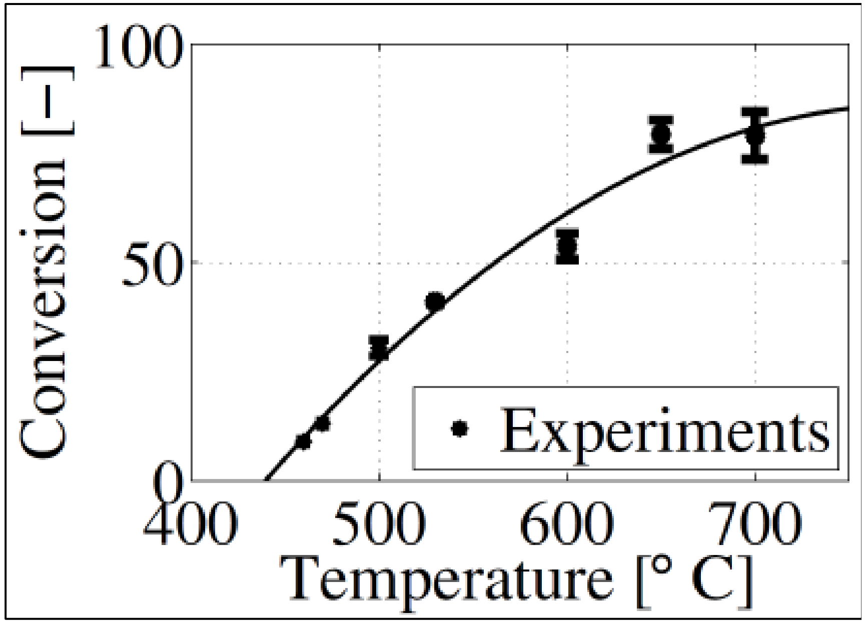


Schematic drawing

EXPERIMENTS

SCWG of Methanol: Experimental results





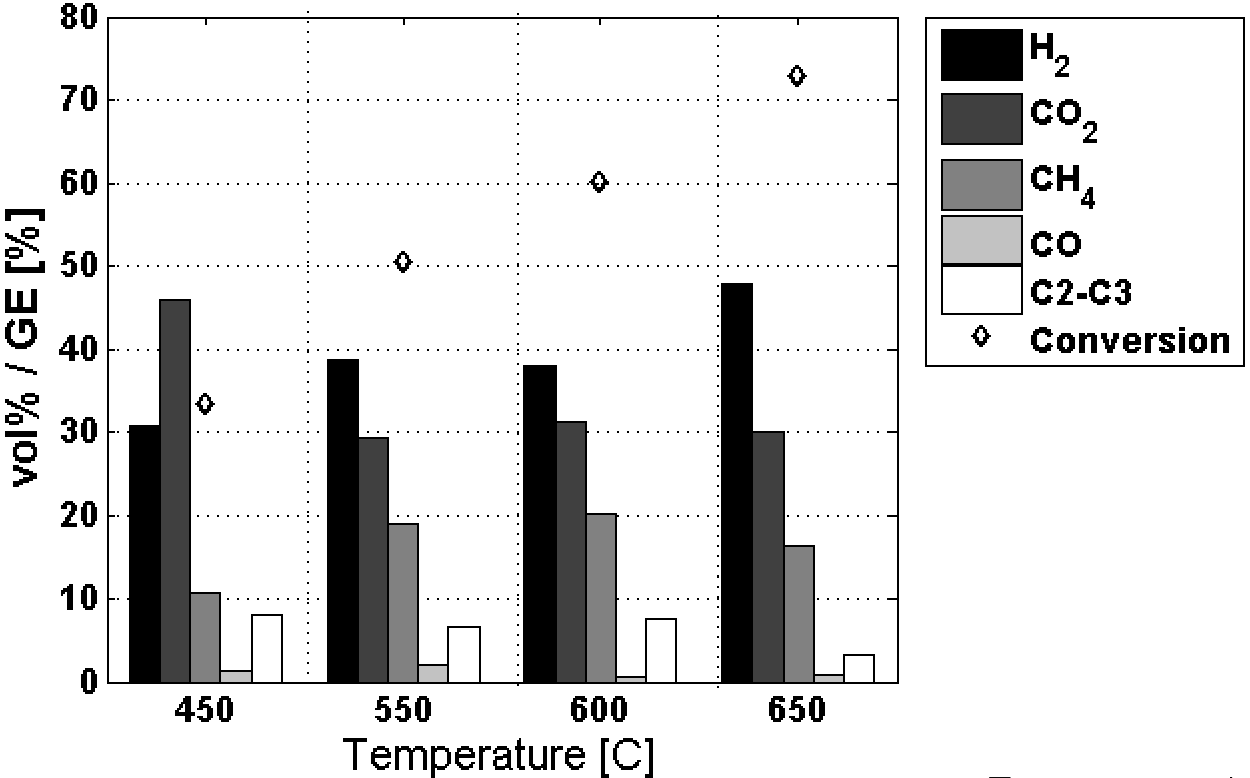
Tau_res = 10 [min]

