Numerical simulation of heat and mass transfer in direct membrane distillation in a hollow fiber module with laminar flow

Table 1. Properties of the PVDF membrane

Material	Density kg/m^3	Specific heat J/(kg·K)	Thermal conductivity W/(m·K)
PVDF[23]	1775	1325	0.2622
Vapor*	0.554	2014	0.0261
Membrane	302.2	1896.9	0.0662

Table 2. Properties of the fluids

Material	Density kg/m^3	Specific heat $J/(kg \cdot K)$	Thermal conductivity $w/(m \cdot K)$	Viscosity $\times 10^{-4}$ $Pa \cdot s$
3.5% synthetic seawater(~323K) [24]	1013.2	4064.8	0.642	5.86
Pure water(~303K) [25]	995.2	4182.1	0.613	8.38

Table 3. PVDF membrane characterization and module specifications

Membrane properties						
Material	Dimension	Contact angle (°)	Porosity ε (%)	LEPw (Bar)	Tensile modulus E_t ,MPa	Strain at break δ_b, %
PVDF	R_{mo}: 1.45 mm δ_m: 275 μm	105±1	85	1.38	44.60	98.60

Module specifications		
Housing diameter, d_s, mm	No. of fibers, n	Effective fiber length L, m
9.5	1	0.25~1.02

Table. 4. The temperature comparison of experimental data and simulation results (Re_f=836, Re_p= 460)

L (m)		T_{fi} (K)	T_{fo} (K)	Error (%)	T_{pi} (K)	T_{po} (K)	Error (%)
0.25	Exp.	327.2	325.7	-	294.0	301.4	-
	Sim.	-	325.9	0.0614		300.9	-0.166
0.34	Exp.	327.2	325.2	-	293.5	302.8	-
	Sim.	-	325.4	0.0615		302.5	-0.0991
0.54	Exp.	327.2	324.8	-	294.0	306.0	-
	Sim.		324.6	-0.0616		306.6	0.196
0.64	Exp.	327.2	324.2	-	294.0	306.3	-
	Sim.	-	324.1	-0.0308		308.6	0.848
0.74	Exp.	327.2	323.7	-	294.7	307.8	-
	Sim.	-	323.7	0.00		310.6	0.910
0.84	Exp.	327.2	322.7	-	293.7	310.0	-
	Sim.		323.3	0.185		311.4	0.452
1.02	Exp.	327.2	322.0	-	294.0	312.1	-
	Sim.	-	322.6	0.186		313.9	0.577

