Modelling and Simulation of an Aseptic Flash Cooler for Tomato Concentrate Sterilization

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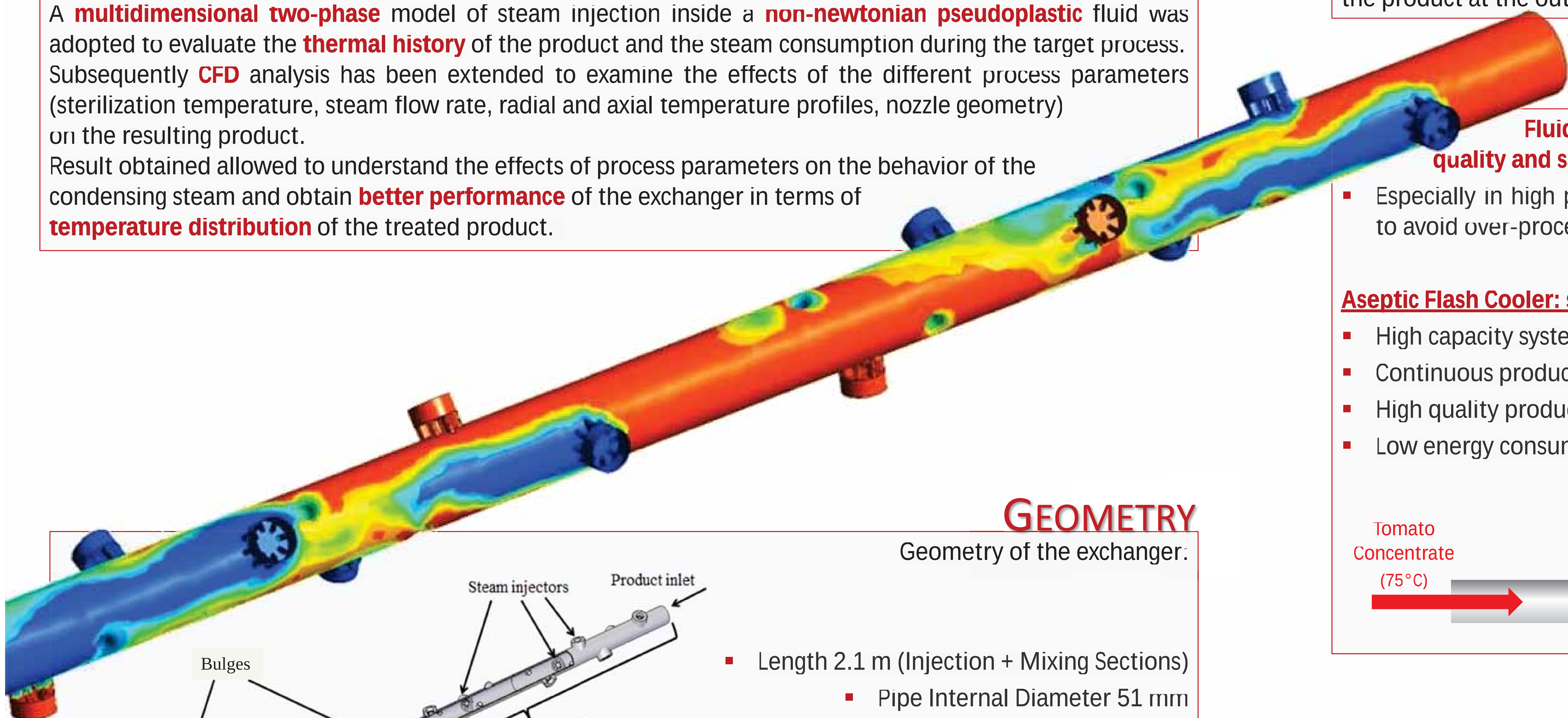
Abstract

Direct steam injection (DSI) is a sterilization technique which is often used for high viscosity fluid food when the preservation of the quality characteristics and energy efficiency are the priority.
In this work an apparatus for the **sterilization of tomato concentrate** has been analyzed by means of multidimensional CFD (Computational Fluid Dynamics) models, in order to optimize the quality and safety of the treated food.
A **multidimensional two-phase** model of steam injection inside a **non-newtonian pseudoplastic** fluid was adopted to evaluate the **thermal history** of the product and the steam consumption during the target process.
Subsequently **CFD** analysis has been extended to examine the effects of the different process parameters (sterilization temperature, steam flow rate, radial and axial temperature profiles, nozzle geometry) on the resulting product.
Result obtained allowed to understand the effects of process parameters on the behavior of the condensing steam and obtain **better performance** of the exchanger in terms of **temperature distribution** of the treated product.