Wt%_algae = 10 %

P_start = 260 [bar]

EXPERIMENTS

SCWG of Micro Algae: Experimental results



Tau_res = 1 [hr]

Wt%_algae = 7.4 %

P_start = 260 [bar]

CFD

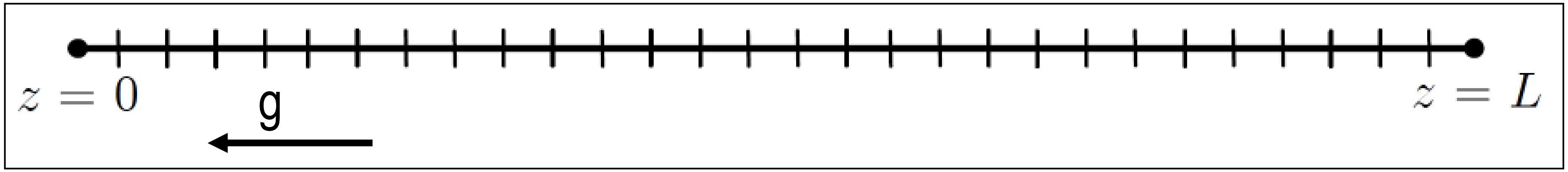
Research goal

- **Determination of heat transfer characteristics of biomass gasification in supercritical water**
  - What is the influence of large property variations on the heat transfer
  - Can this be described using a 1D modeling approach?
  - Is it necessary to use a 2D modeling approach?

P = 30 MPa
G = 200 kg/m².s
D = 10 mm
L = 2.5m
Tw = 873 K
Tin = 573 degC

CFD 1D model

This model is used to compare with the 2D model



$$\frac{d}{dz}(\rho u) = 0$$

$$(\rho u)_0 \frac{du}{dz} + \frac{dp}{dz} = -\rho g$$

$$\frac{dT}{dz} = \frac{4}{D} \frac{h}{(\rho u)_0 C_p} (T_w - T)$$

Nusselt correlaties

Author(s)	Year	p [MPa]	G [kg/m²s]	Q [kW/m²]	D [mm]	T_b [°C]
Bishop et al.	1964	23 – 28	650 - 3660	310 - 3460	2.5 – 5.1	282 - 527
Swenson et al.	1965	23 – 41	542 - 2150	200 - 2000	9.4	75 - 576
Yamagata et al.	1972	23 – 29	310 - 1830	120 - 930	7.5, 10	230 - 540
Aicher and Martin	1996	N/A	N/A	N/A	27, 37	N/A
Mokry et al.	2011	24	200 - 1500	≤ 1250	10	320 - 406

CFD 2D model

Pipe flow model supercritical water

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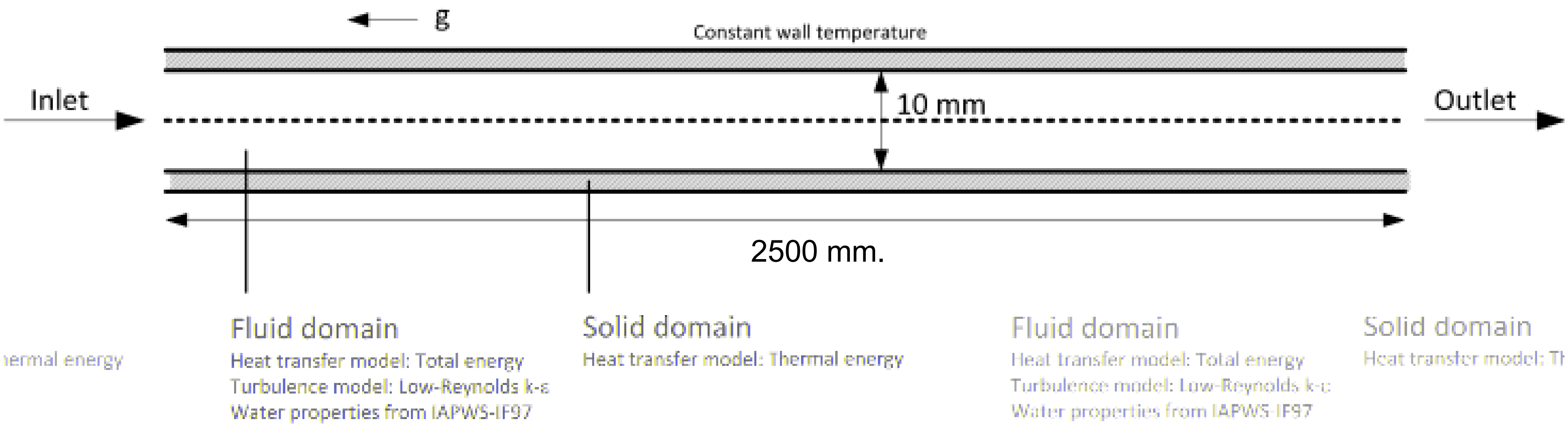

