CFD characterization of pressure drop and heat transfer inside Gyroid lattices structures.

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Outline

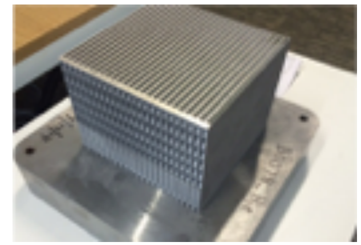
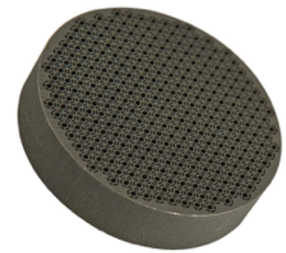
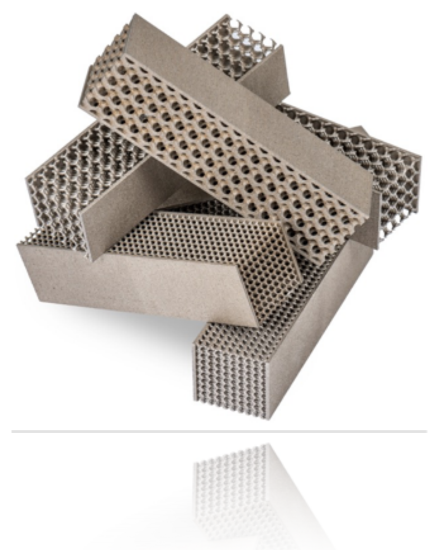
- Motivation
- Methodology
- Result and Discussion
- Conclusion and Future Directions

HiETA Technologies

Design, engineering and industrialisation solutions for Additive Manufacturing.

- **Heat Exchangers :**
  High-efficiency, compact Heat Exchangers to increase thermal performance and to reduce component weight and volume.

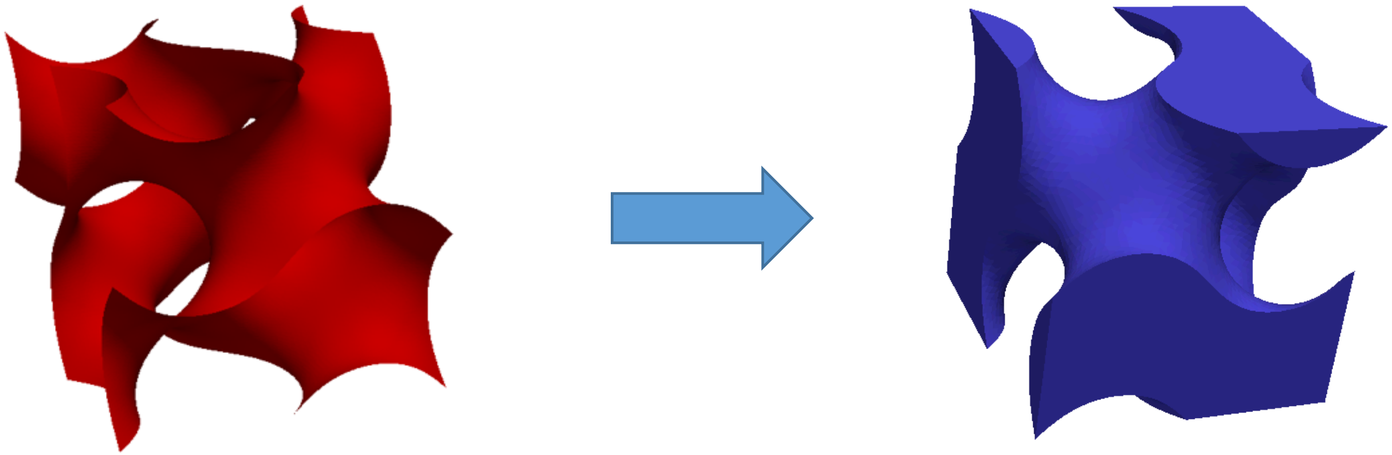
- **Lightweighting :**
  Space-efficient components & systems to minimise mass and volume whilst maintaining/improving functionality and capability.