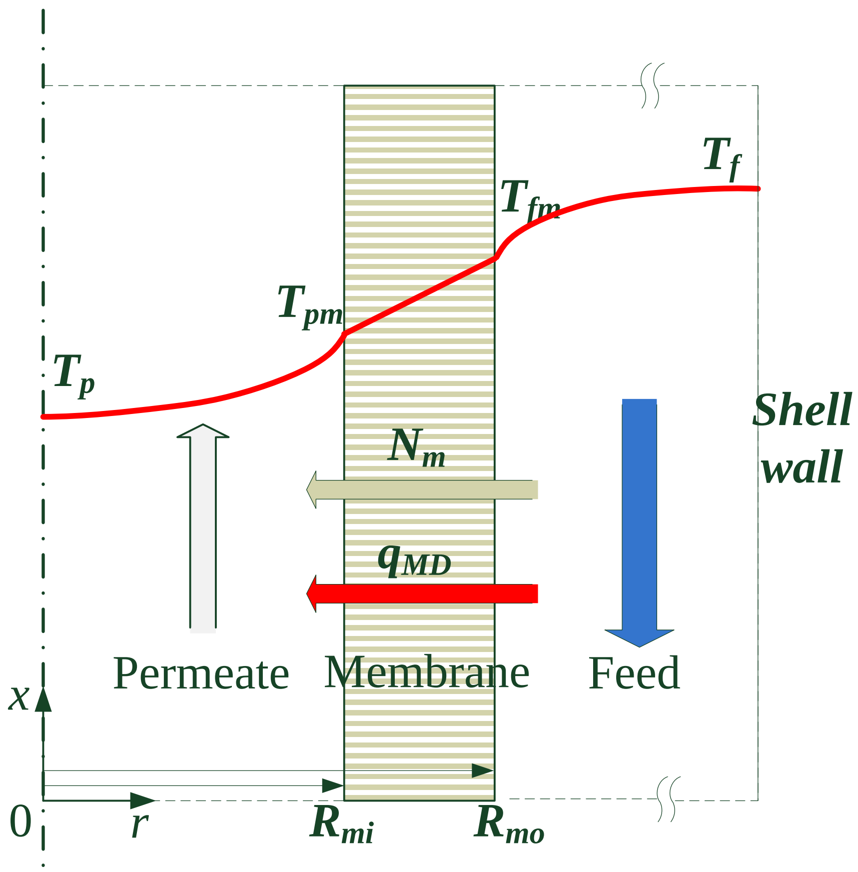

Fig. 1. Schematic diagram of heat & mass transfers

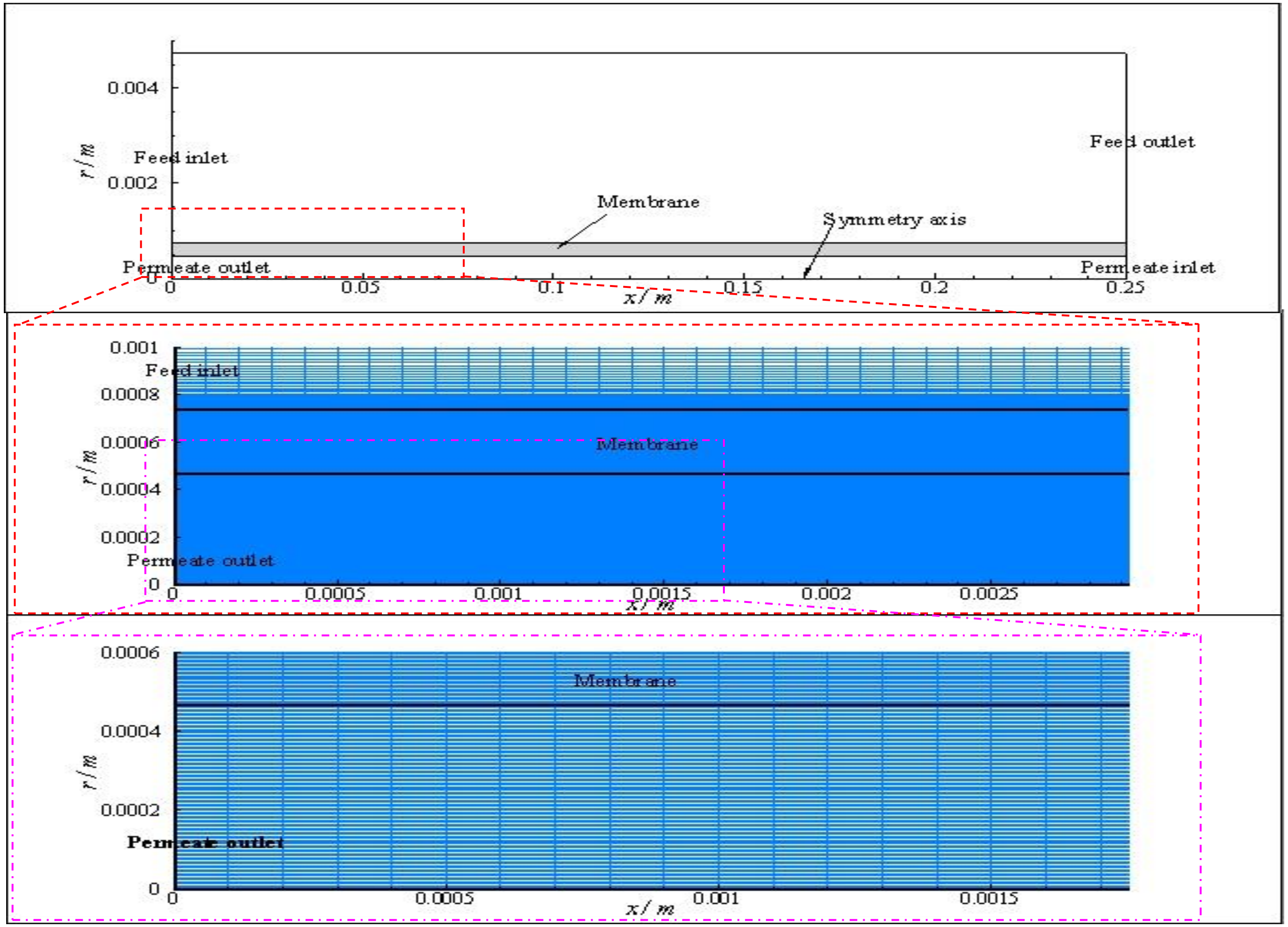

Fig. 2 CFD domain & meshes of the single-fiber module in a 2D model

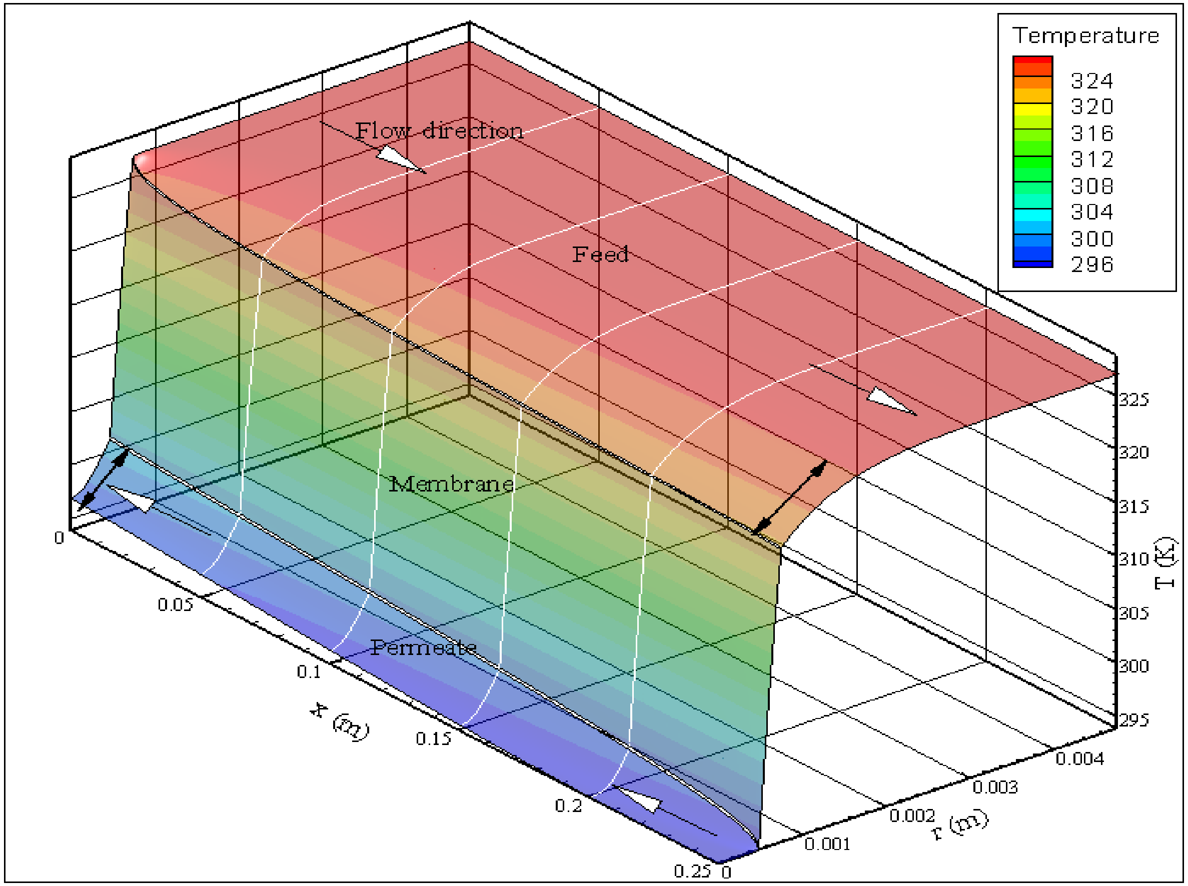

Fig. 3. Temperature distribution inside the module
(Re_f=836, T_{fi} = 327.2 K, Re_p= 460, T_{pi} = 294.0 K)

