New/Advanced Hybrid Heat Recovery Systems with Integrated Vortex Generators - Numerical and Parametric Studies

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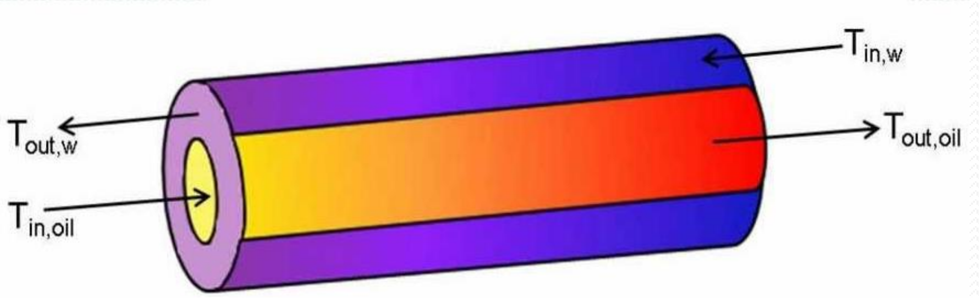
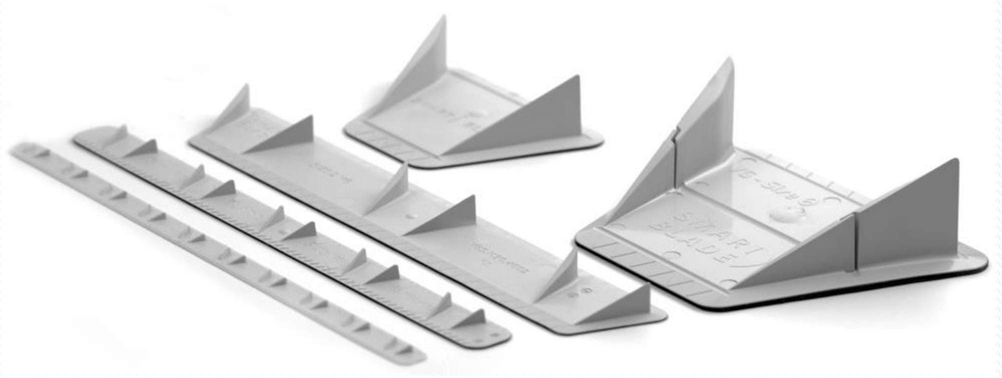
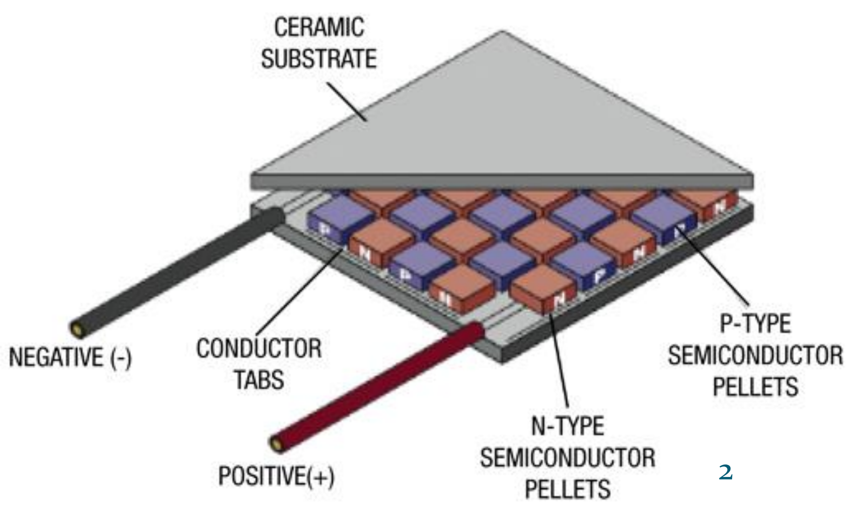
Concentric Tube Heat Exchanger



Vortex Generators



Thermoelectric Generators



Context and PhD objectives

Extensive literature reviews

- Heat Recovery systems (HRSs)
- Hybrid Heat Recovery systems (HHRSs)
- Thermoelectric Generators (TEGs)

Context and PhD objectives

Numerical Studies

- Suggesting a new design for heat recovery system with Vortex Generators (VGs).
- Performing numerical and parametric studies on four different cases of the presented design using Ansys Fluent.
- Applying the design on a heat recovery application to study its economical, environmental, and social impacts using the openLCA software.
- Replacing the VGs in the best design we obtain by TEGs.
- Replacing the tube of the concentric tube heat exchanger by a flexible TEG.

Context and PhD objectives

Objectives

- Tremendous literature reviews on Energy Recovery Systems.
- Effect of vortex generators on heat transfer, to define the enhancement of heat transfer that VGs offer.
- Employing TEGs as VGs in CTHE of the optimal design, to study the power generation TEG may generate.

1. Energy recovery in air conditioning systems: Comprehensive Review, Classifications, Critical Analysis and Potential Recommendations.

Rima Aridi, Jalal Faraj, Samer Ali, Mostafa Gad El-Rab, Thierry Lemenand, and Mahmoud khaled Energies, vol. 14, no. 18, p. 5869, 2021.

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- Heat Recovery systems are must in all applications

2. A Comprehensive Review on Hybrid Heat Recovery Systems: Classifications, Applications, Pros and Cons, and New Systems.

Rima Aridi, Jalal Faraj, Samer Ali, Thierry Lemenand, and Mahmoud khaled, **Renewable and Sustainable Energy Reviews**, vol 167, p 112669, 2022. Impact factor: **14,985** Rank **1 out of 44**

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- Hybrid Heat Recovery Systems are highly used especially with TEG

3. Thermoelectric Generators for Power Generation: Applications, Heat Recovery Methods, and Challenges.

Rima Aridi, Jalal Faraj, Samer Ali, Thierry Lemenand, and Mahmoud khaled, Electricity, vol.2, no. 3, pp. 359-386, 2021