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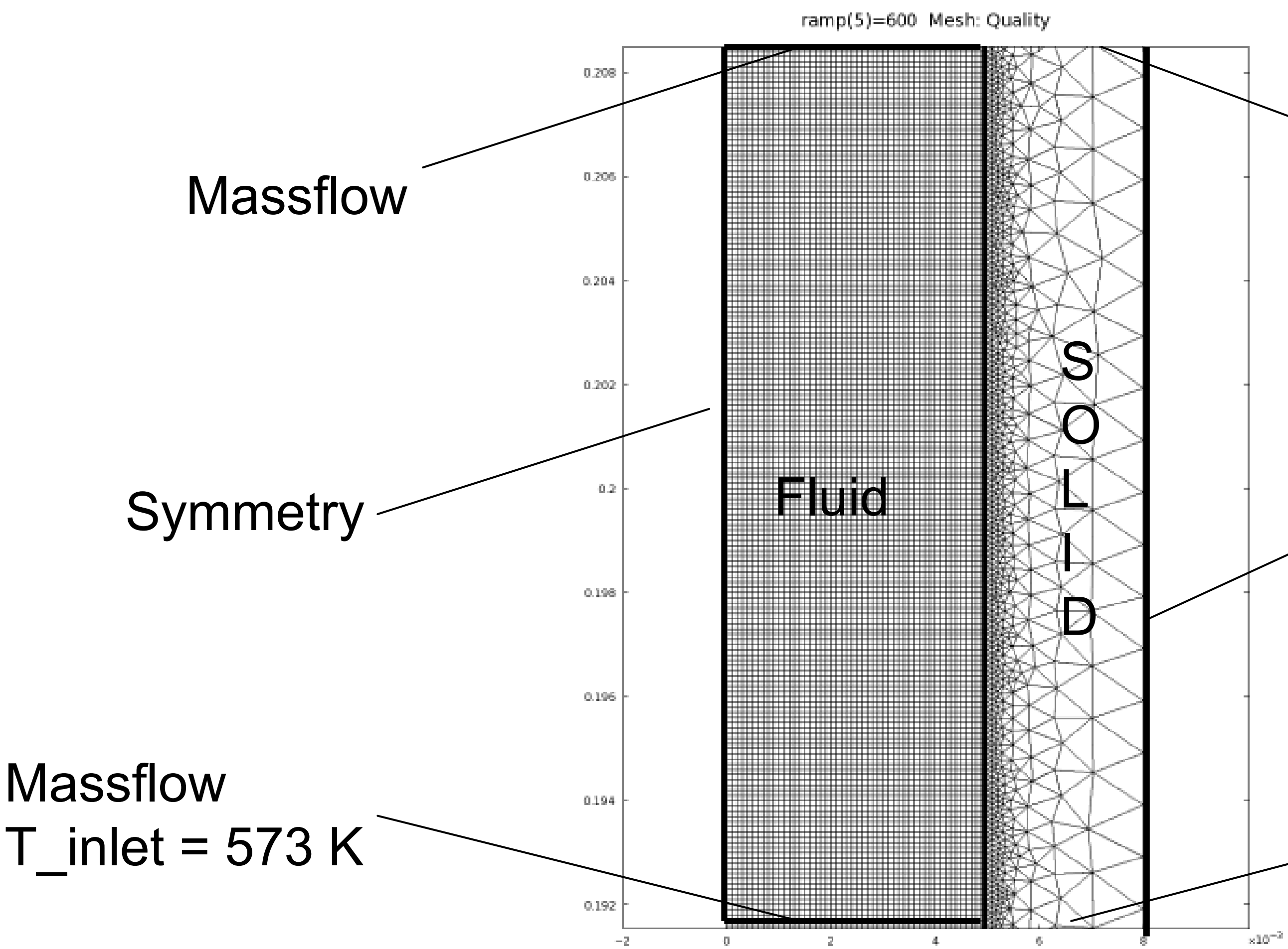
CFD 2D model