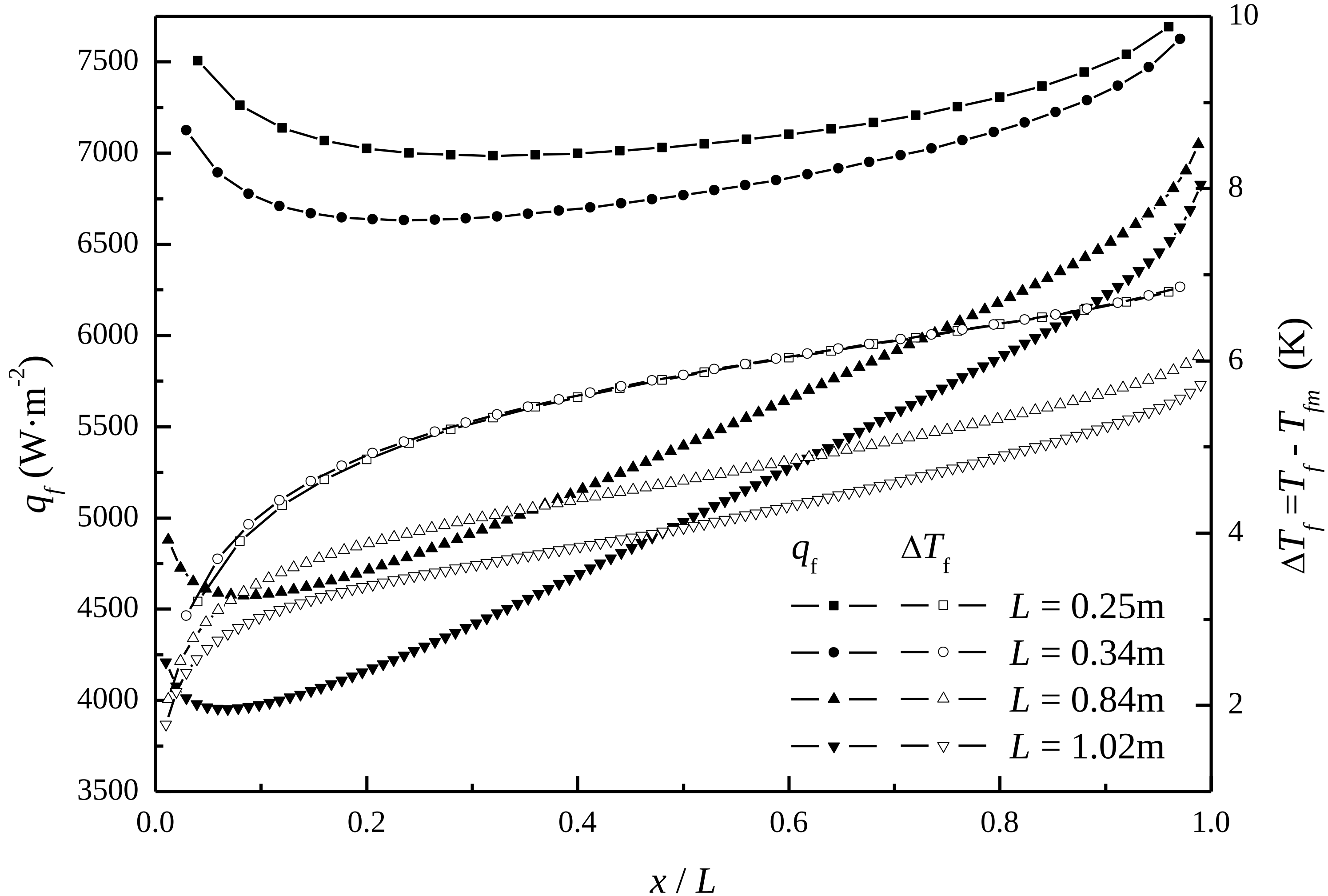

Fig. 4. q_f & ΔT_f distributions along the dimensionless module length x/L
(Re_f=836, T_{fi} = 327.2 K, Re_p= 460, T_{pi} = 294.0 K)

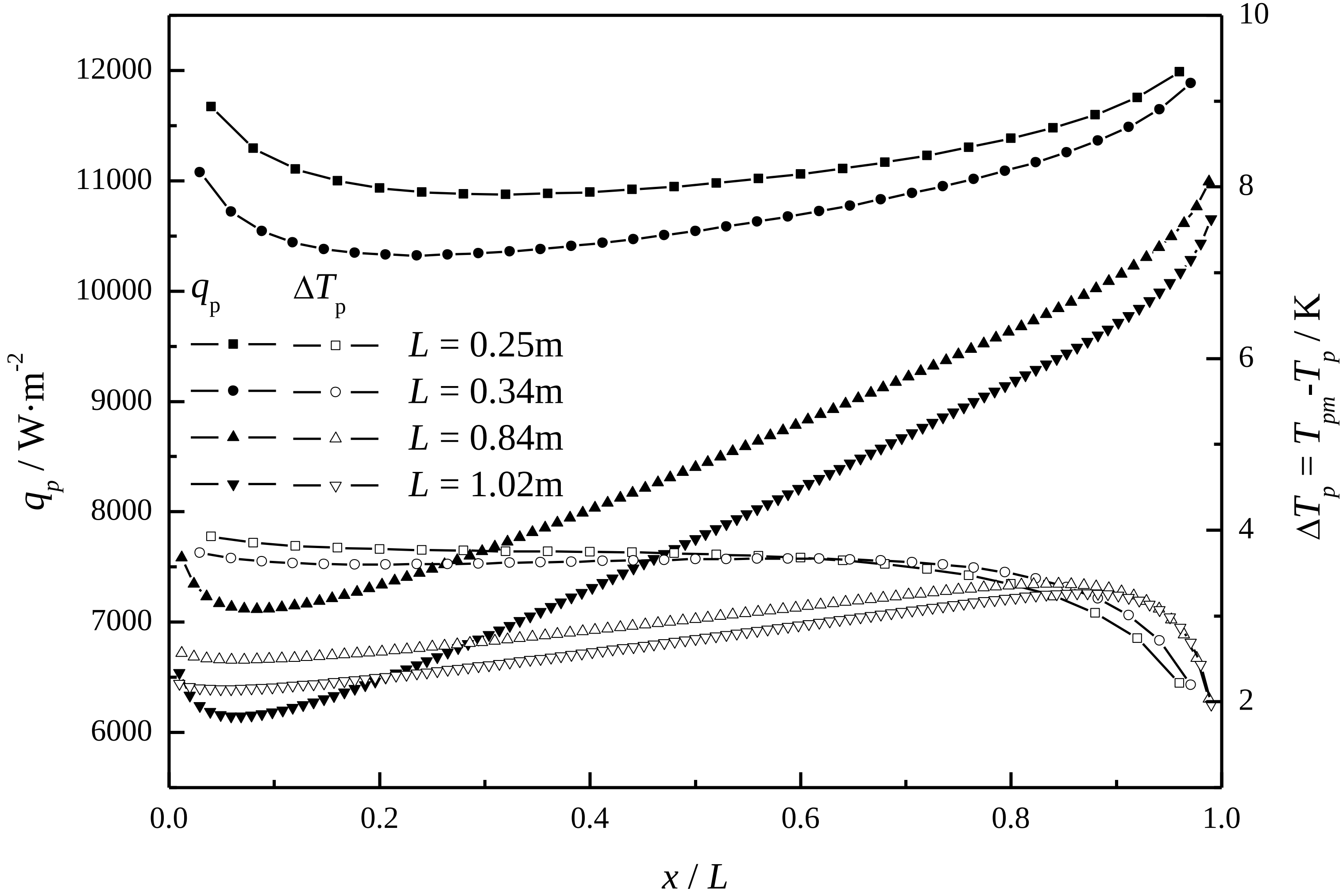

Fig. 5. q_p & ΔT_p distributions on the membrane surface along the dimensionless module length x/L (Re_f=836, T_{fi} = 327.2 K, Re_p= 460, T_{pi} = 294.0 K)