→

- TEG is promising
- TEG was mainly used with HE

Energy Recovery Systems

Hybrid Heat Recovery Systems

Thermoelectric Generators

Heat Recovery System

+

TEGS in HHRS

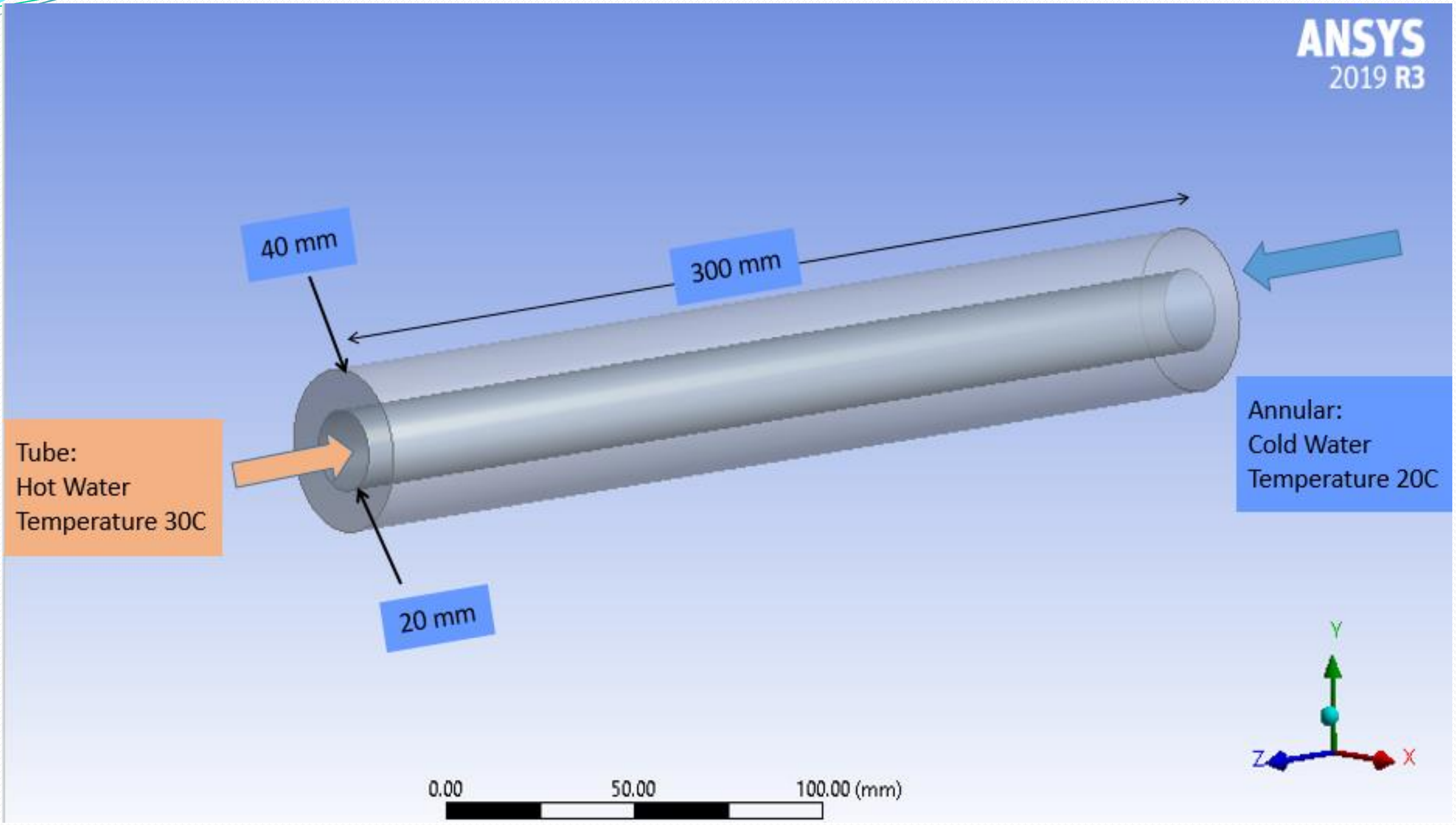
+

TEGs favorable advantages

→

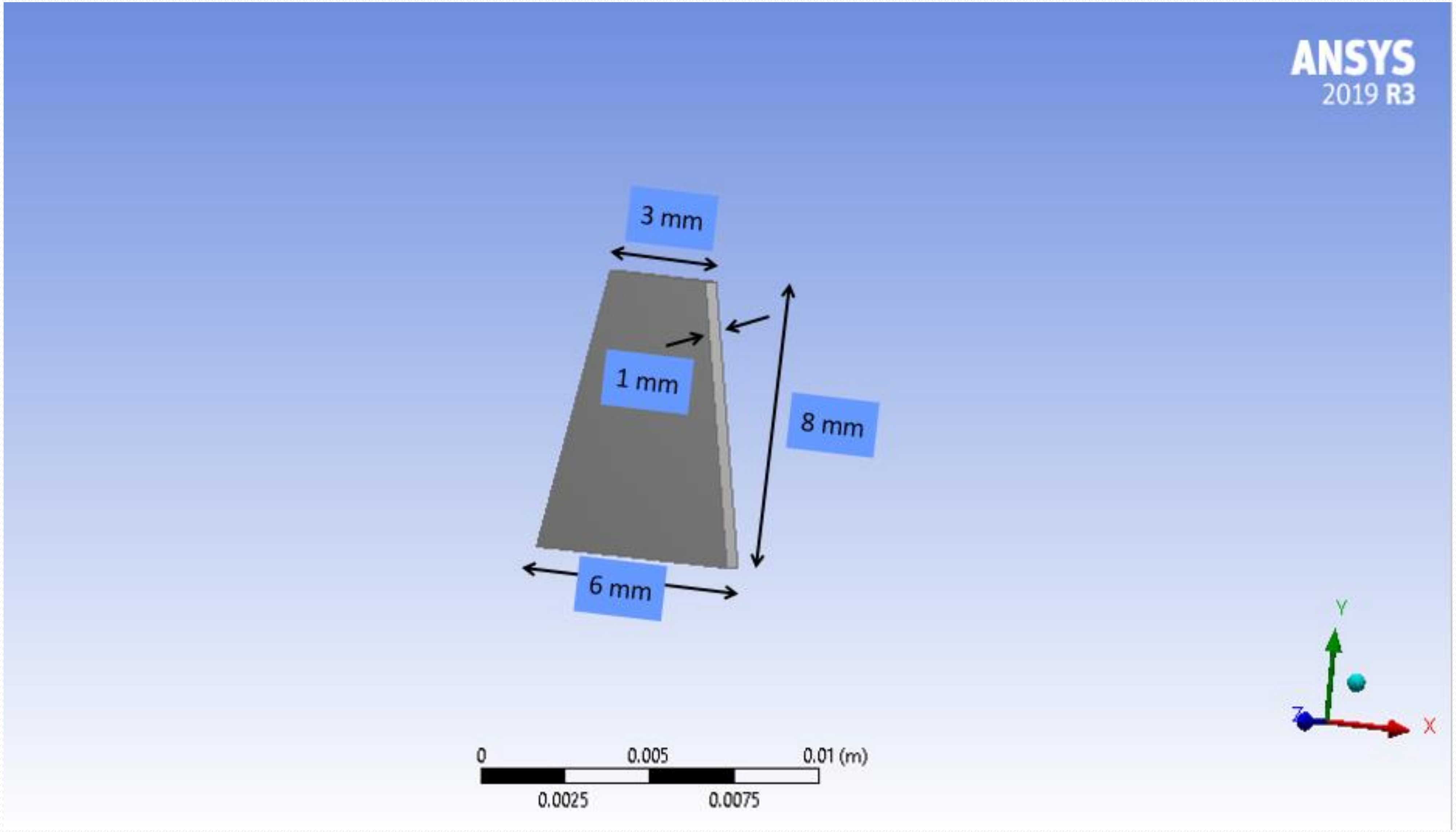
TEG in Heat Exchangers

Numerical Achievements



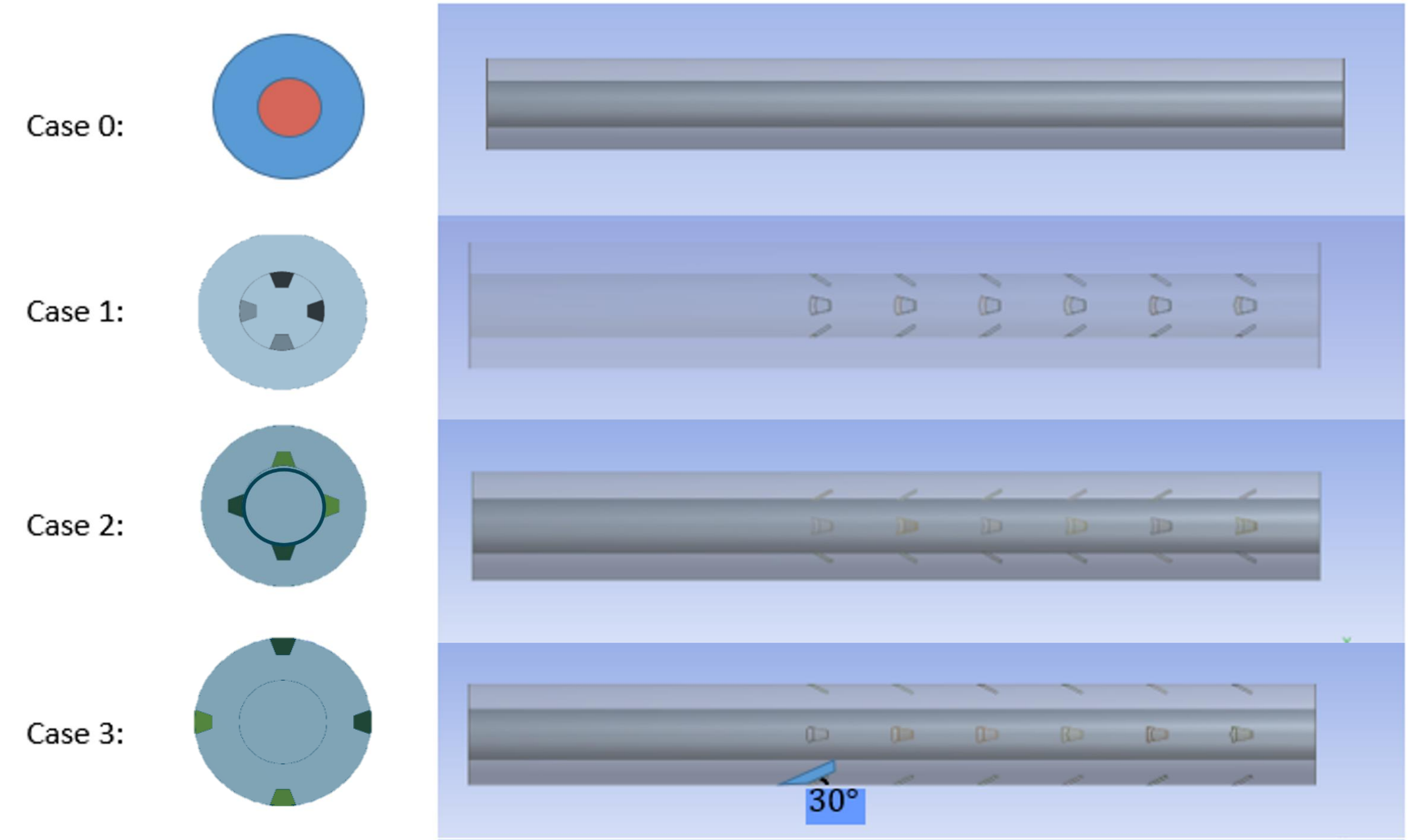
Concentric Tube Heat Exchanger design

Numerical Achievements



VG design

Numerical Achievements



Four different cases under study

Reynolds Number (Re)

$$Re = \frac{\rho\, u\, L}{\mu} = \frac{u\, L}{\nu}$$

ρ is the density of the fluid (kg/ m^3)

u is the velocity of the fluid (m/s)

L is the linear dimension (m)

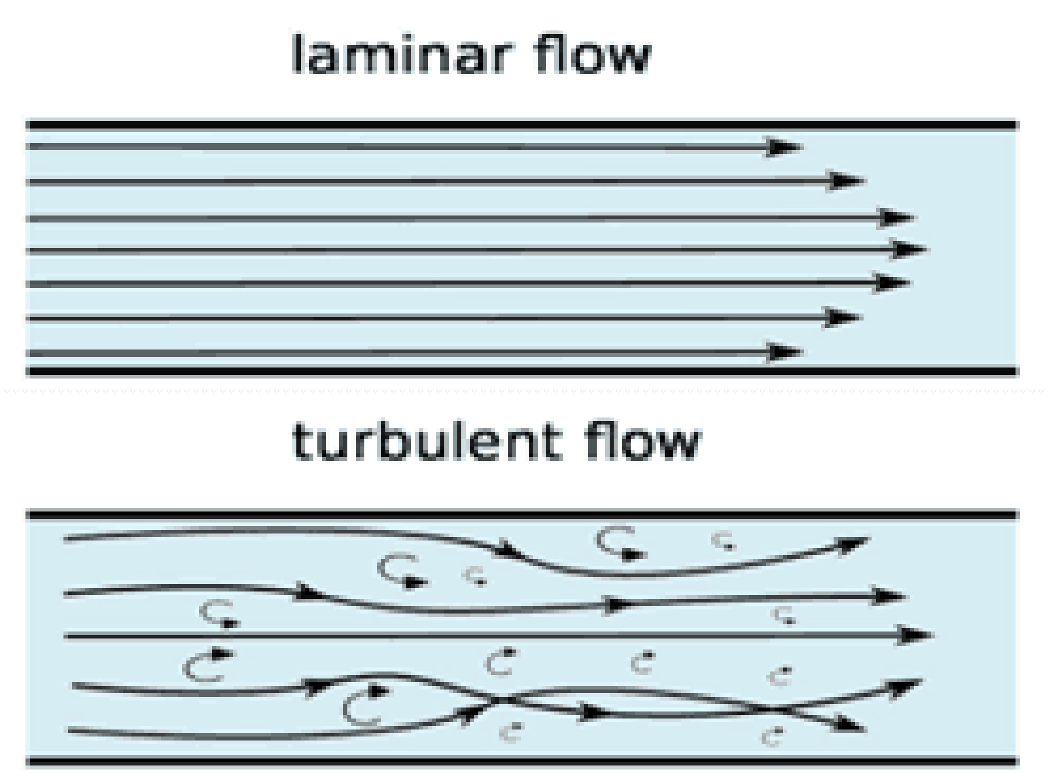
μ is the dynamic viscosity of the fluid kg/m.s

ν is the kinematic viscosity of the fluid (m^2/s)

