RYERSON UNIVERSITY

Numerical Investigation of Heat Transfer of Aluminum Metal Foam Subjected to Pulsating flow

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Objectives

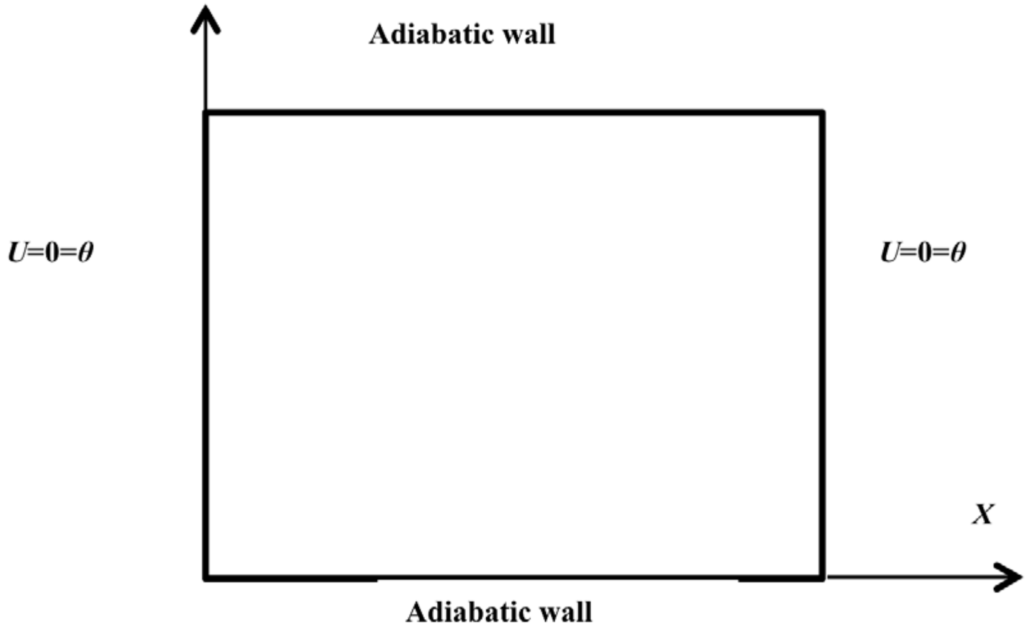
- To investigate whether nanofluids enhance the heat extraction

- To study numerically the heat transfer characteristics of using aluminum metal foam (porous media) as heat sink of electronic devices surface subjected to both steady and pulsating air flow and then nanofluids.

Nanofluids

- Nanofluids are engineered colloids= base fluid(water or any other liquid)+nanoparticles.
- Nanoparticles materials:Oxides(Al_2O_3, ZrO_2,SiO_2,Fe_3O_4), Stable metals (Au, Cu), Carbon(fullerene),Polymers (Teflon)
- Particle size is small(1-100 nm)
- High surface to volume ratio(High energy and mass transfer rates)

Finite element model



Nanofluid: Water-Al_2O_3

$$\frac{\mu_{nf}}{\mu_{bf}} = 1 + 4.93c_v + 222.4\, c_v^2$$

$$\rho_{nf} = c_v\rho_p + (1 - c_v)\rho_{bf}$$

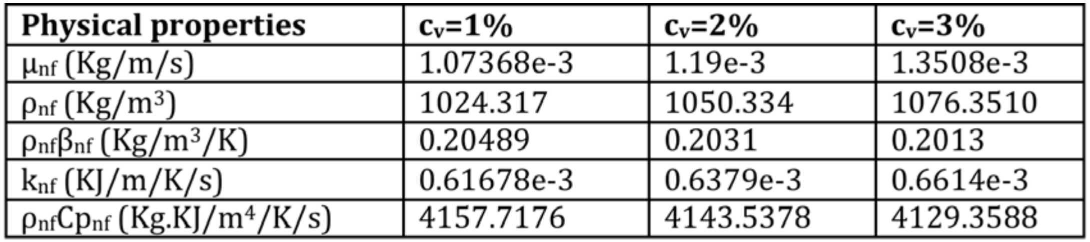
$$\rho_{nf}\beta_{nf} = (1 - c_v)\rho_{bf}\beta_{bf} + c_v\rho_p\beta_p$$