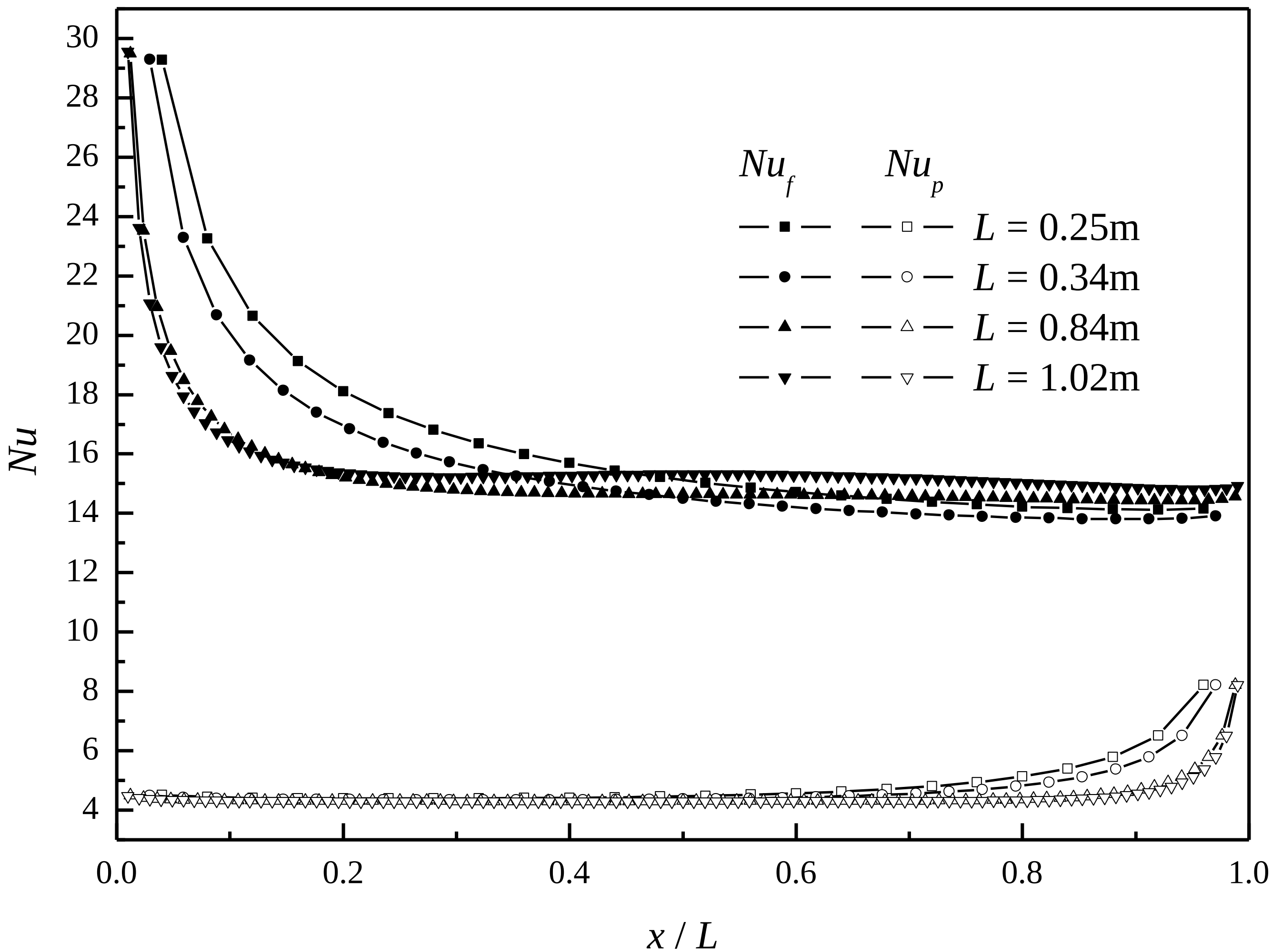

Fig. 6. Distribution of *Nu* along the dimensionless *x* distance
(Re_f=836, T_{fi} = 327.2 K, Re_p= 460, T_{pi} = 294.0 K)