Aims and Objective

Investigate the thermal performance of targeted lattice structures at a unit cell level.

The Gyroid minimal surface used as interface between the fluid and the solid:



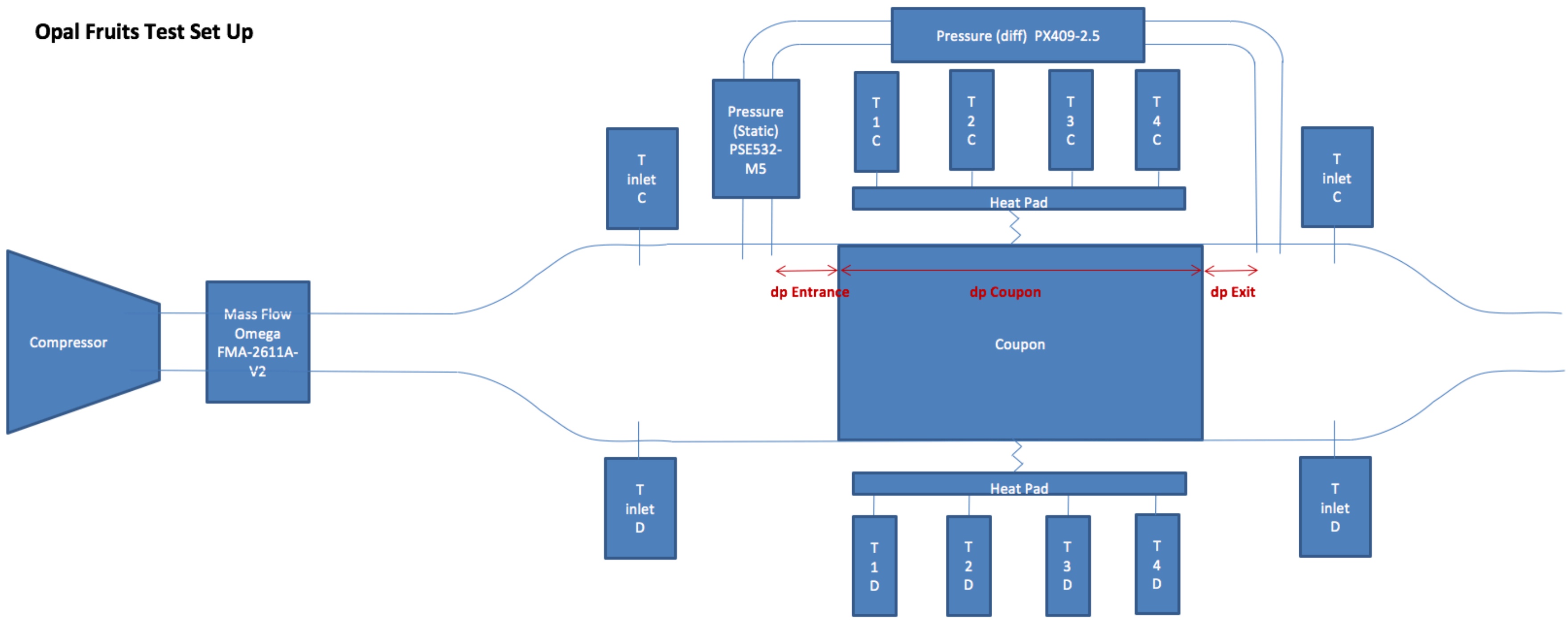
- Model for pressure drop and heat transfer of the flow through the gyroid as a function of the Reynolds number.

Methodology

1. **Validation :**
   - Manufacture of the test piece
   - Experimental evaluation
   - CFD analysis on the test piece

2. **CFD at Unit Cell Level of lattices with varying unit cell size and volume fraction:**
   - Developing a model for heat transfer and pressure drop in function of Re and Volume fraction.