Pipe flow model supercritical water



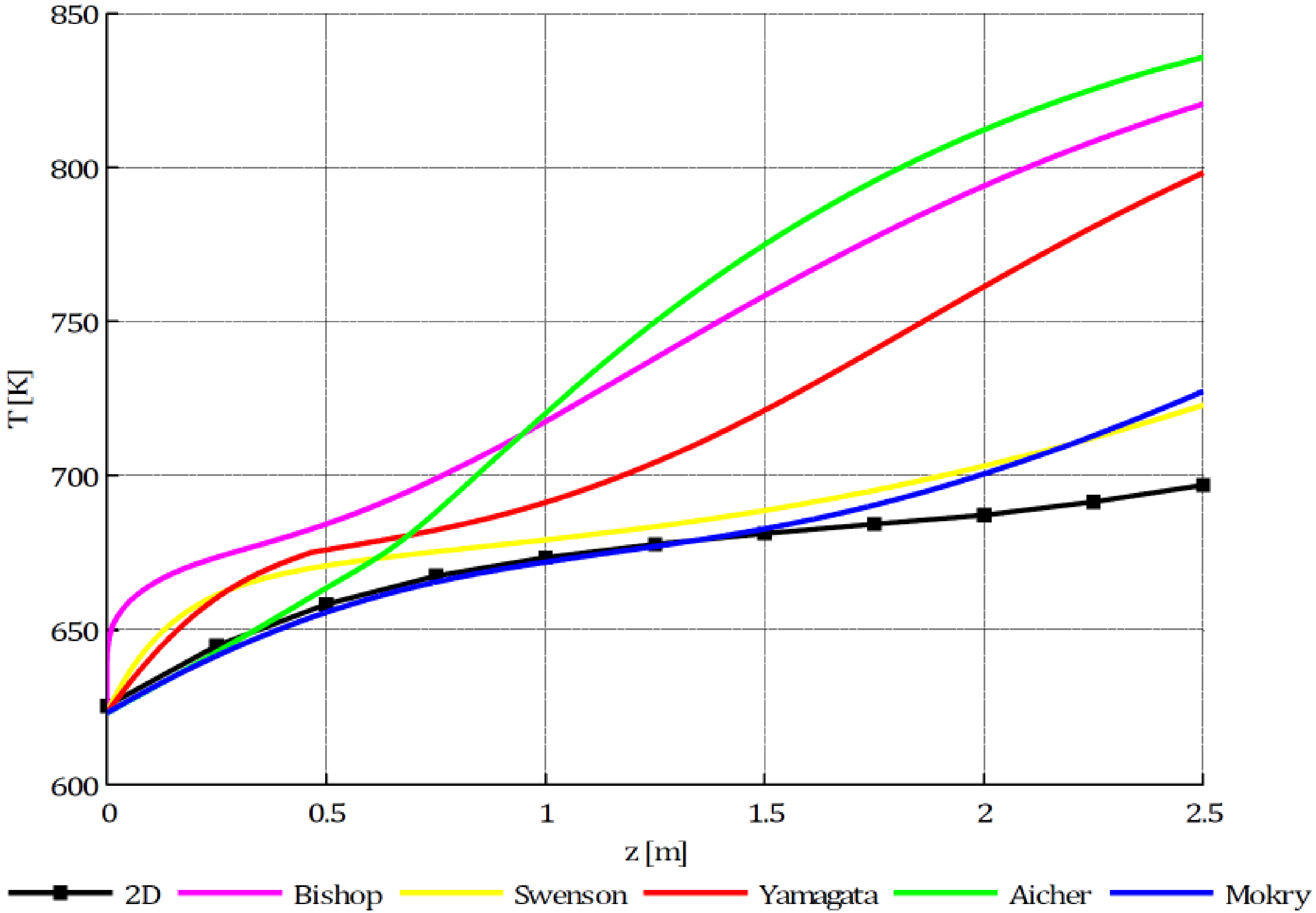
CFD 2D model

Temperature comparison 1D and 2D

Massflux = 200 [kg/m^2 . s]

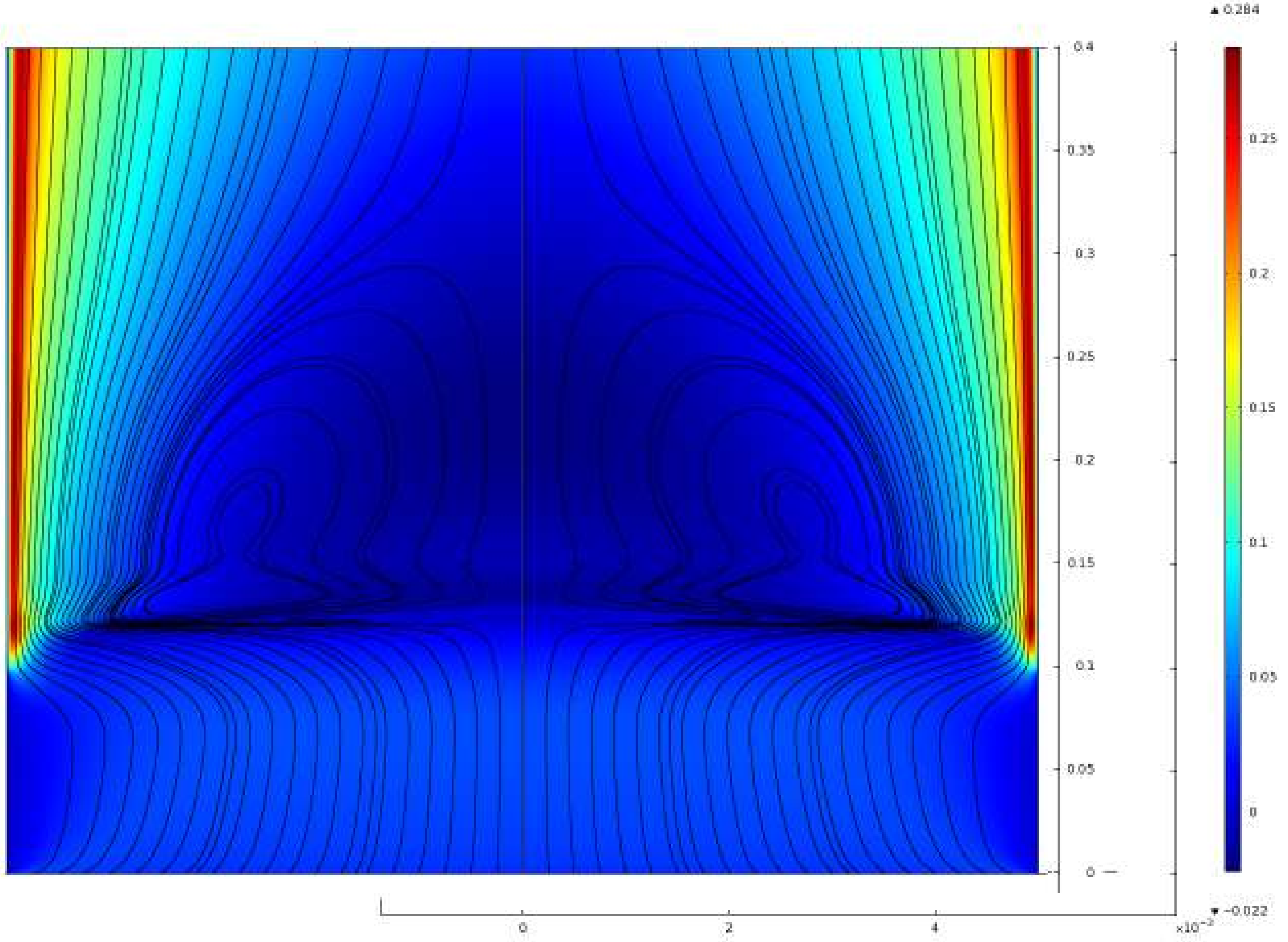
Inlet temperature = 573 [K]