Motivation

Great potential of CFD to predict behaviour of complex flow, including multiphase and phase change (condensation or evaporation).

Objective

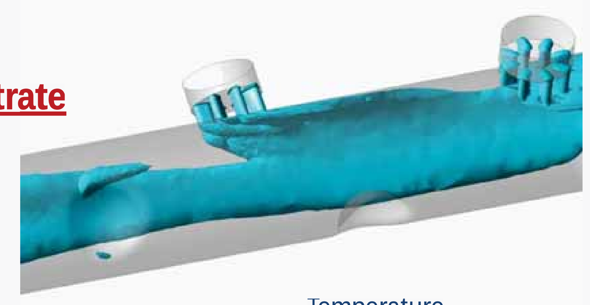
Improve the performances of a Direct Steam Injection exchanger in terms of temperature distribution of the product at the outlet.

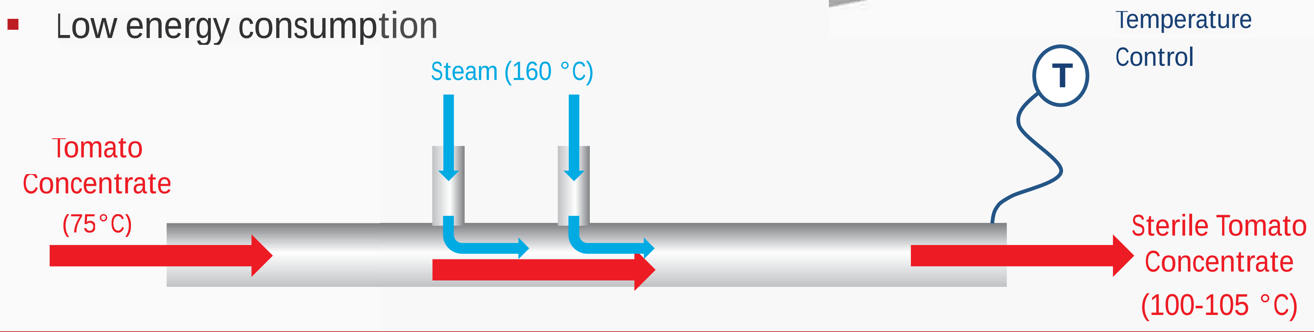
Problem Description

- **Fluid food products** are commonly subjected to thermal treatments to ensure their **quality and safety**
- Especially in high production plants, thermal treatments must be **accurately selected and monitored** to avoid over-processing

Aseptic Flash Cooler: sterilization of tomato concentrate

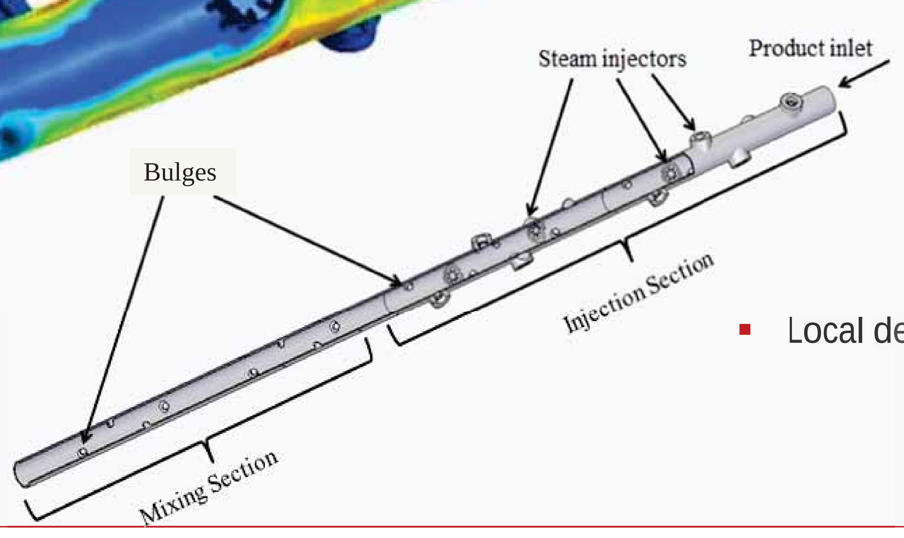
- High capacity systems (12.000-35.000 l/h)
- Continuous production
- High quality products
- Low energy consumption