Re < 2000 the flow is said to be laminar

2000 < Re <4000 the flow is in transition

Re > 4000 the flow is said to be turbulent



HW (tube)			CW (annular)		
		Re_i			Re_j
Laminar	i=1	500	Laminar	j=1	500
				j=2	1000
				j=3	2000
			Turbulent	j=4	4000
				j=5	6000
				j=6	8000
	i=2	1000	Laminar	j=1	500
				j=2	1000
				j=3	2000
			Turbulent	j=4	4000
				j=5	6000
				j=6	8000
	i=3	2000	Laminar	j=1	500
				j=2	1000
				j=3	2000
			Turbulent	j=4	4000
				j=5	6000
				j=6	8000
					18 simulations

HW (tube)			CW (annular)		
		Re_i			Re_j
Turbulent	i=4	4000	Laminar	j=1	500
				j=2	1000
				j=3	2000
			Turbulent	j=4	4000
				j=5	6000
				j=6	8000
	i=5	6000	Laminar	j=1	500
				j=2	1000
				j=3	2000
			Turbulent	j=4	4000
				j=5	6000
				j=6	8000
	i=6	8000	Laminar	j=1	500
				j=2	1000
				j=3	2000
			Turbulent	j=4	4000
				j=5	6000
				j=6	8000
					18 simulations