Wall temperature = 873 [K]



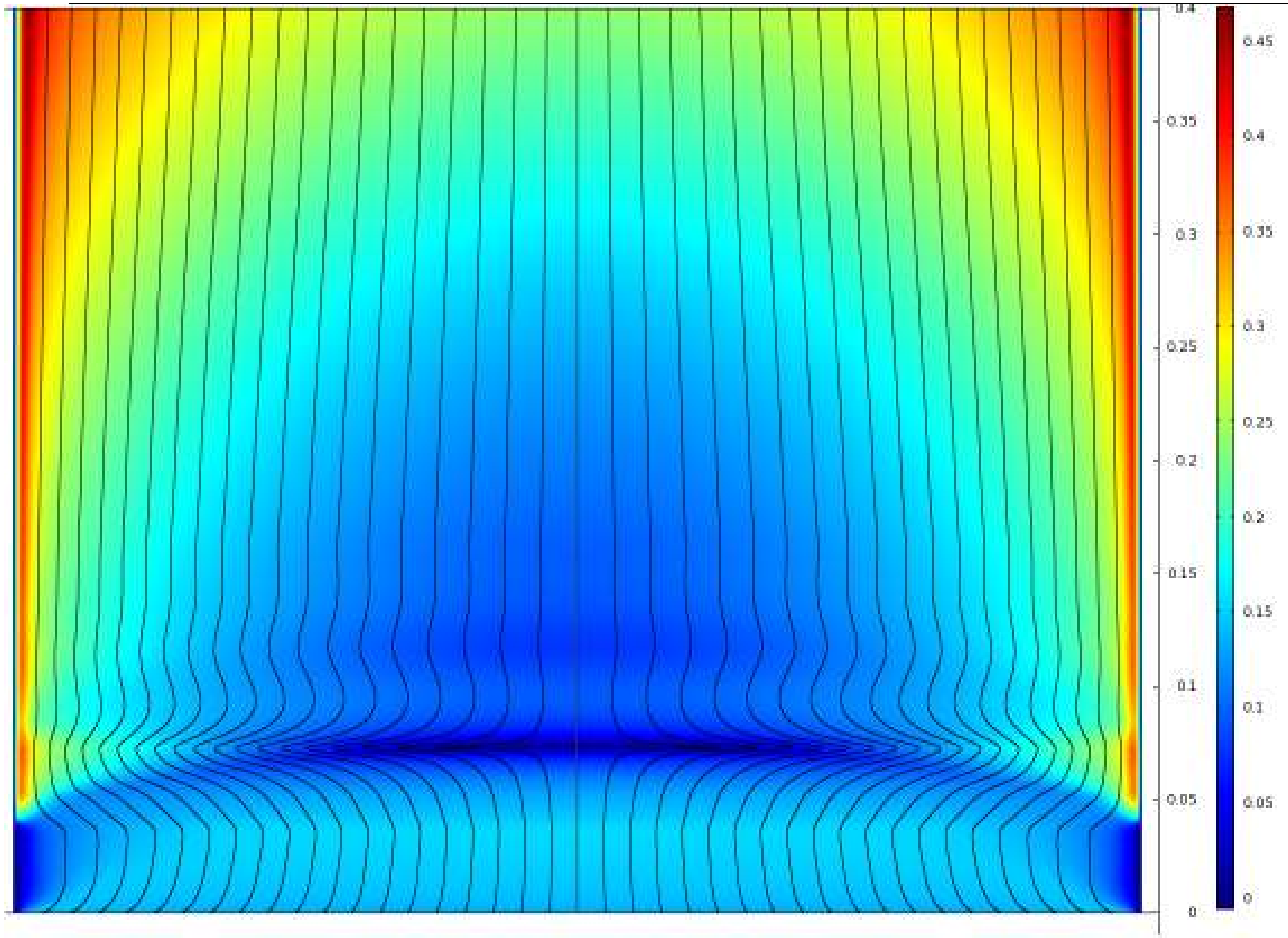
CFD 2D model

Velocity profiles at a mass flux of 20 [kg/m^2.s]