Geometry

Geometry of the exchanger.



- Length 2.1 m (Injection + Mixing Sections)
- Pipe Internal Diameter 51 mm
- 12 radial steam injectors
- Local deformations (bulges) to improve mixing effects

Model Set-Up

Tomato Concentrate Rheological Model

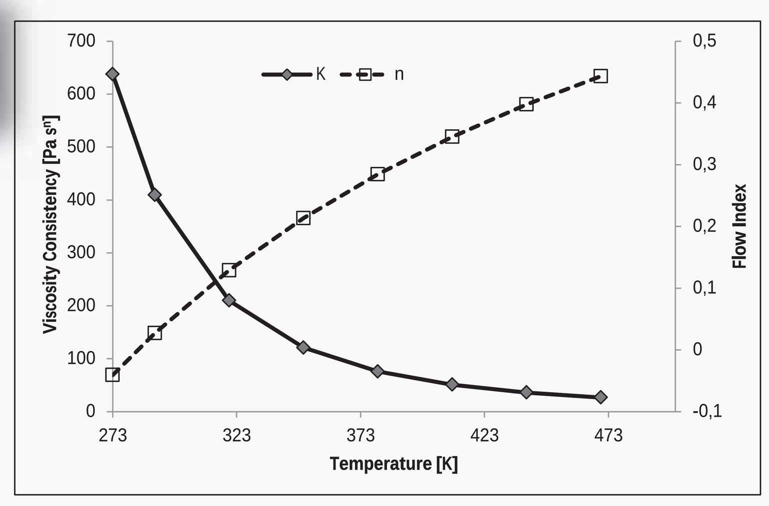
- Pseudoplastic non-Newtonian fluid

$$\mu = K\,\dot{\gamma}^{n-1}$$

- Exponential dependence on temperature for K and linear dependence on 1/T for n

$$K = K_0 \cdot \frac{K_T \cdot 1000/T}{1000}$$

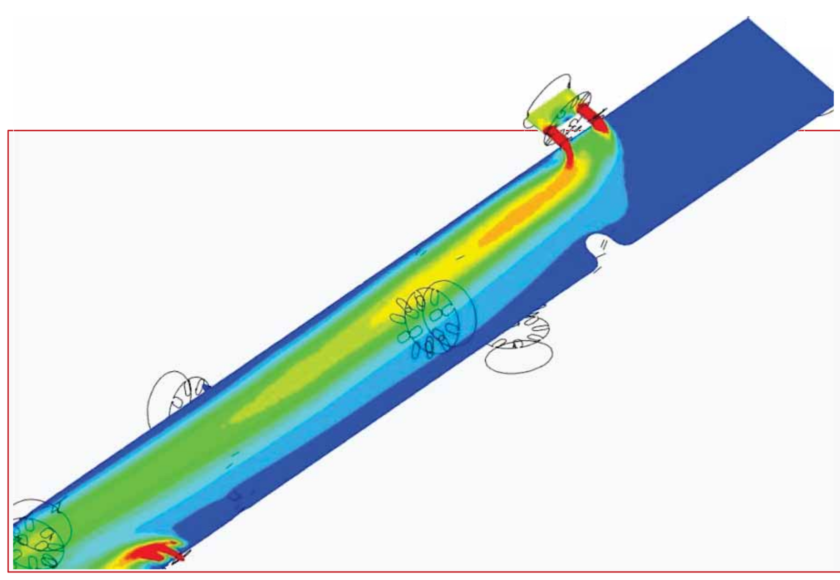
$$n = n_0 + n_T \cdot 1000/T$$



The flow of tomato concentrate, due to its high viscosity, is laminar.
An Eulerian-Eulerian homogeneous two-phase model was used to describe the flow of tomato concentrate and steam entering the heat exchanger. Tomato concentrate has been modeled as a continuous phase, while saturated water vapor was modeled as a dispersed phase.
Tracked interphase heat and mass transfer due to the condensation of steam droplet inside the continuous phase.