Reynolds number variation

36 simulations

36 x 4 = 144 simulations

Numerical Achievements

U/U0 overall heat transfer

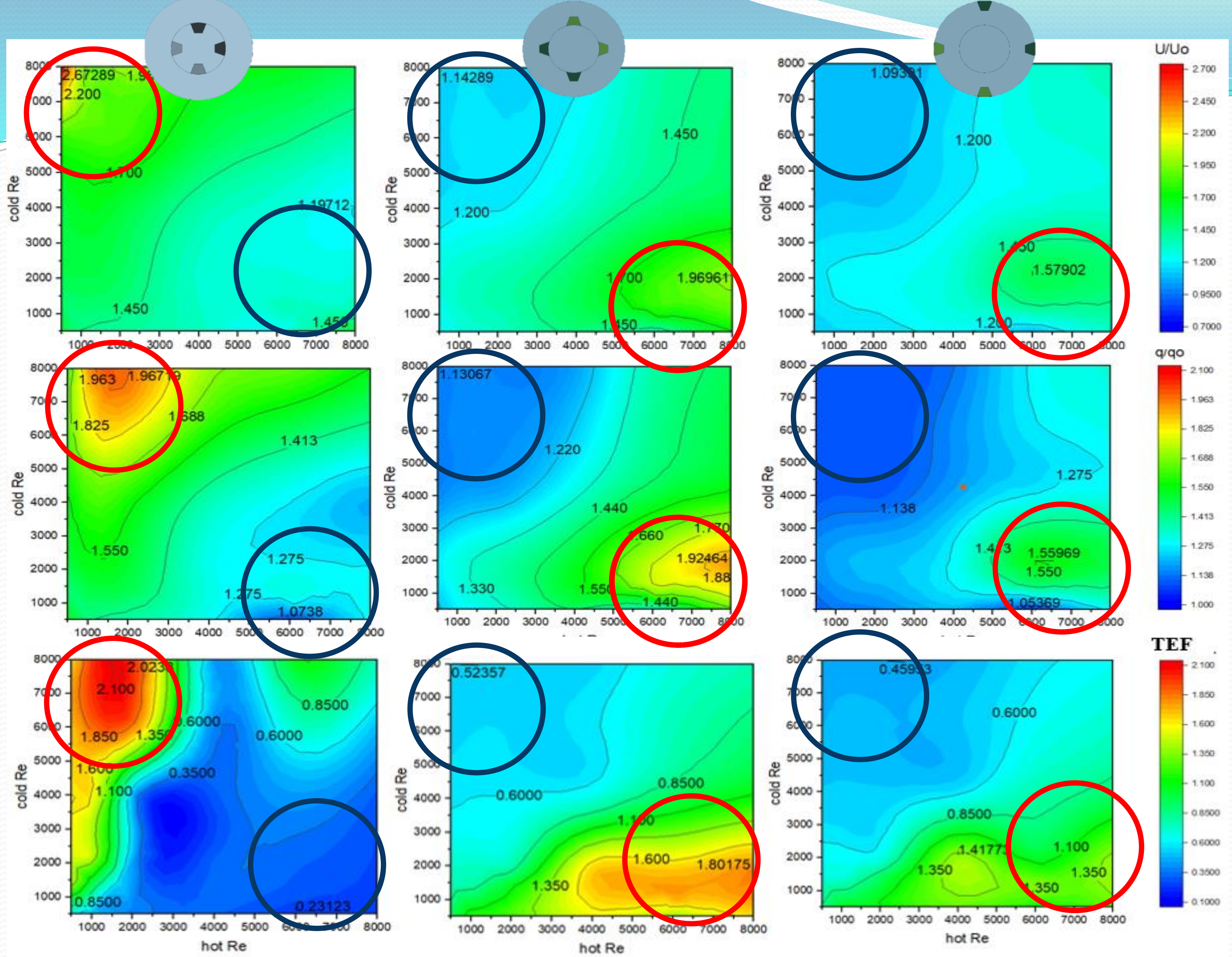
$$U = \frac{1}{\frac{1}{h_{annular}} + \frac{1}{h_{tube}}}$$

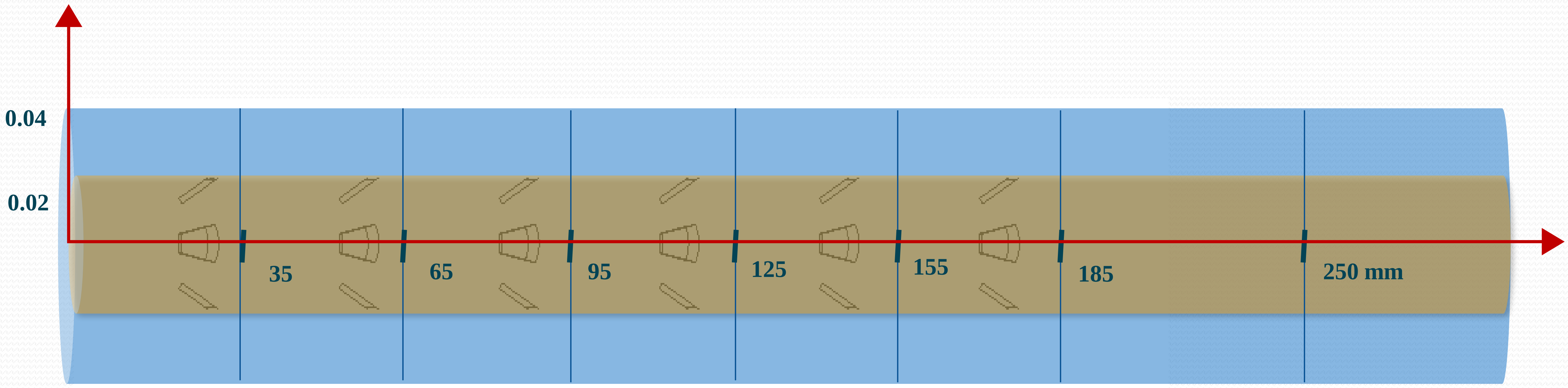
q/q0 heat transfer ratio that quantifies the enhancement in heat transfer when adding VGs to the empty design

$$q = \dot{m} \,.\, Cp \,.\, (T_i - T_o)$$

TEF Thermal Enhancement Factor quantifies the relative enhancement in heat transfer to the increasing in pumping power

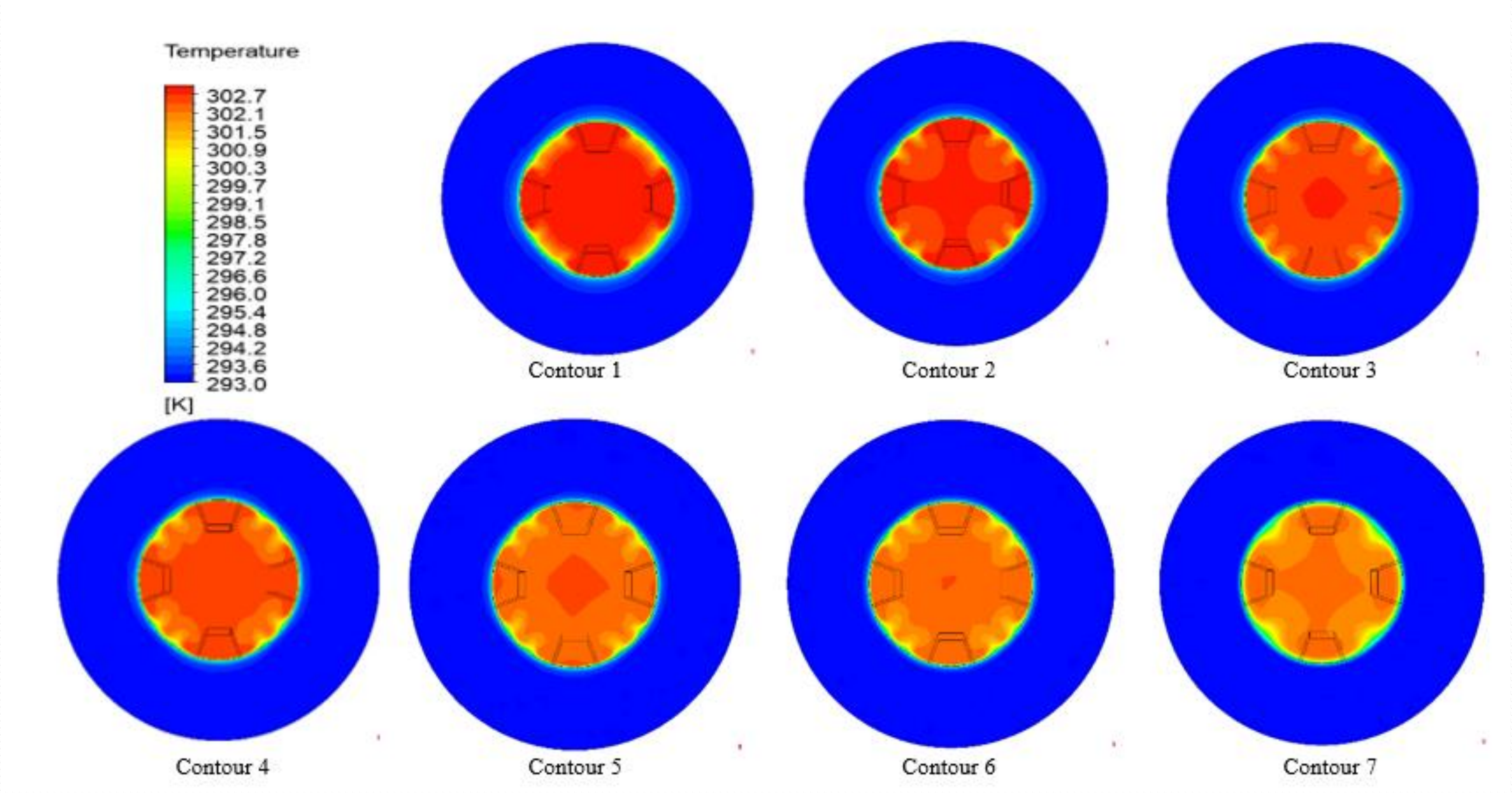
$$\boldsymbol{TEF} = \frac{q/q_0}{P/P_0} \text{ with } P/P_0 = \frac{(\Delta P_{hw} \,.\, \dot{m}_{hw} + \Delta P_{cw} \,.\, \dot{m}_{cw})}{(\Delta P_{hw,0} \,.\, \dot{m}_{hw,0} + \Delta P_{cw,0} \,.\, \dot{m}_{cw,0})}$$