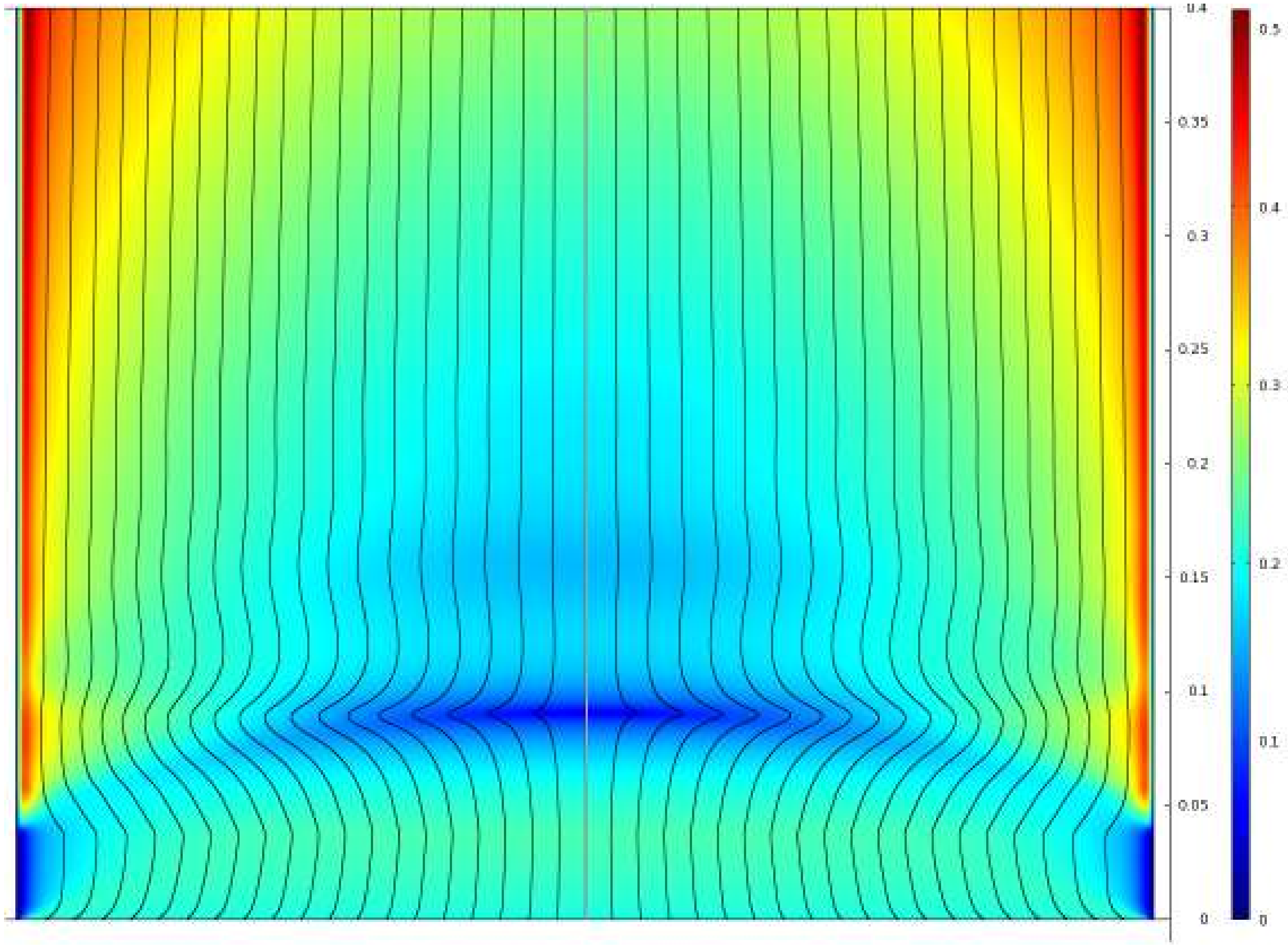
CFD 2D model

Velocity profiles at a mass flux of 100 [kg/m^2.s]