Boundary Conditions

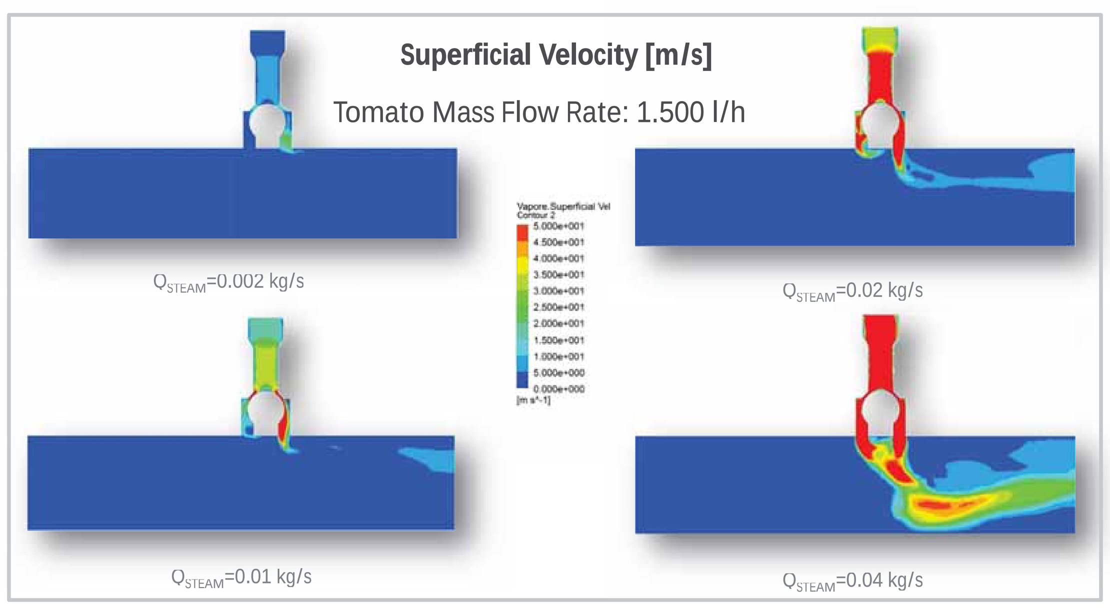
Geometry of the exchanger.