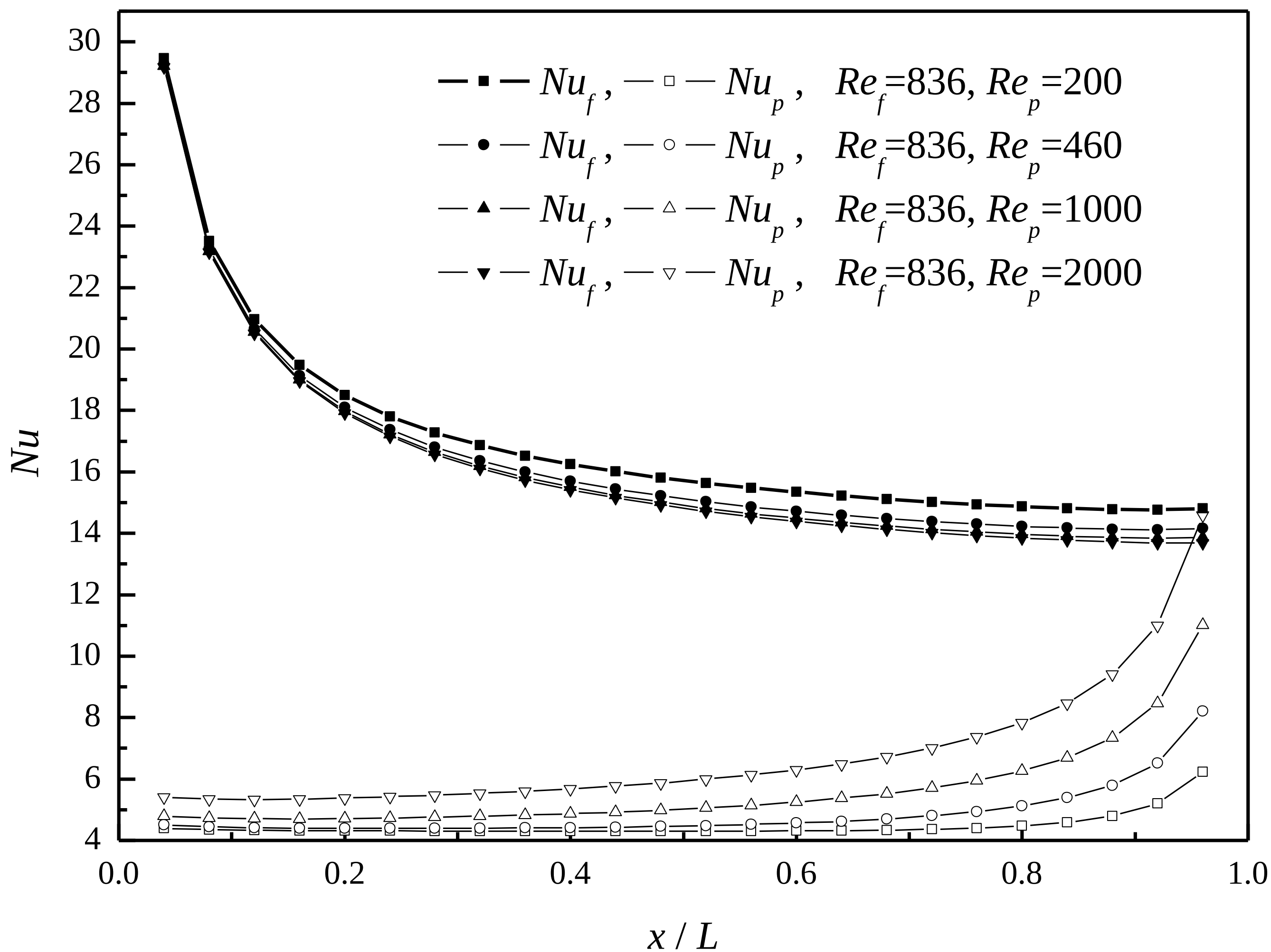

Fig. 7. Nu_f & Nu_p distributions along the module length at different Re_p (L=0.25m, Re_f=836, T_{fi} = 327.2 K, Re_p= 200~2000, T_{pi} = 294.0 K)

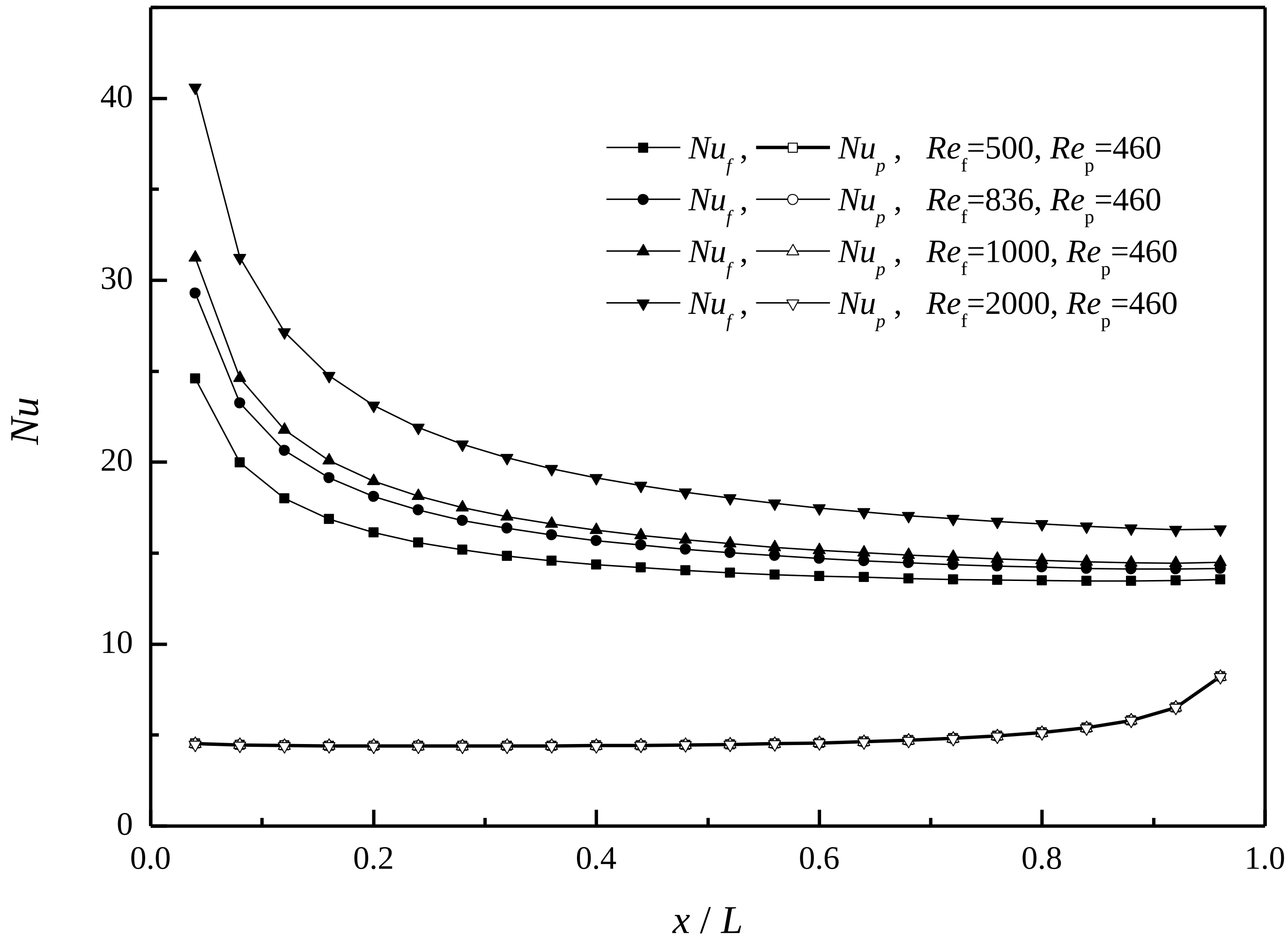

Fig. 8. Nu_f & Nu_p distributions along the module length at different Re_f (L=0.25m, Re_f=500~2000, T_{fi} = 327.2 K, Re_p= 460, T_{pi} = 294.0 K)