$$\frac{k_{nf}}{k_{bf}} = 1 + 2.944c_v + 19.672c_v^2$$

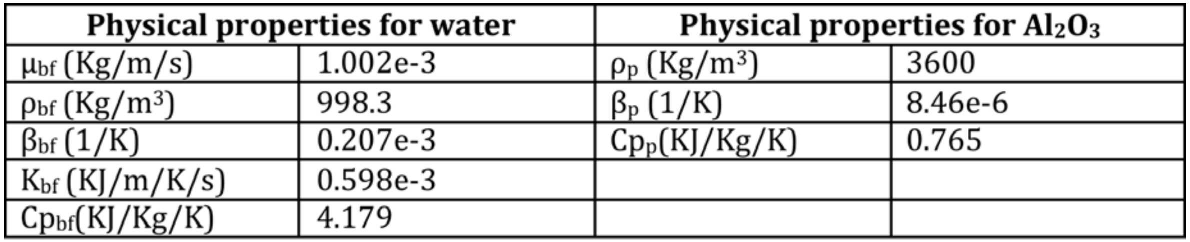
$$\rho_{nf}Cp_{nf} = c_v\rho_pCp_p + (1 - c_v)\rho_{bf}Cp_{bf}$$

c_v	Rayleigh number	Prandtl number
1%	7.74547e7	7.0659
2%	6.6751180e7	7.3593
3%	5.6020687e7	7.8353

Nanofluid: Water-Al_2O_3(cont'd)



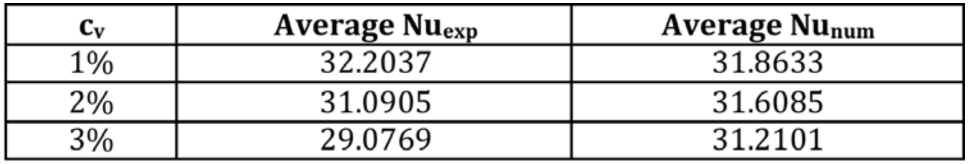
Physical properties	**c_v=1%**	**c_v=2%**	**c_v=3%**
μ_{nf} (Kg/m/s)	1.07368e-3	1.19e-3	1.3508e-3
ρ_{nf} (Kg/m^3)	1024.317	1050.334	1076.3510
$\rho_{nf}\beta_{nf}$ (Kg/m^3/K)	0.20489	0.2031	0.2013
k_{nf} (KJ/m/K/s)	0.61678e-3	0.6379e-3	0.6614e-3
$\rho_{nf}Cp_{nf}$ (Kg.KJ/m^4/K/s)	4157.7176	4143.5378	4129.3588



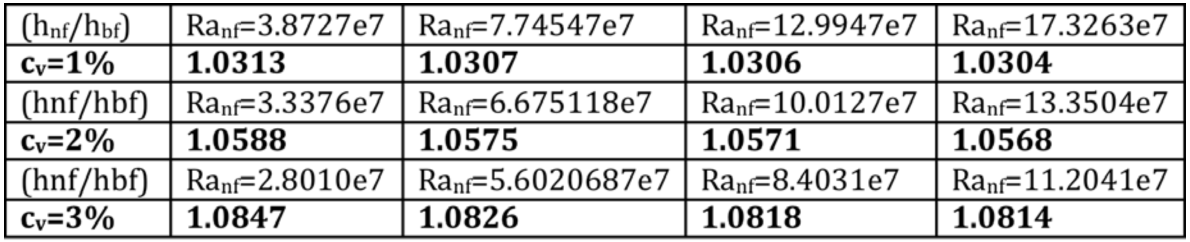
Physical properties for water		**Physical properties for Al_2O_3**	
μ_{bf} (Kg/m/s)	1.002e-3	ρ_p (Kg/m^3)	3600
ρ_{bf} (Kg/m^3)	998.3	β_p (1/K)	8.46e-6
β_{bf} (1/K)	0.207e-3	Cp_p(KJ/Kg/K)	0.765
K_{bf} (KJ/m/K/s)	0.598e-3		
Cp_{bf}(KJ/Kg/K)	4.179		

Nanofluid: Water-Al_2O_3(cont’d)

$$\overline{Nu_{nf}} = 0.069 * \left(\frac{Pr_{nf,h}}{Pr_{nf}}\right)^{0.333} * (\frac{\beta_{nf,h}}{\beta_{nf}})^{0.404}$$