Experimental Set up



Measure the difference in heat transfer and pressure drop between variations in geometry at different mass flow rates.

Cylindrical channel study

Comparison between testing, correlation and CFD for a cylindrical pipe.

Laminar Flow

Re <2300

$$Nu_{average} = \frac{h_{average}D}{k} = 3.66 + \frac{0.065\,\mathrm{Re}\,\mathrm{Pr}\,\frac{D}{L}}{1+0.04\left(\mathrm{Re}\,\mathrm{Pr}\,\frac{D}{L}\right)^{2/3}}$$

$$f = \frac{64}{Re}$$

Turbulent Flow

Re >4000

$$Nu = \frac{(f/8)(\mathrm{Re}-1{,}000)\mathrm{Pr}}{1+12.7(f/8)^{1/2}\left(\mathrm{Pr}^{2/3}-1\right)}$$

Re >10000

$$f = \frac{1}{\left[0.790\ln(\mathrm{Re})-1.64\right]^2}$$

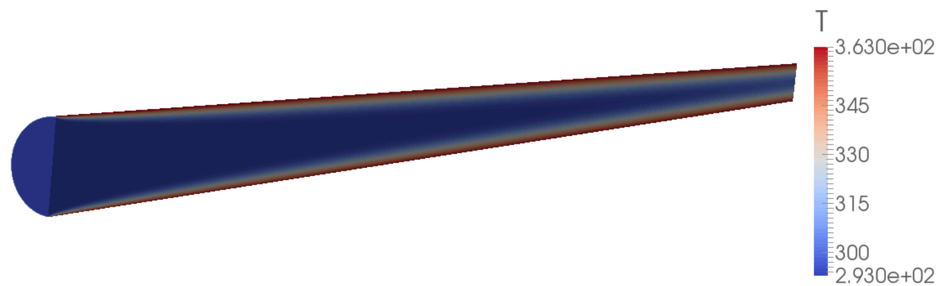
Cylindrical channel study

CFD set up

- Dimension : D = 3mm and L = 90mm
- Steady state simulations
- Constant wall temperature

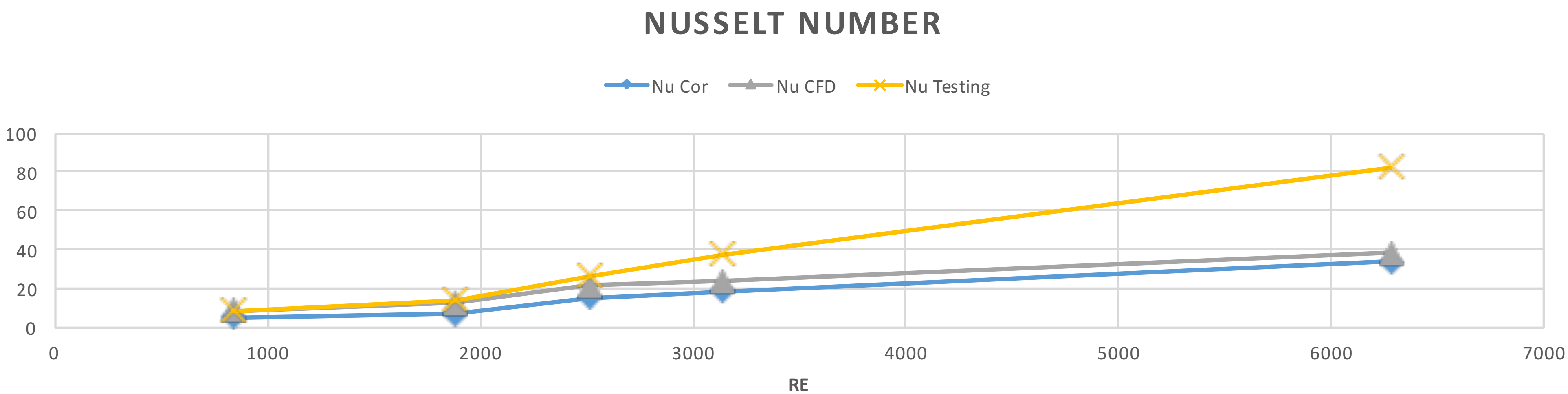
OpenFoam Solver used : BuoyantBoussinesqSimpleFoam