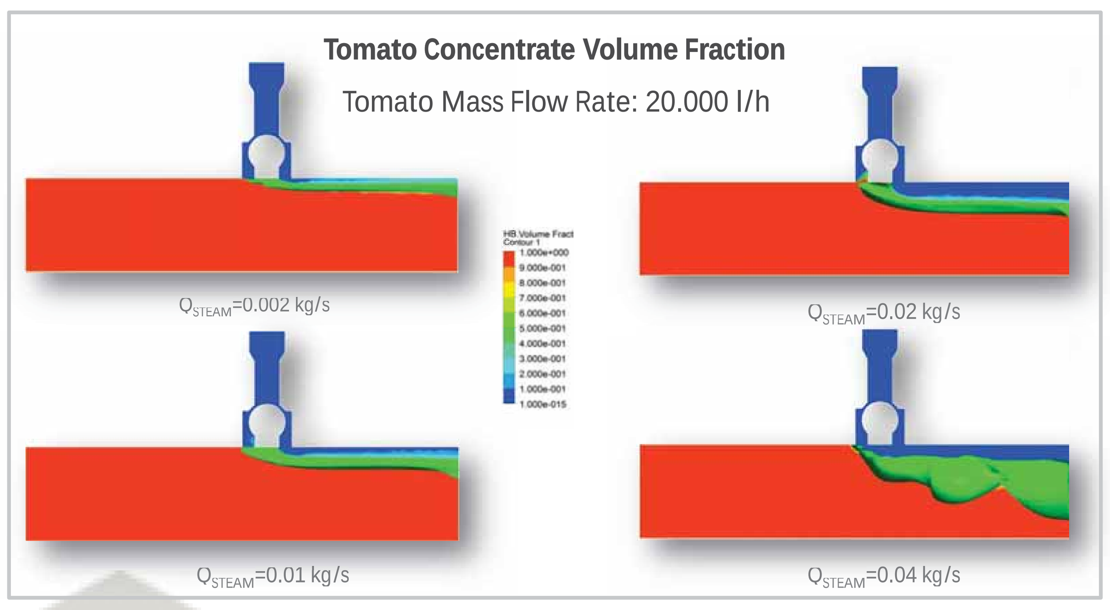


- Tomato concentrate flow rate
- Tomato concentrate inlet temperature
- Water steam temperature and quality
- Steam pressure

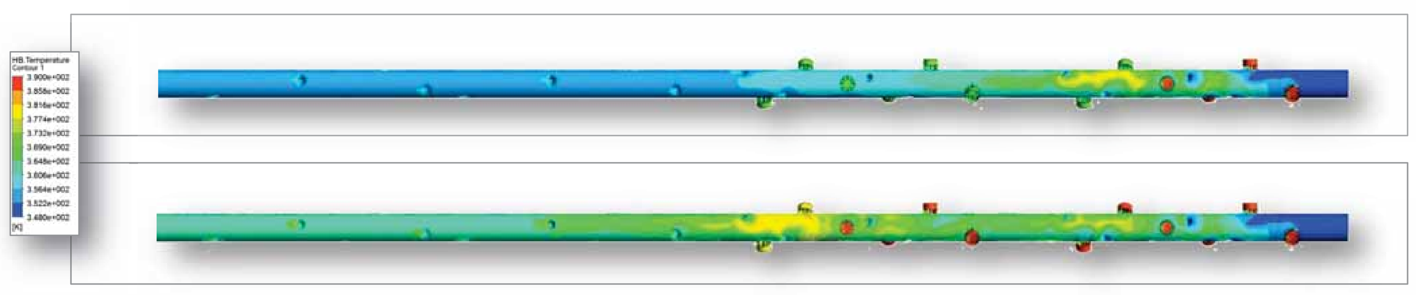
Results

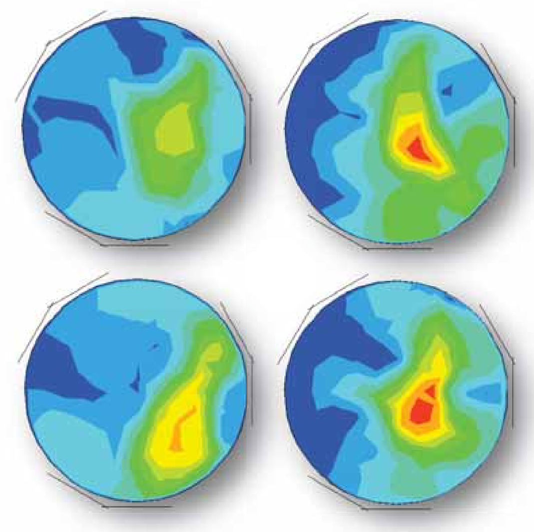
1 Predicted steam penetration inside tomato concentrate for different working conditions.