U/Uo
q/qo
TEF
cold Re
hot Re
1.450
1.200
1.700
1.96961
1.57902
1.413
1.275
1.550
1.220
1.440
1.92464
1.138
1.55969
0.8500
0.6000
0.3500
2.100
1.850
1.600
1.80175
1.350
1.100

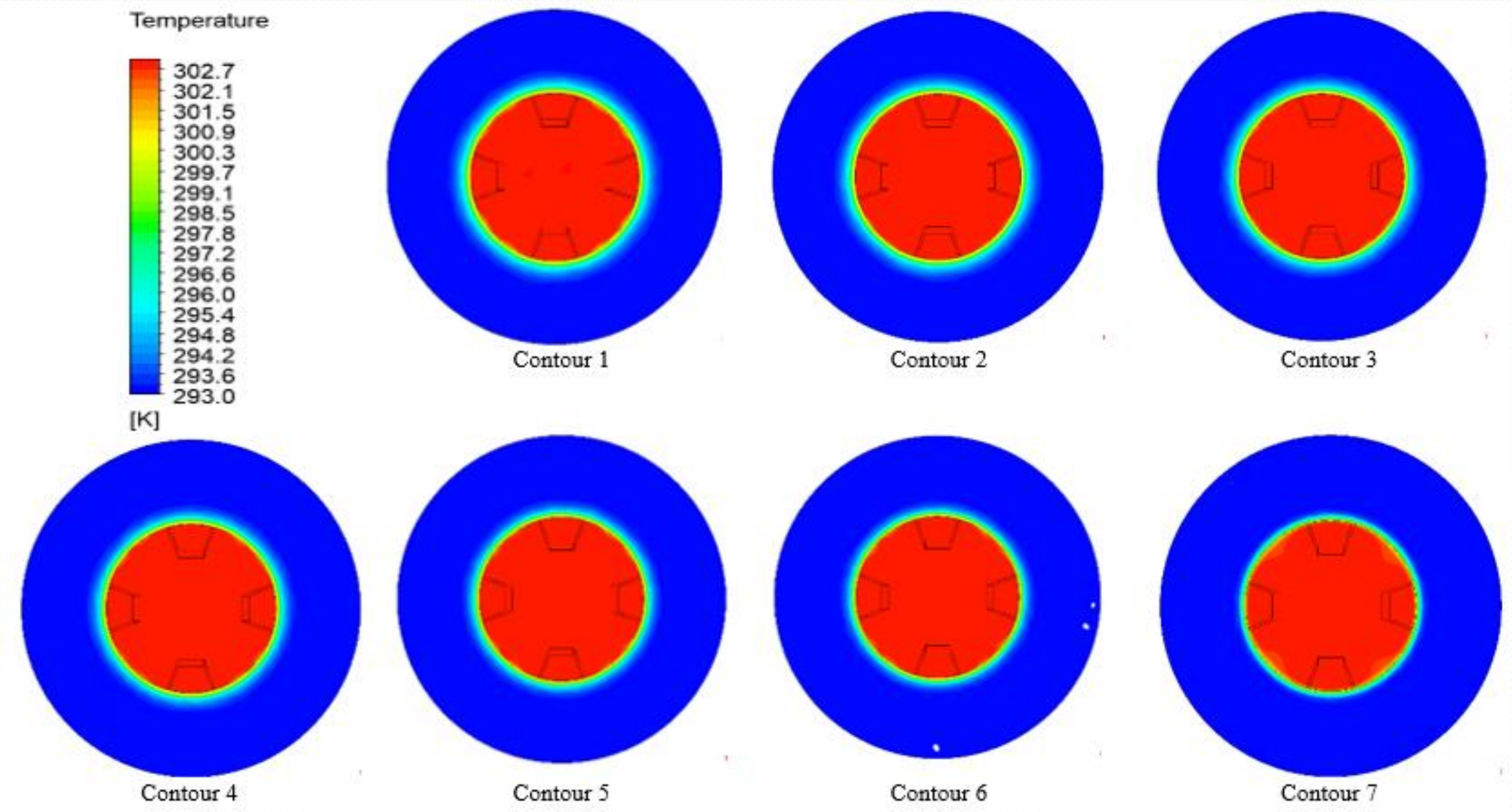


0.04
0.02
35
65
95
125
155
185
250 mm

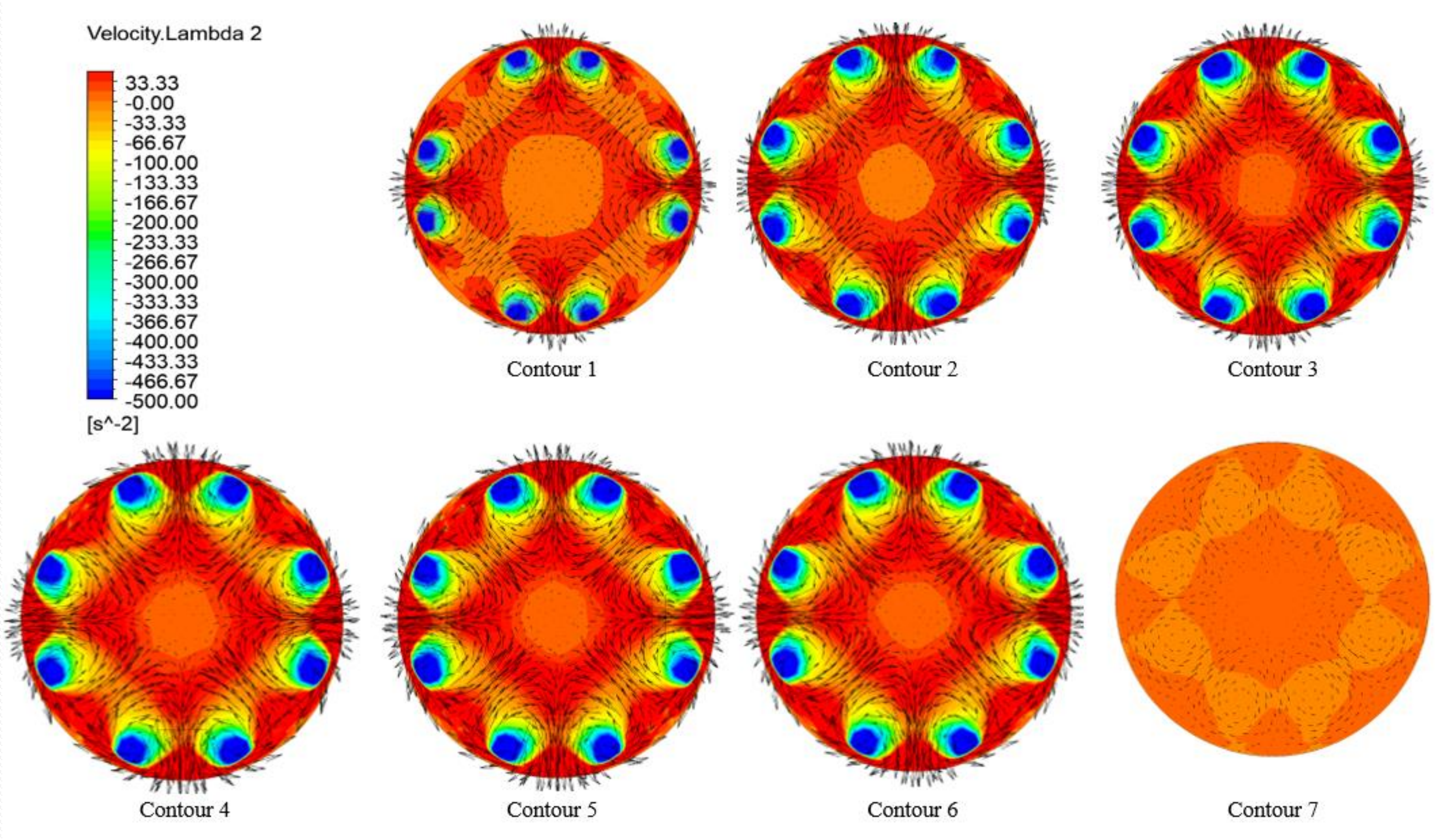
Temperature profiles of case 1 for Re_{hw} =2000 - Re_{cw} =8000.