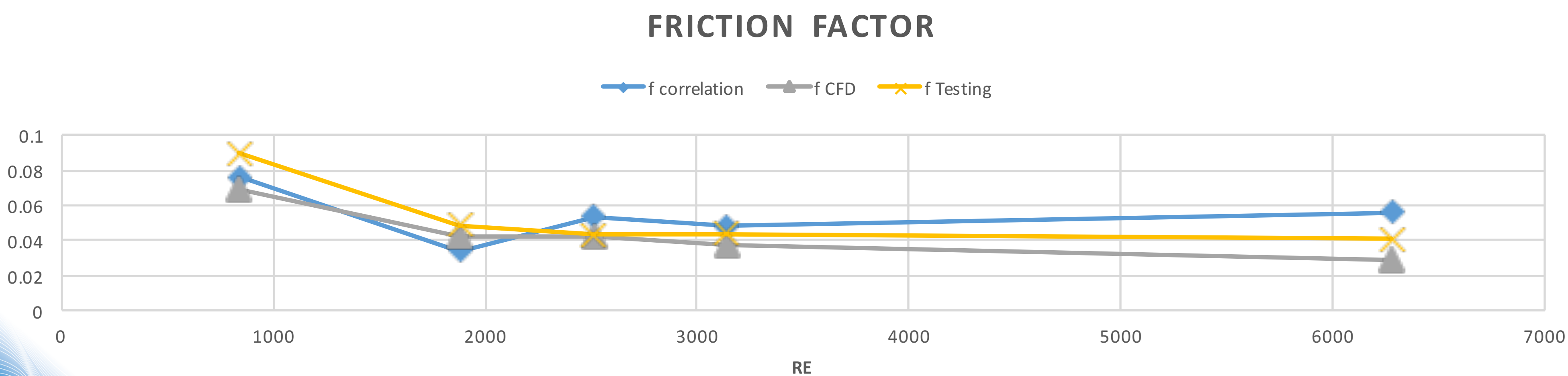
Various Reynolds numbers are modeled to cover different flow regimes.