2 Temperature history and temperature distribution of tomato concentrate for standard working conditions.





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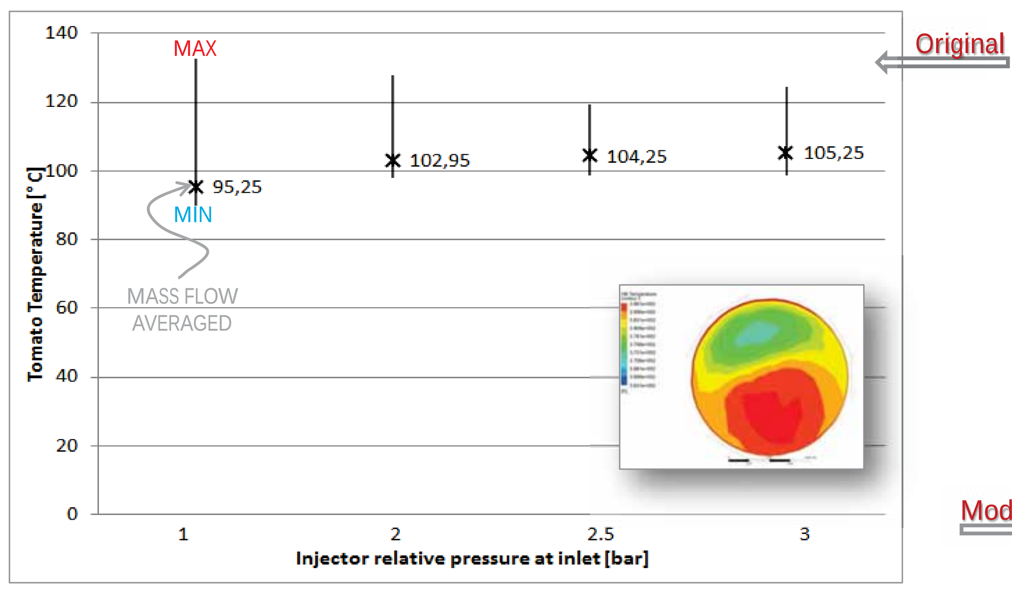
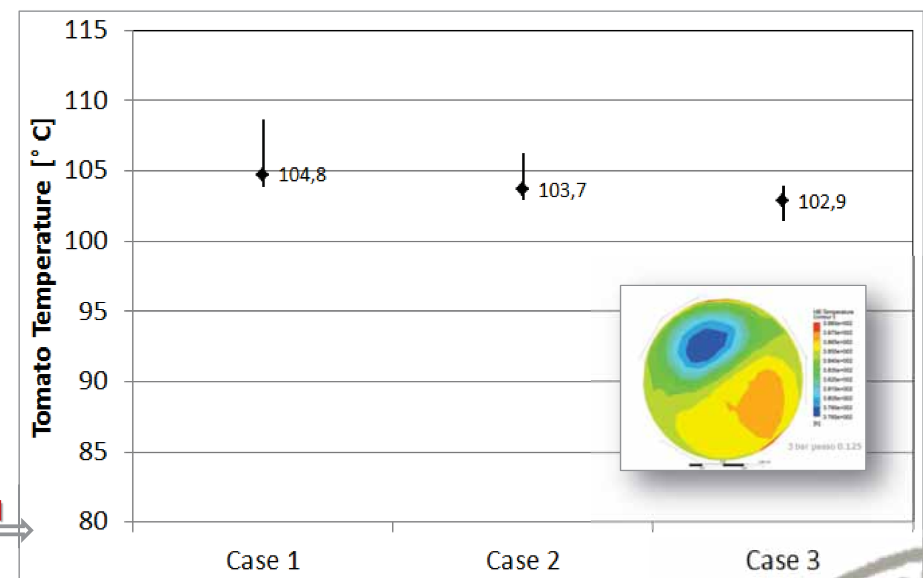
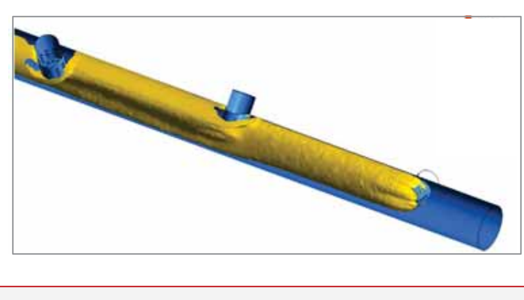
- Simulations showed temperature control issues due to the application of constant pressure on injectors
- Better temperature distribution and thermal control obtained with different pressure settings on the injectors
- Temperature difference on outlet section 2.5 times lower





Future Work....

Injectors design optimization



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