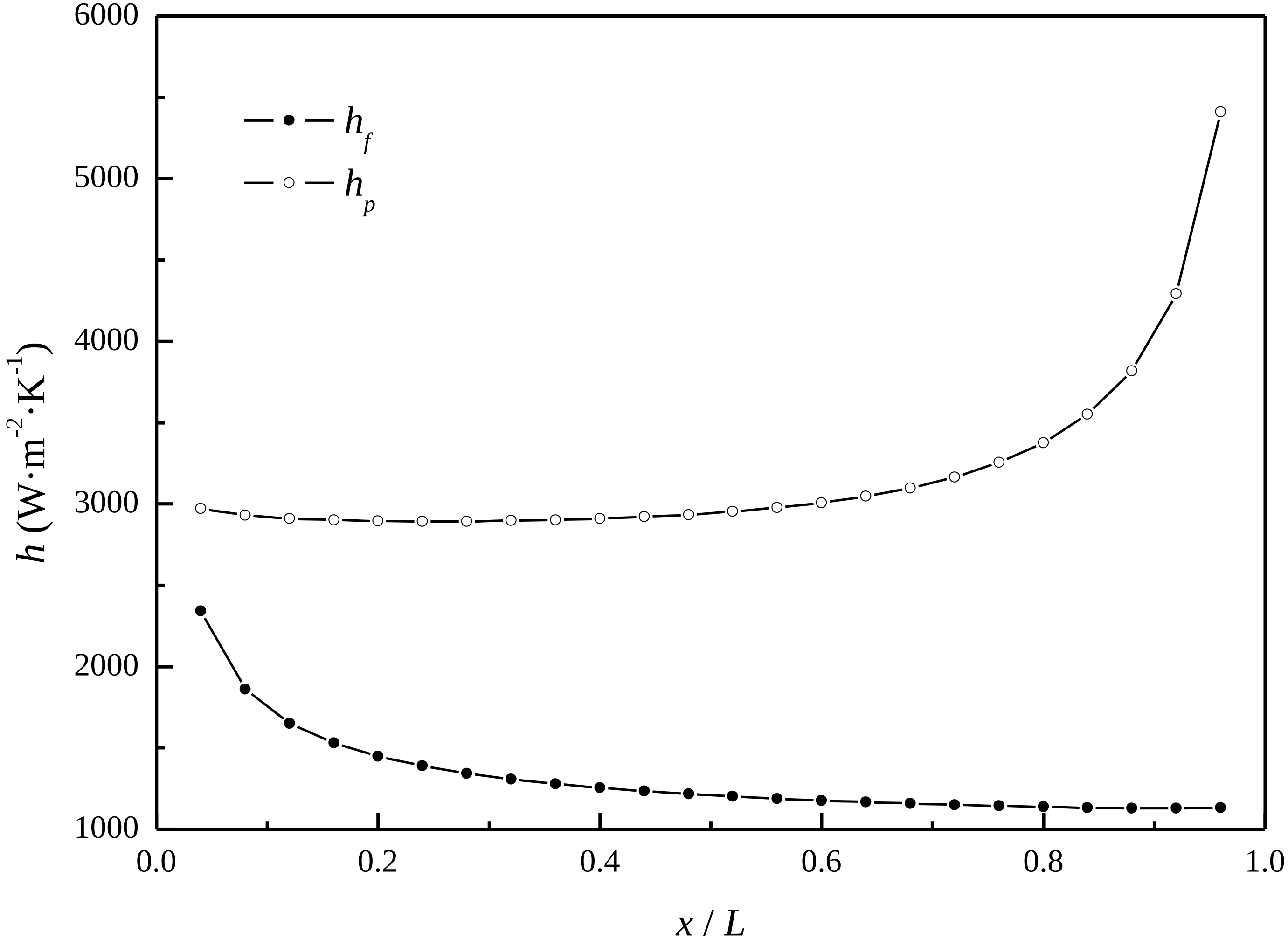

Fig. 9. h_f & h_p distributions along the module length at constant flow conditions (L=0.25m, Re_f= 836, T_{fi} = 327.2 K, Re_p=460, T_{pi} = 294.0 K)