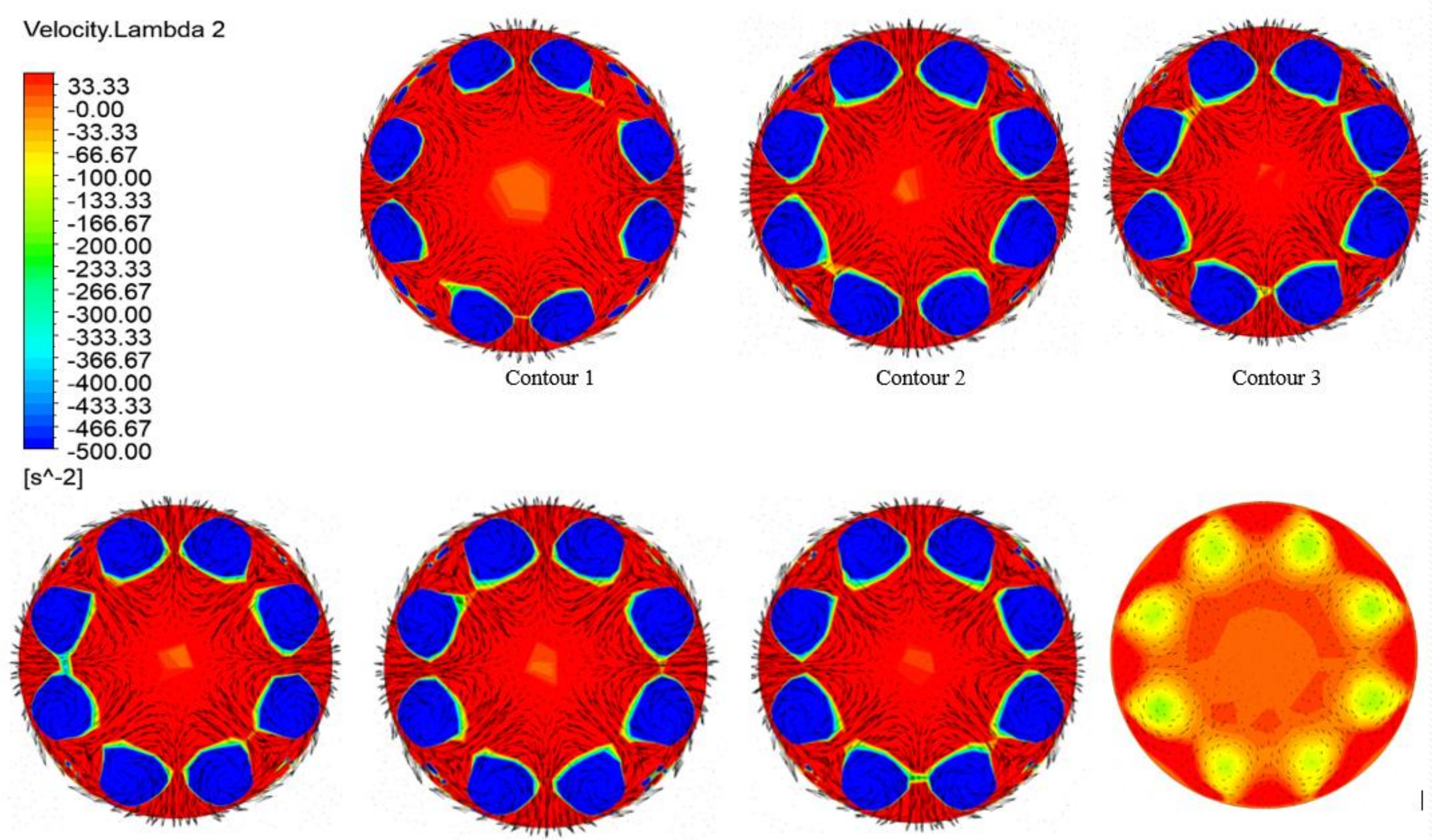
Temperature profiles of case 1 for Re_{hw} =8000 - Re_{cw} =2000.

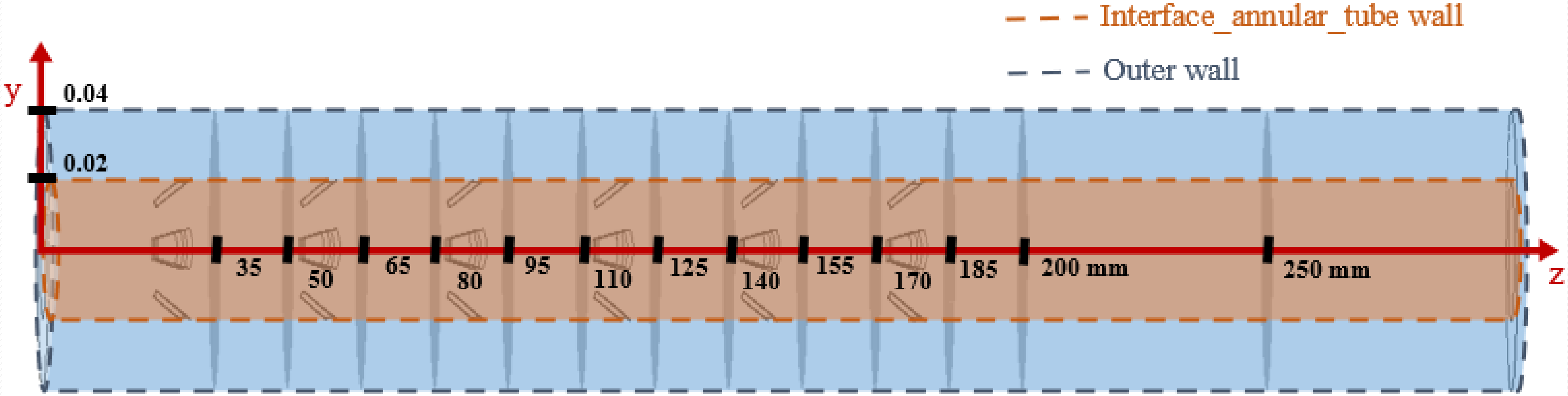


Velocity profiles of case 1 for Re_{hw} =2000 - Re_{cw} =8000.