Cylindrical channel study

Experimental, Simulation and Correlation results



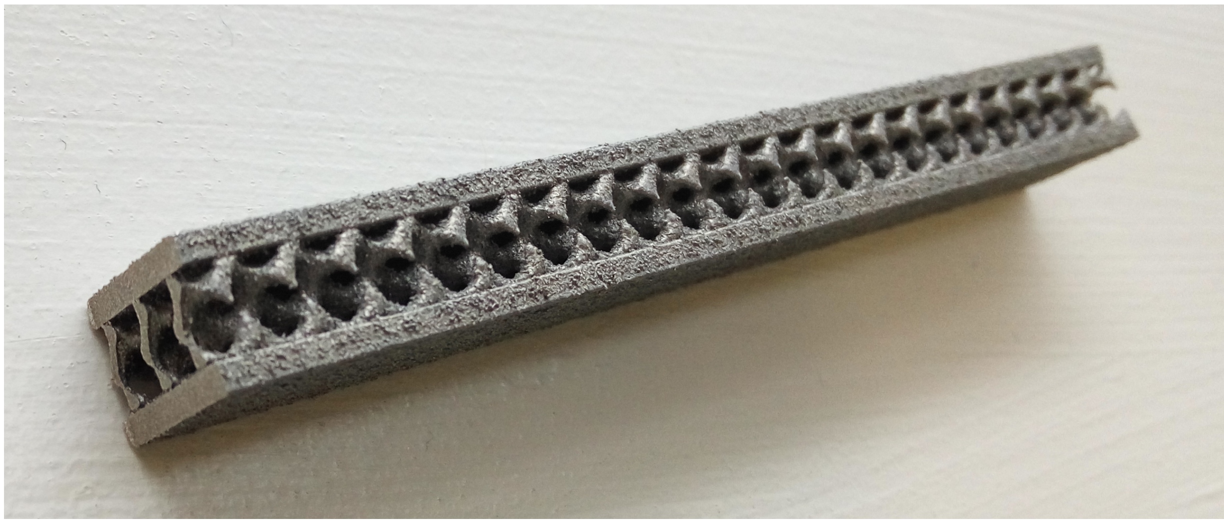


CFD characterization of pressure drop and heat transfer inside Gyroid lattices structures.

Gyroid test sample study

Lattice test specimen

Gyroid of 4mm cell size and 30% volume fraction:



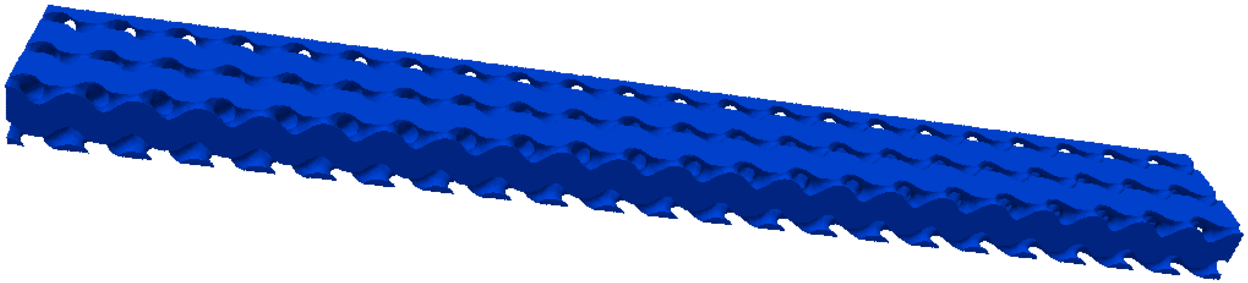
Reynolds numbers tested :