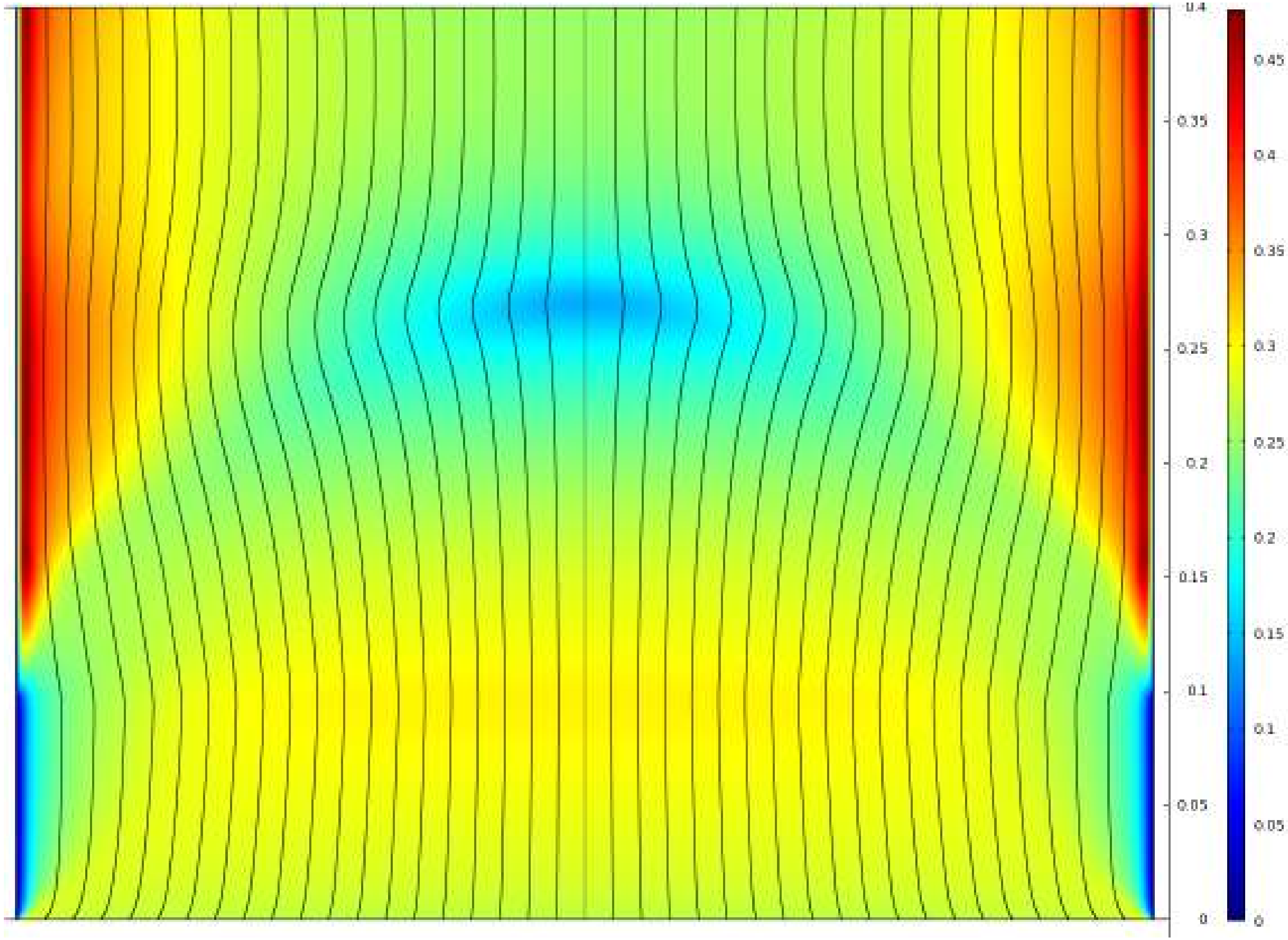
CFD 2D model

Velocity profiles at a mass flux of 150 [kg/m^2.s]