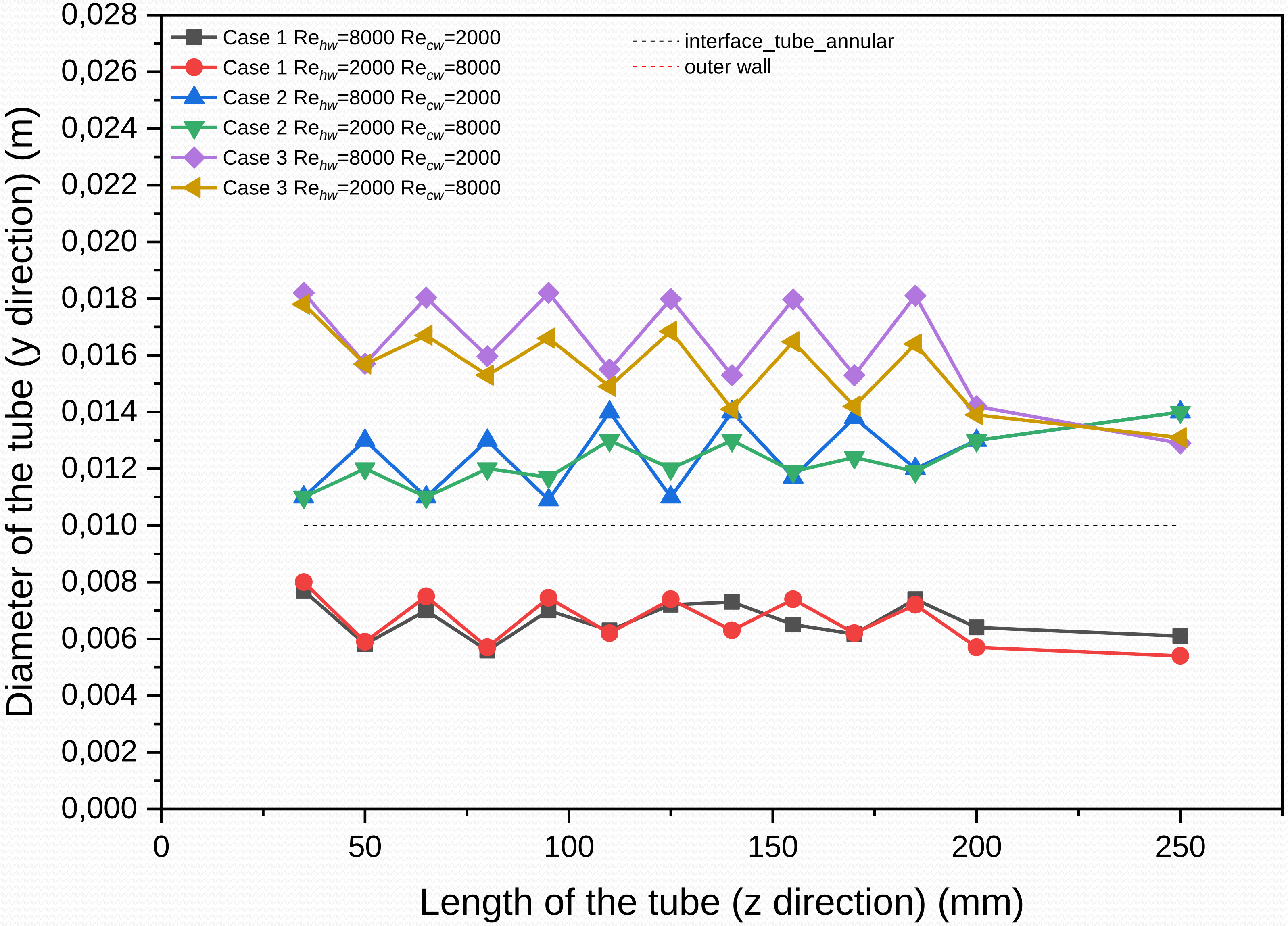


Velocity profiles of case 1 for Re_{hw} =8000 - Re_{cw} =2000.

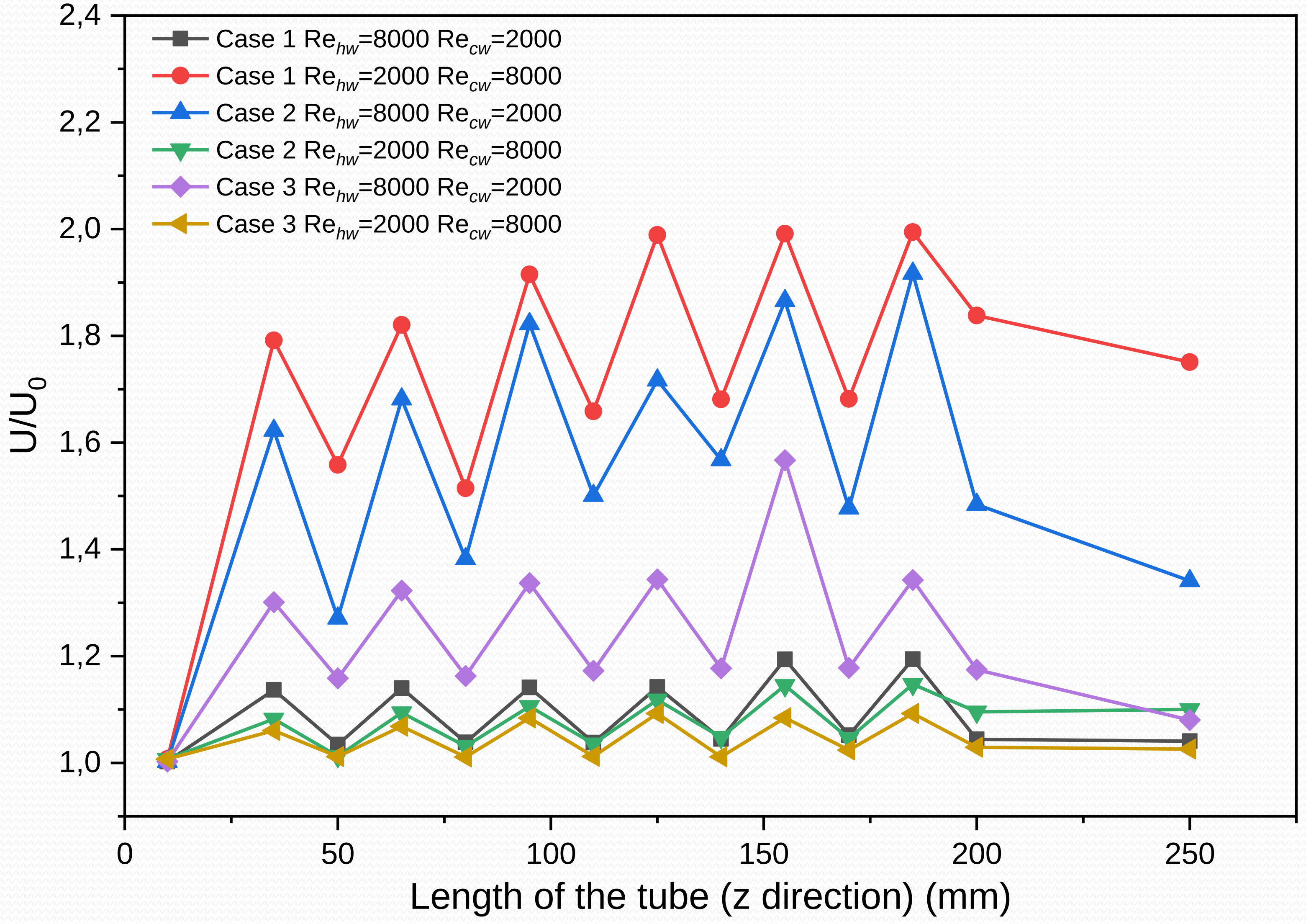



Interface_annular_tube wall
Outer wall
y
0.04
0.02
35
50
65
80
95
110
125
140
155
170
185
200 mm
250 mm
z