- Re= 920
- Re=1840
- Re=2400

Test piece dimension: 11 mm x 9 mm x 90 mm

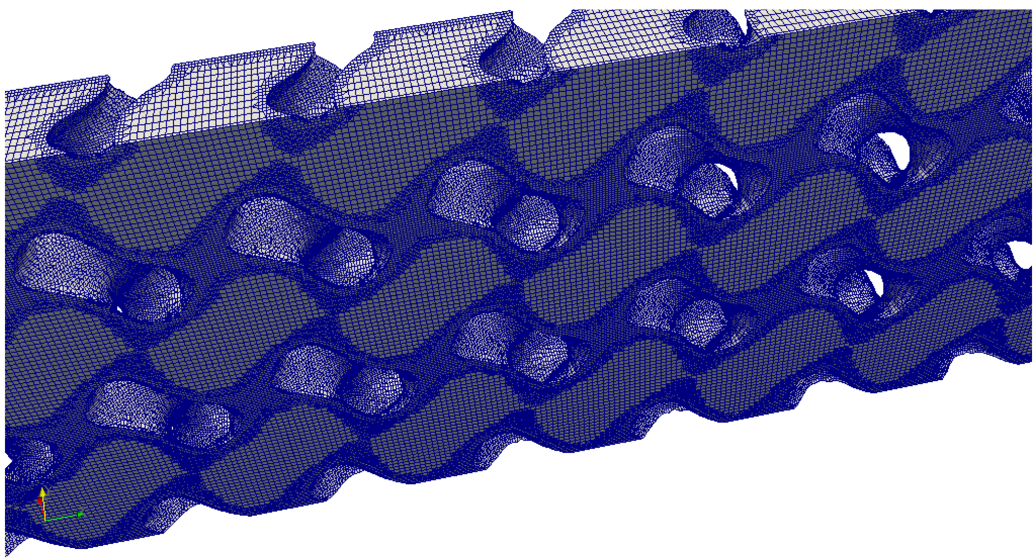
Gyroid test sample study

CFD set up

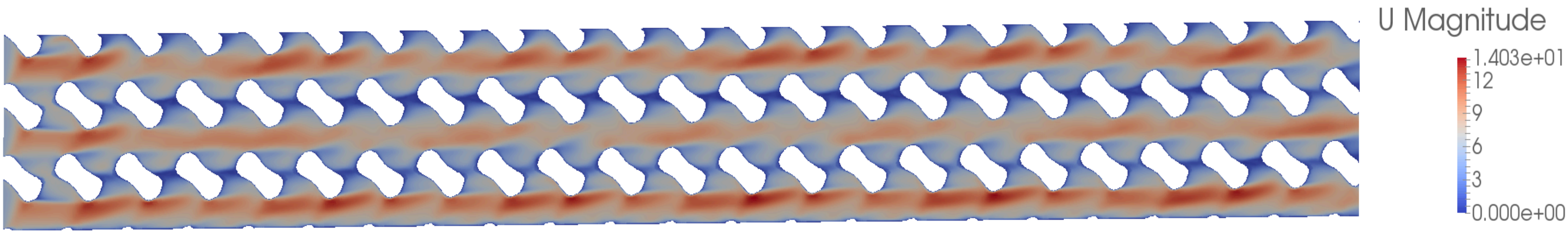


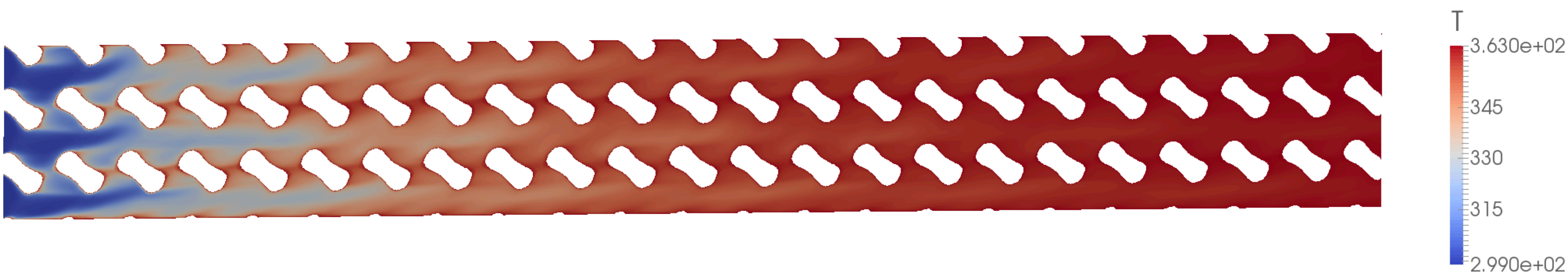
Steady state simulations
Constant wall temperature