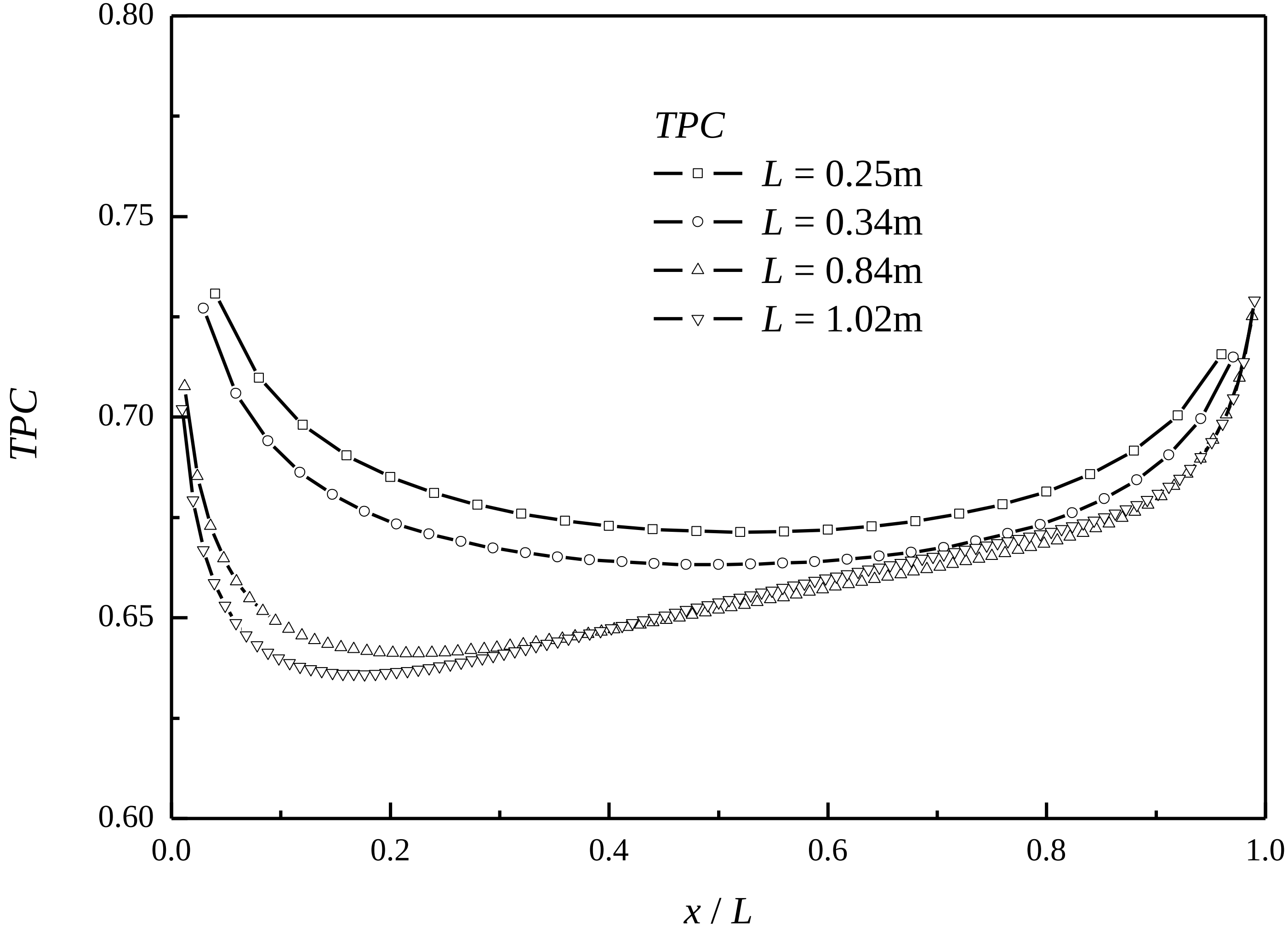

Fig. 10. *TPC* distributions along the dimensionless module length x/L (Re_f= 836, T_{fi} = 327.2 K, Re_p=460, T_{pi} = 294.0 K)

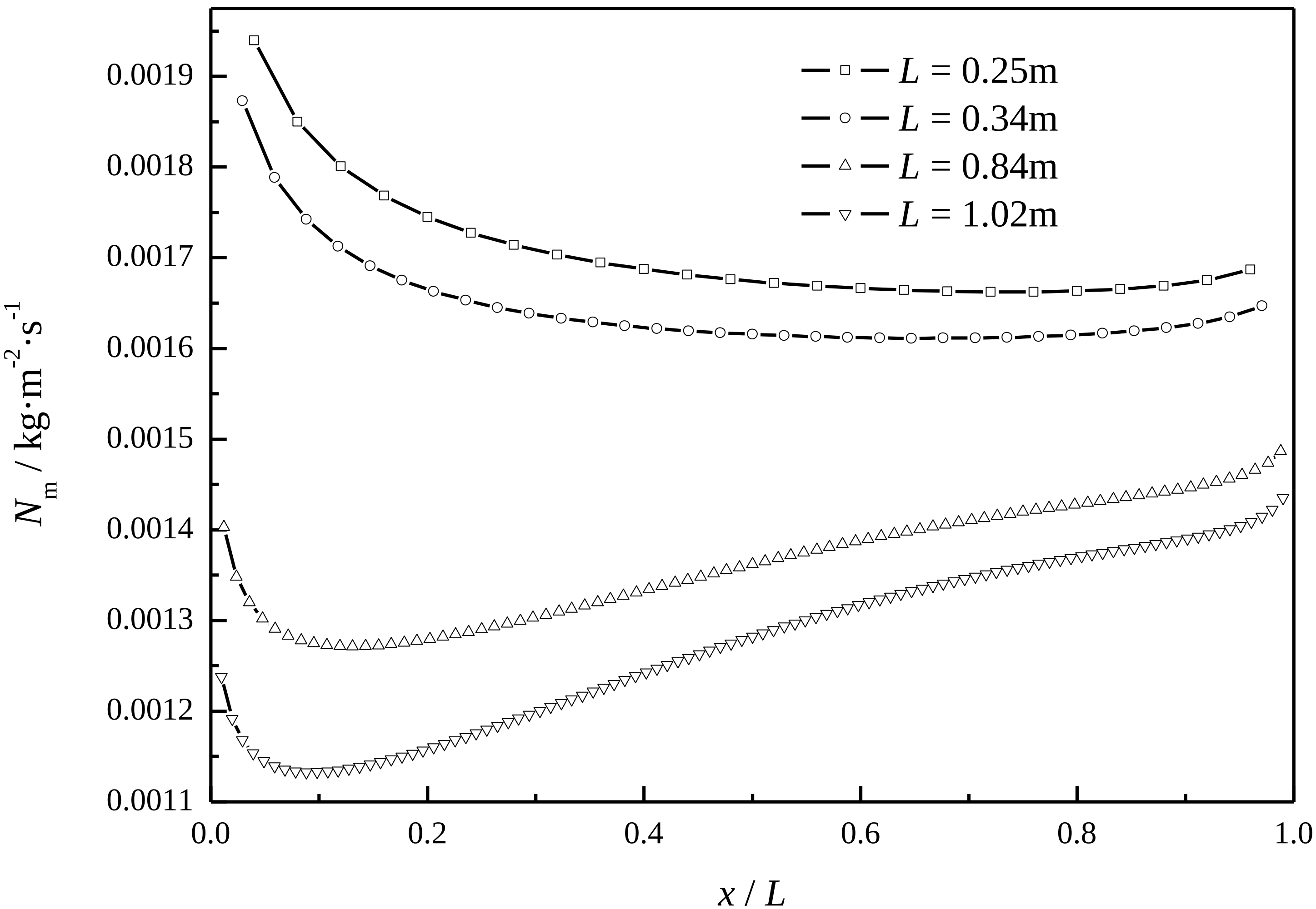

Fig. 11. Distributions of local mass fluxes along the dimensionless x/L distance (Re_f= 836, T_{fi} = 327.2 K, Re_p=460, T_{pi} = 294.0 K)