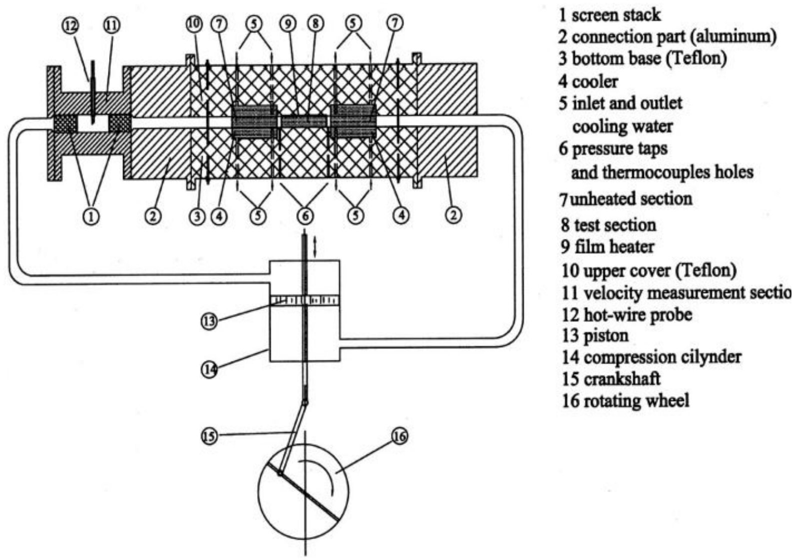


c_v	**Average Nu_{exp}**	**Average Nu_{num}**
1%	32.2037	31.8633
2%	31.0905	31.6085
3%	29.0769	31.2101

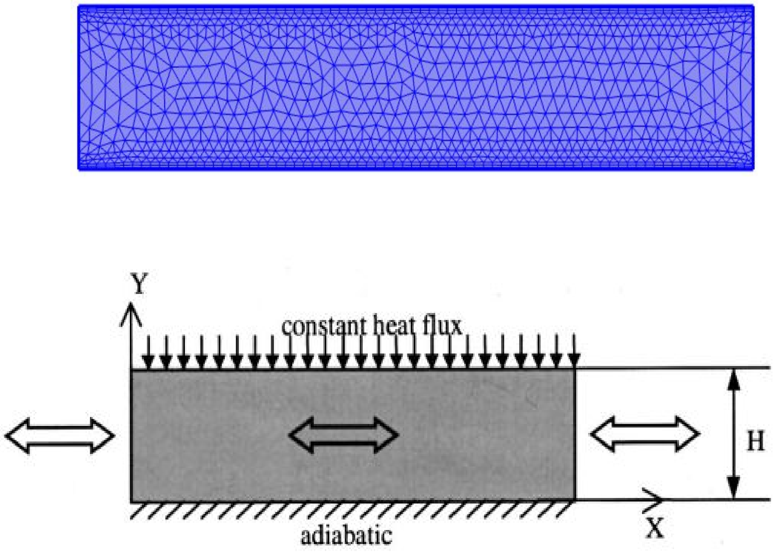


(h_{nf}/h_{bf})	Ra_{nf}=3.8727e7	Ra_{nf}=7.74547e7	Ra_{nf}=12.9947e7	Ra_{nf}=17.3263e7
c_v=1%	**1.0313**	**1.0307**	**1.0306**	**1.0304**
(hnf/hbf)	Ra_{nf}=3.3376e7	Ra_{nf}=6.675118e7	Ra_{nf}=10.0127e7	Ra_{nf}=13.3504e7
c_v=2%	**1.0588**	**1.0575**	**1.0571**	**1.0568**
(hnf/hbf)	Ra_{nf}=2.8010e7	Ra_{nf}=5.6020687e7	Ra_{nf}=8.4031e7	Ra_{nf}=11.2041e7
c_v=3%	**1.0847**	**1.0826**	**1.0818**	**1.0814**