OpenFoam Solver used : BuoyantBoussinesqSimpleFoam



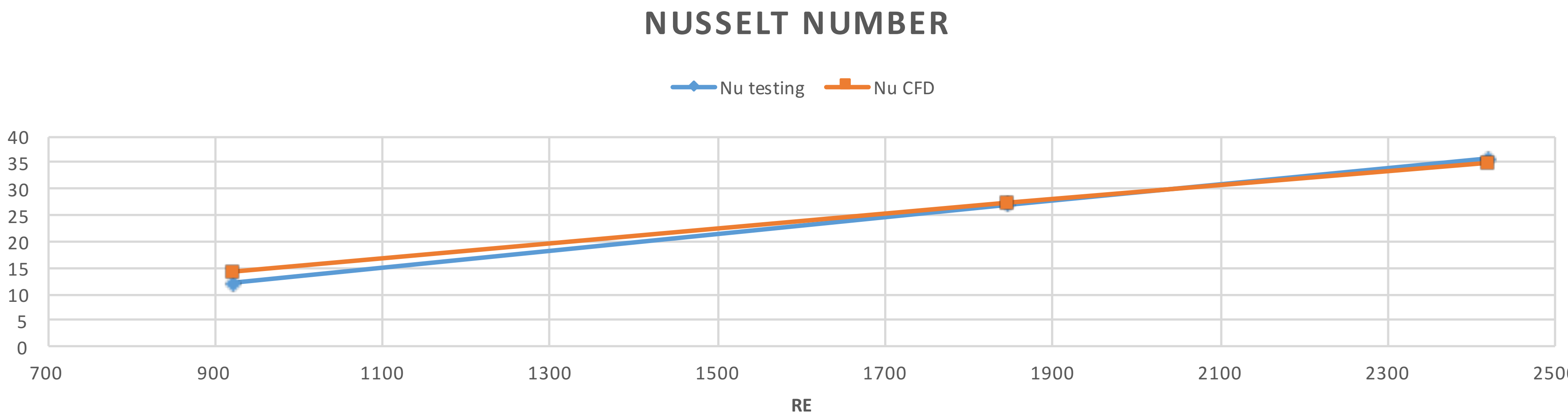
CFD results for Re=920

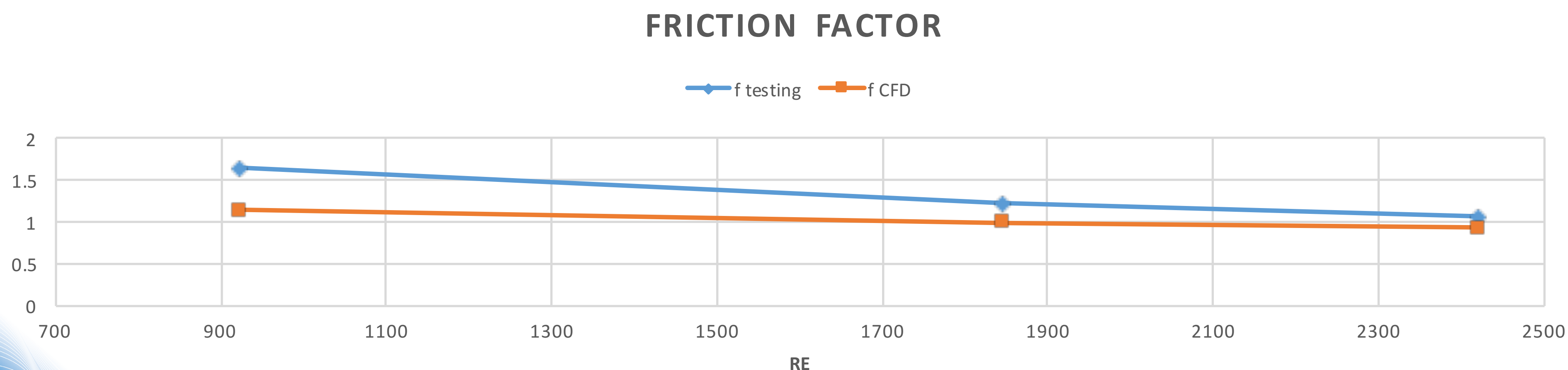




Gyroid test sample study

Comparison between CFD and experimental results





Conclusion

- The experimental results agree well with the CFD and the empirical correlations for pressure drop and heat transfer. This validates the utilization of the experimental results for the Gyroid lattice geometry.
- The CFD analysis on the test piece shows consistent results compared to the experimental results.
- The discrepancies between the experimental and modelled pressure drop can be explained by the roughness of the build part. Further analysis to be done to verify this point.

Future plan

- After completing the validation study:

  - Micro CT-scan of the part and evaluate the impact of the manufacturing process on the heat transfer and pressure drop.

  - Run the CFD at the unit cell level for several configurations and develop a model for heat transfer and pressure drop.