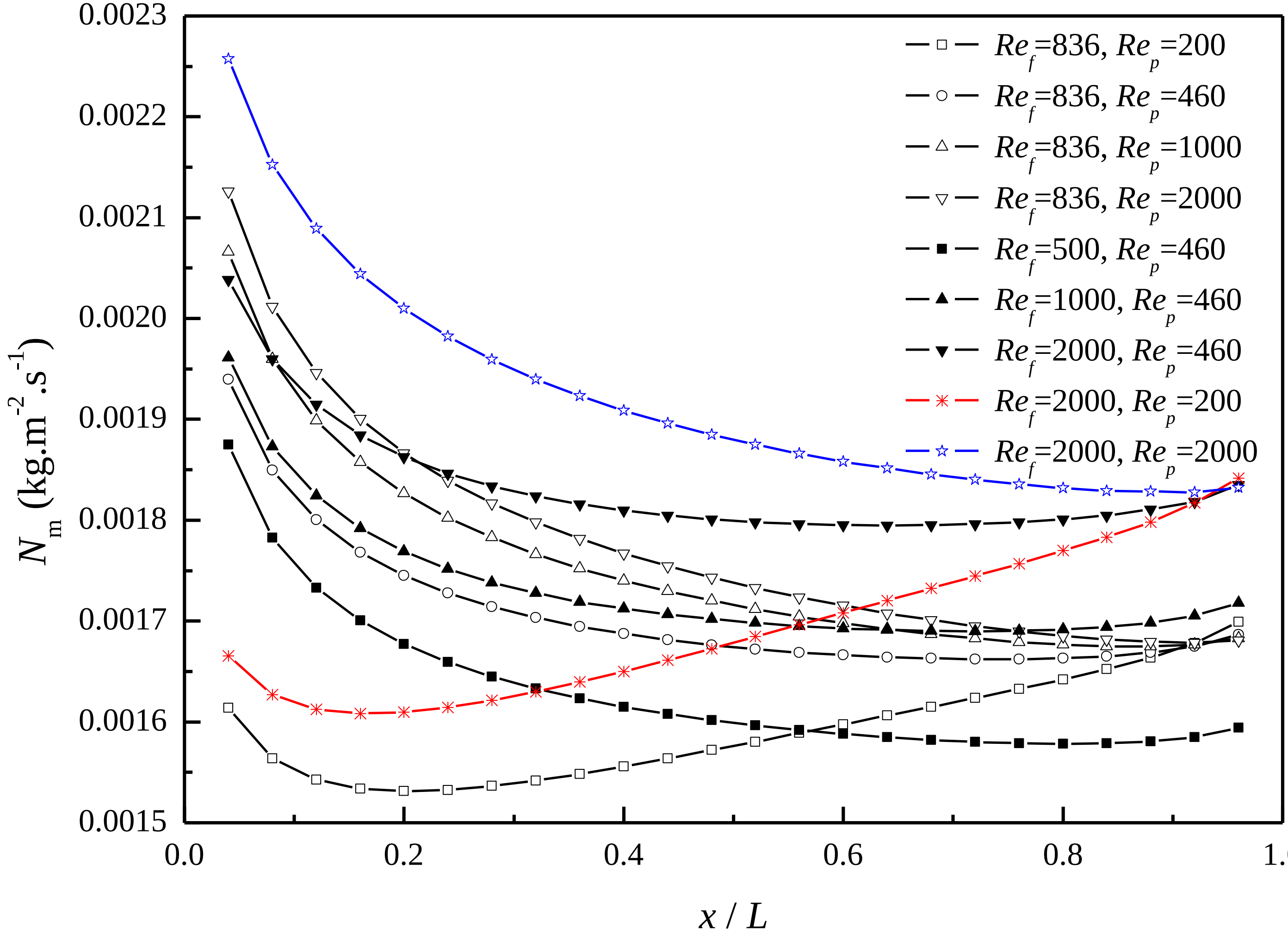

Fig. 12. Distributions of local N_m along the dimensionless module length x/L (L=0.25m, Re_f=500~2000, T_{fi} = 327.2 K, Re_p= 200~2000, T_{pi} = 294.0 K)

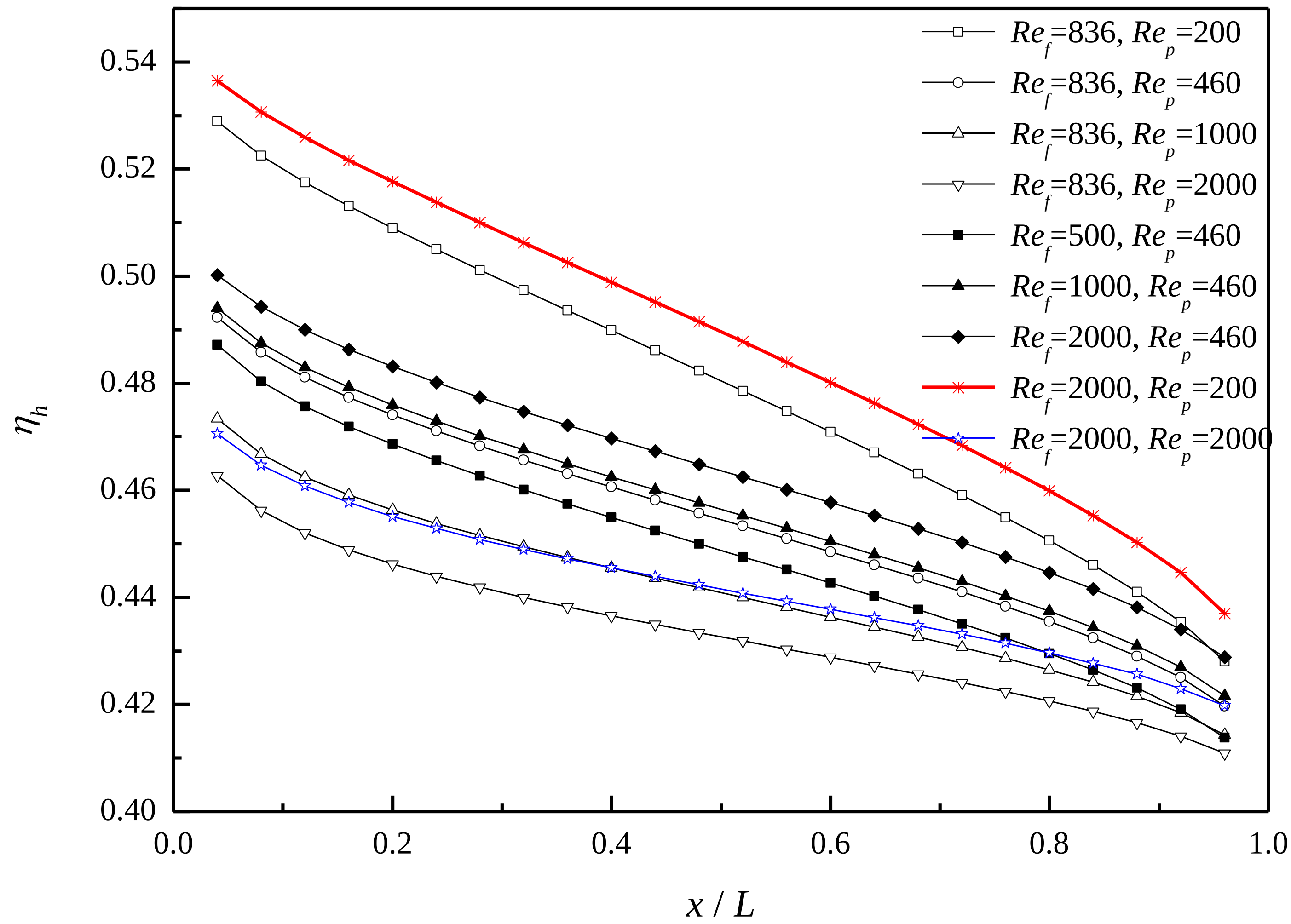

Fig. 13. Distributions of η_h along the dimensionless x/L distance (L=0.25m, Re_f=500~2000, T_{fi} = 327.2 K, Re_p= 200~2000, T_{pi} = 294.0 K)