Model Description



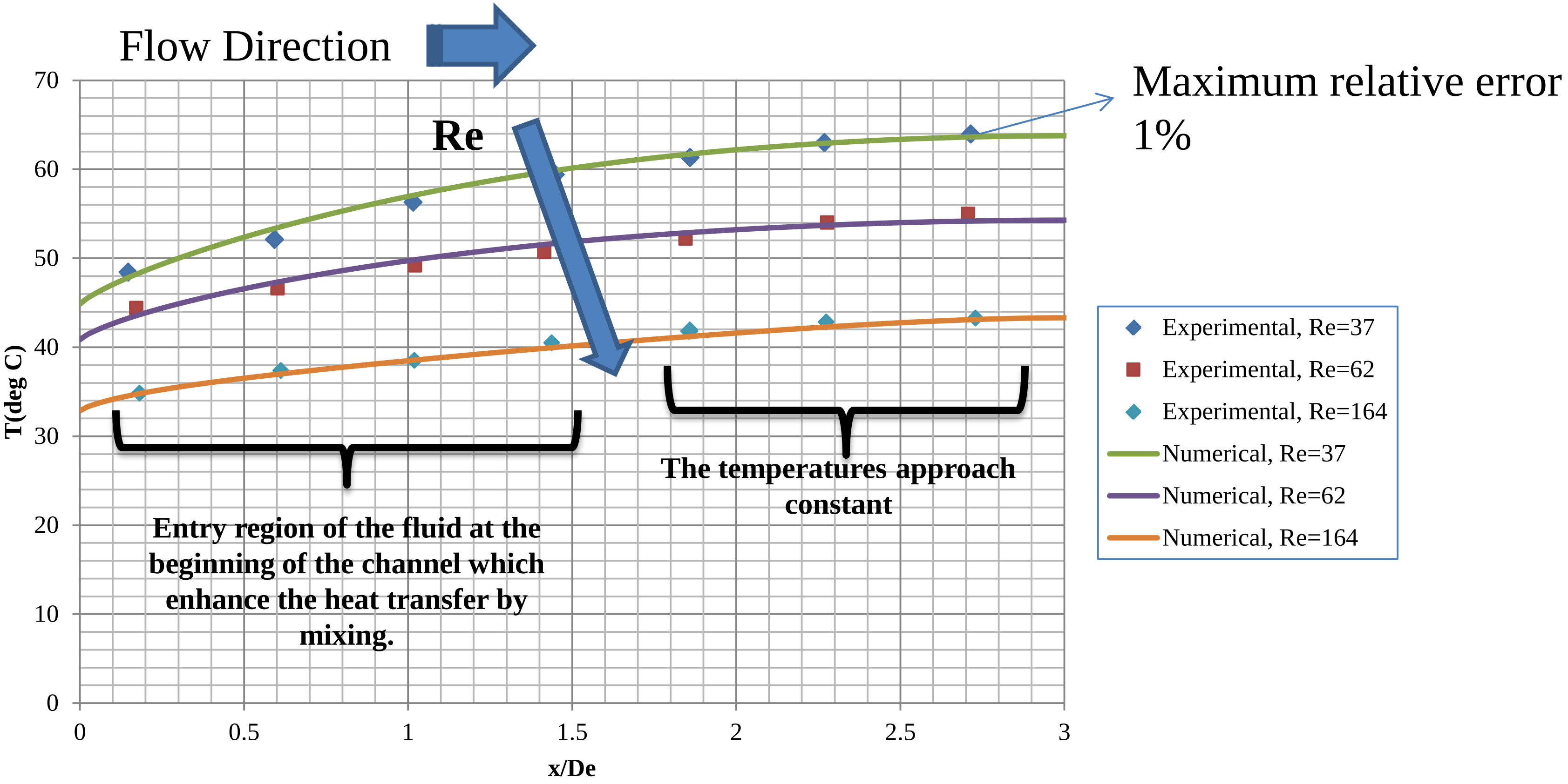
Schematic diagram of the experimental facility presented by Fu et al. [3]