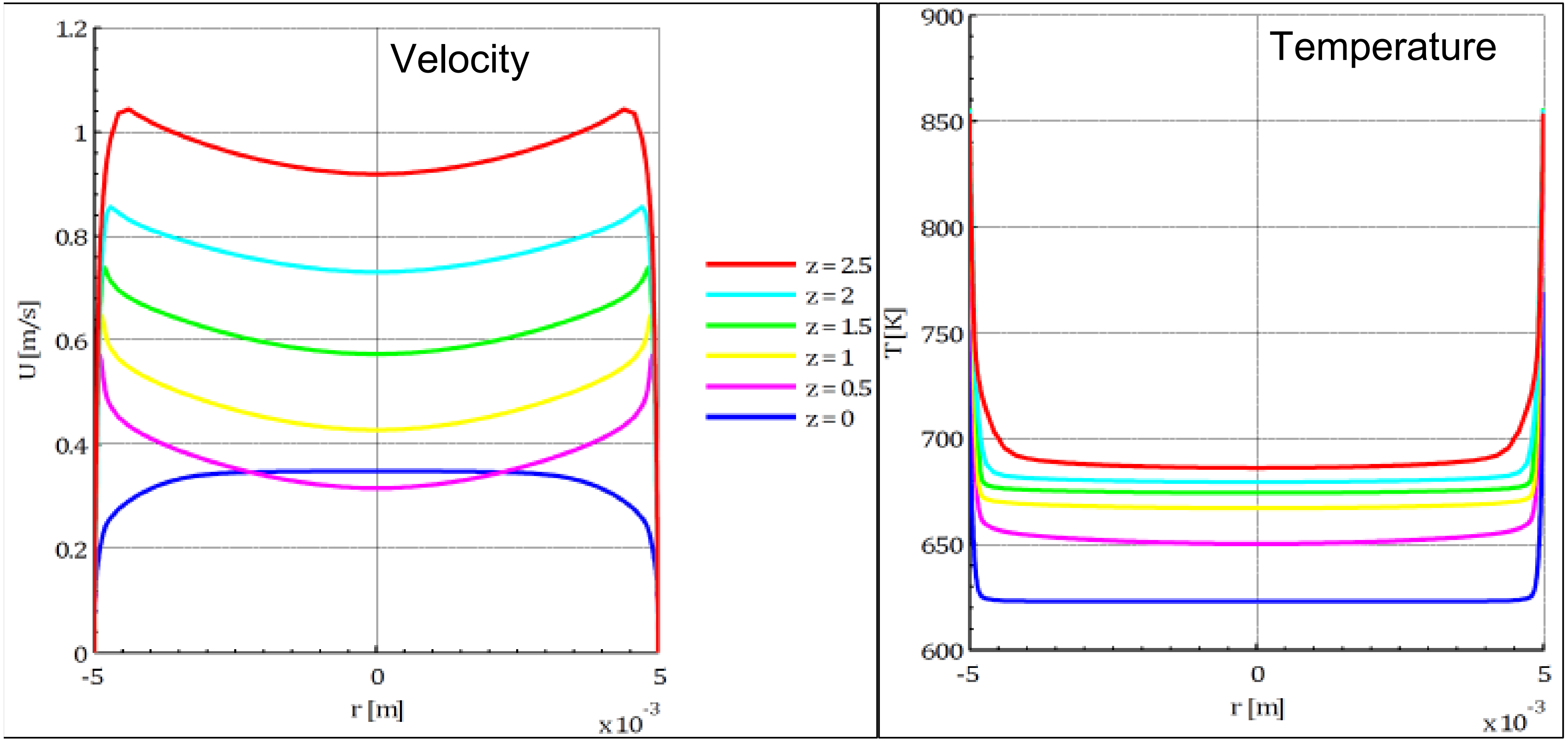
CFD 2D model

Velocity profiles at a mass flux of 200 [kg/m^2.s]

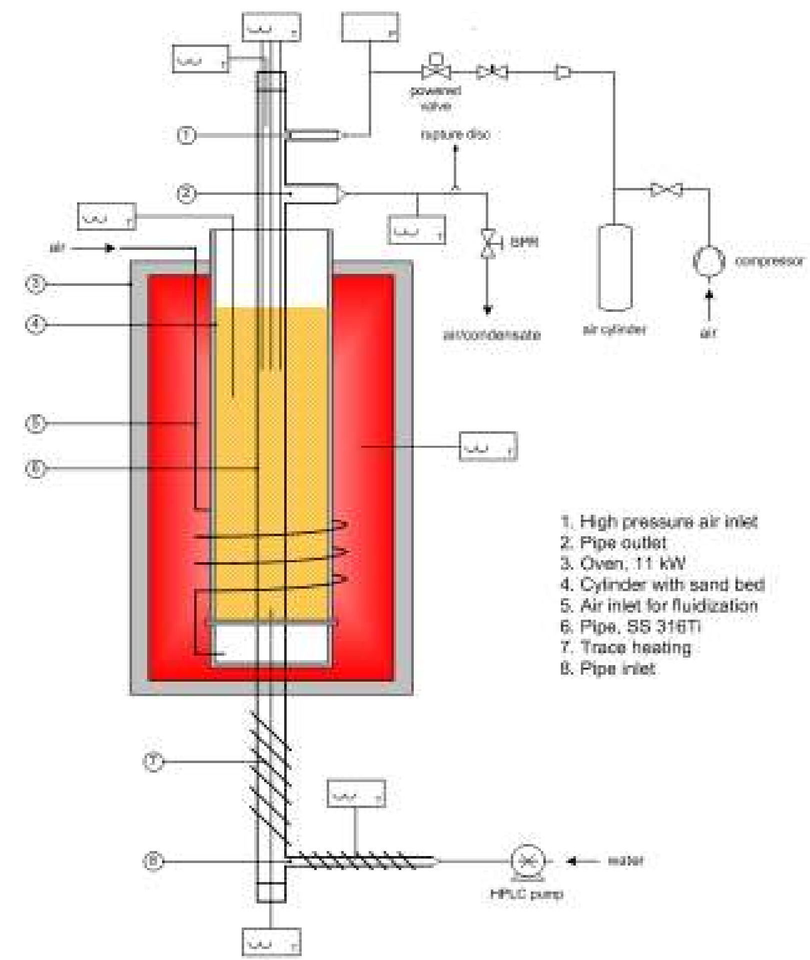


CFD 2D model

Velocity & temperature profiles at a mass flux of 200 [kg/m^2.s]



Setup for temperature measurements in supercritical water



Conclusions

- A high throughput screening reactor for wet biomass is developed and tested.
- A 2D model for heat transfer to sub- and supercritical water is developed.
- The 2D models is validated using a dedicated experiment.
  This work is in progress!