Second year work

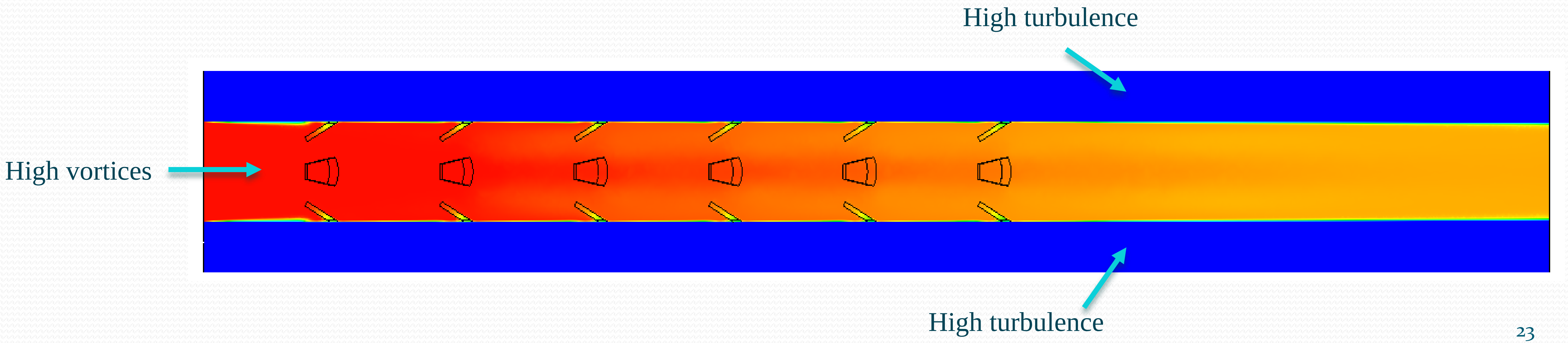


Second year work

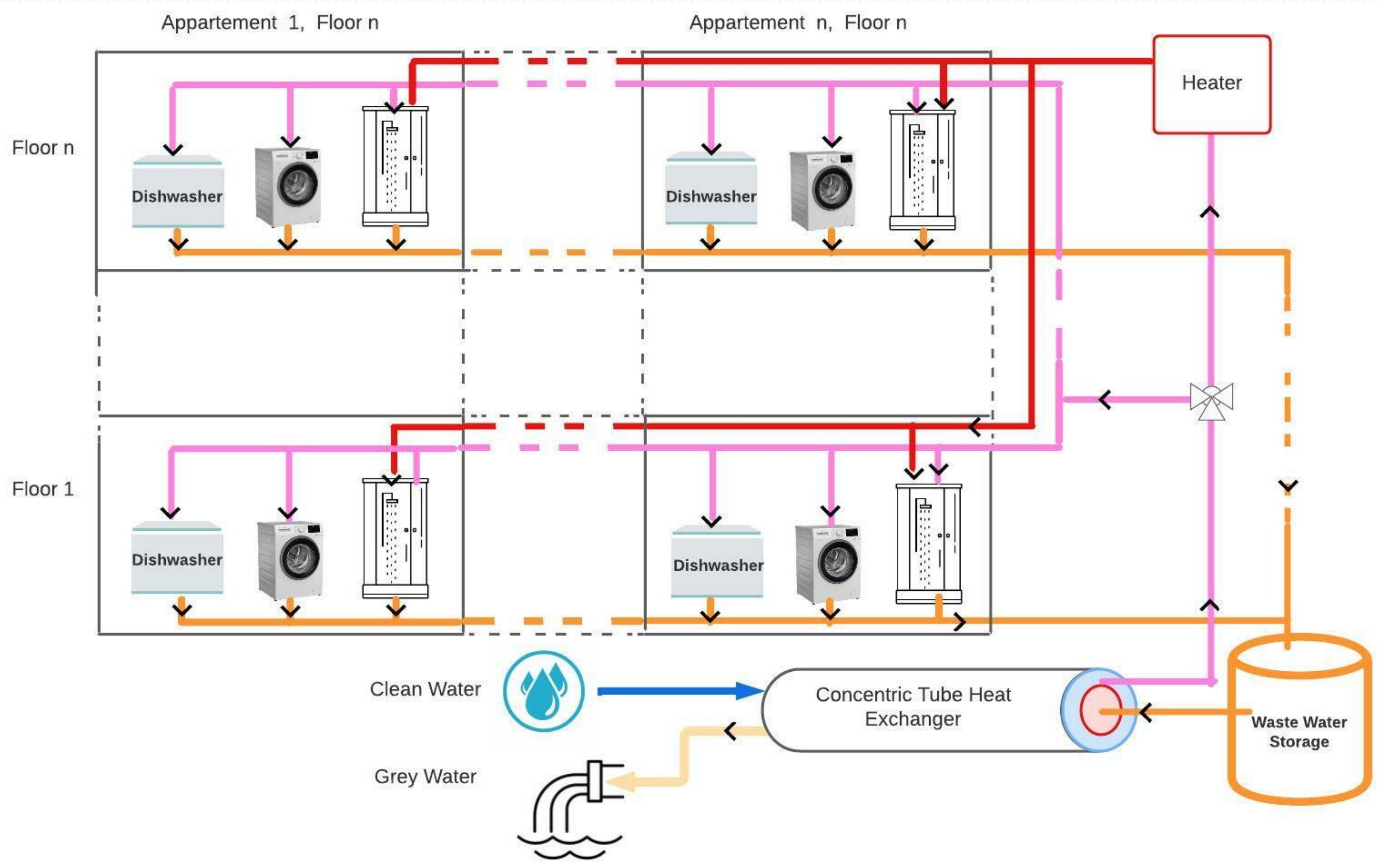


Conclusion

- VGs enhance heat transfer in all the three cases.
- Turbulence in both regions not just one region.
- Having vortices in hot region and turbulence in cold region is the optimal case for this study.



Practical Study



Economical

Environmental

Social

Impacts of the HRS

Published work

1. A Comprehensive Review on Hybrid Heat Recovery Systems: Classifications, Applications, Pros and Cons, and New Systems.

Rima Aridi, Jalal Faraj, Samer Ali, Thierry Lemenand, and Mahmoud khaled, **Renewable and Sustainable Energy Reviews**, vol 167, p 112669, 2022. Impact factor: **14,985** Rank **1 out of 44**

2. Energy recovery in air conditioning systems: Comprehensive Review, Classifications, Critical Analysis and Potential Recommendations.

Rima Aridi, Jalal Faraj, Samer Ali, Mostafa Gad El-Rab, Thierry Lemenand, **Energies**, vol. 14, no. 18, p. 5869, 2021. Impact factor: **3,004**

3. Thermoelectric Generators for Power Generation: Applications, Heat Recovery Methods, and Challenges.

Rima Aridi, Samer Ali, Thierry Lemenand, Jalal Faraj, and Mahmoud khaled, **Electricity**, vol.2, no. 3, pp. 359-386, 2021. Impact factor: **2,62**

Literature review

4. CFD analysis on the spatial effect of Vortex Generators in Concentric Tube Heat Exchangers – A comparative study.

Rima Aridi, Samer Ali, Thierry Lemenand, Jalal Faraj, and Mahmoud khaled, **International Journal of Thermofluids,**

Impact Factor: **9,47**,

5. Thermoeconomic, environmental, and social analysis of vortex generator-equipped multi-drain heat recovery systems

Rima Aridi, Samer Ali, Thierry Lemenand, Jalal Faraj, and Mahmoud khaled, **to be submitted**

Numerical analysis

THANK YOU FOR LISTENING