COMSOL model

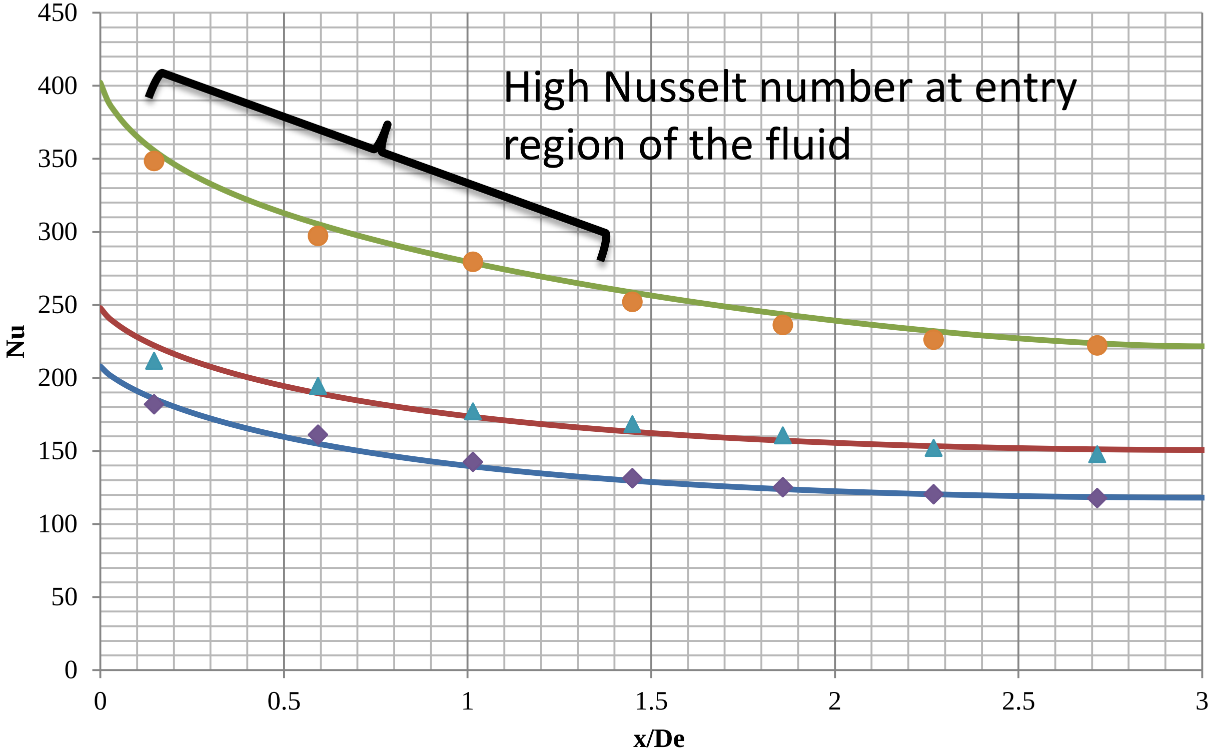
Results

- Time average local temperature distribution for **steady flow** at 0.8 W/cm^2



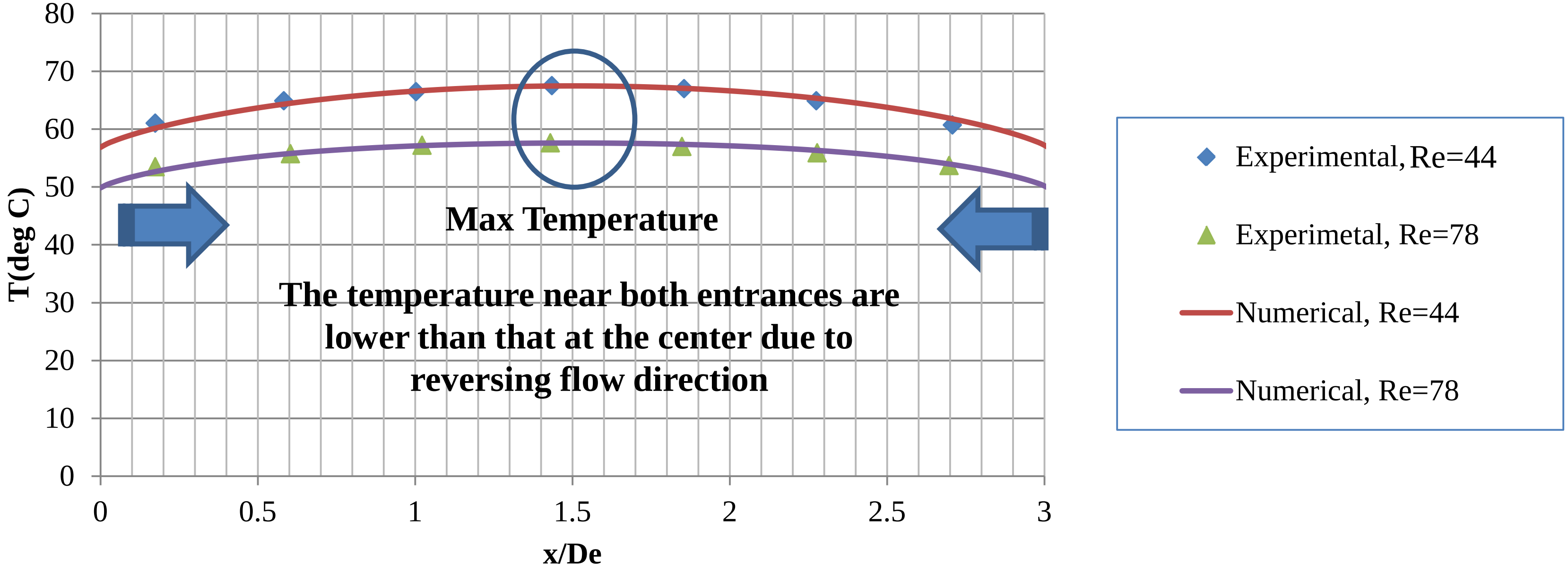
Results (cont'd)

- local Nusselt number distribution for **steady flow** at 0.8 W/cm^2



Results(cont’d)

- Time average local temperature distribution for **Pulsating flow** at 0.8 W/cm^2

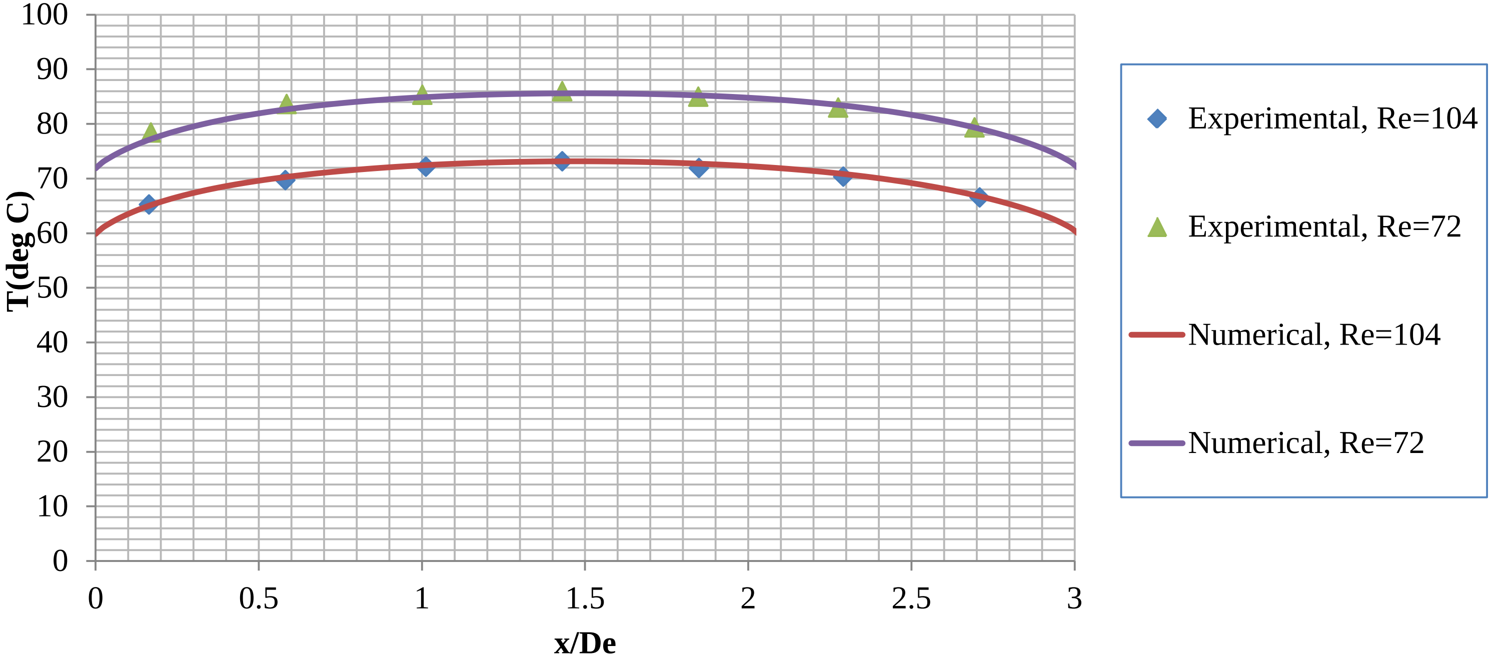


Max Temperature

The temperature near both entrances are lower than that at the center due to reversing flow direction

Results(cont’d)

- Time average local temperature distribution for **Pulsating flow** at 1.6 W/cm^2



Conclusions

- **For steady flow** the local average temperature distribution along heated surface increases with increasing the dimensionless axial position and decreasing the Reynolds number

- **For pulsating flow** the local temperature distributions acts as convex curve with a maximum point at the center

- The pulsating flow achieves more temperature uniformity than steady flow