Fluent在自然对流科学研究中的应用

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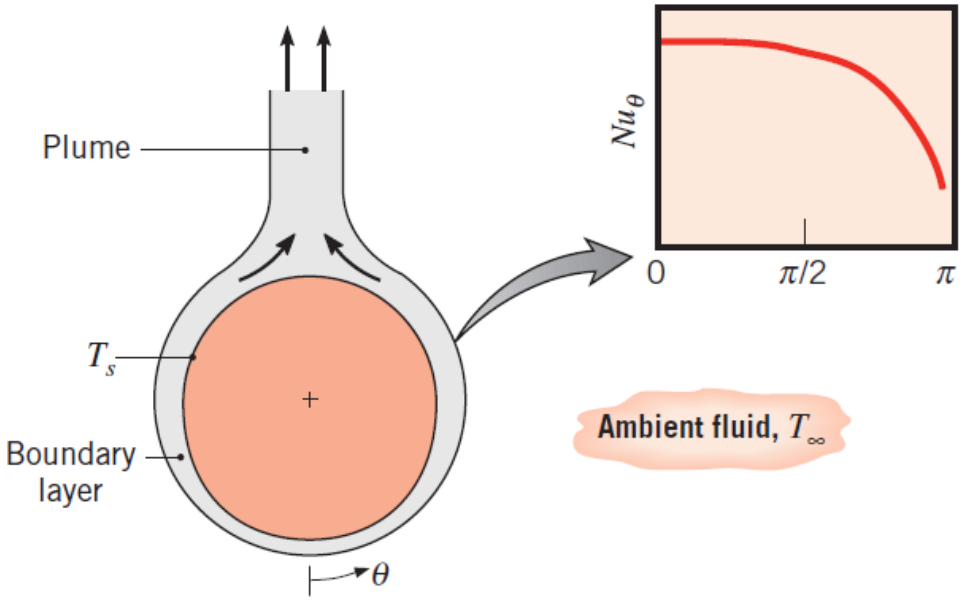
主要内容

1 自然对流研究领域内的应用

2 接触双圆管自然对流的应用

Fluent 在自然对流科学研究领域内的应用



水平长圆柱

Morgan $\overline{Nu} = CRa_D^n$

C	n	Ra_D^n
0.675	0.058	10^{-10}~10^{-2}
1.02	0.148	10^{-2}~10^{2}
0.850	0.188	10^{2}~10^{4}
0.480	0.250	10^{4}~10^{7}
0.125	0.333	10^{7}~10^{12}

Churchill and Chu $\overline{Nu} = \left\{0.60 + \frac{0.387Ra_D^{1/6}}{[1 + (0.559/\mathrm{Pr})^{9/16}]^{8/27}}\right\}$ $Ra_D \le 10^{12}$

[1] T.L. Bergman, A.S. Lavine, F.P. Incropera, et al., Fundamentals of Heat and Mass Transfer, Wiley, seventh edition, 2011.

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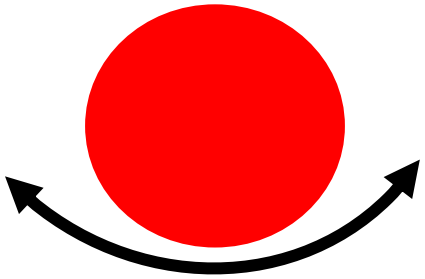
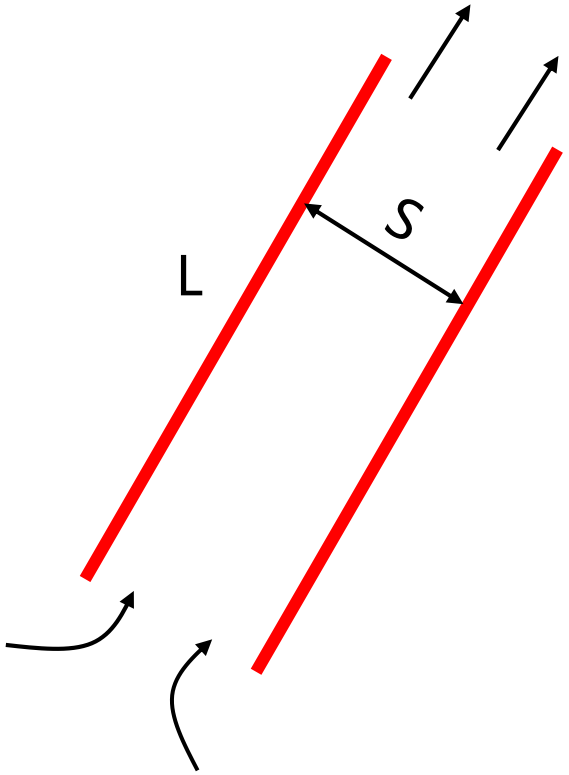
球



$$\overline{Nu} = 2 + \frac{0.589Ra_D^{1/4}}{[1+(0.469/\mathrm{Pr})^{9/16}]^{4/9}}$$

槽道



$$\overline{Nu_S} = \frac{1}{24}Ra_S\left(\frac{S}{L}\right)\left\{1-exp\left[-\frac{35}{Ra_S(S/L)}\right]\right\}^{3/4}$$

[1] T.L. Bergman, A.S. Lavine, F.P. Incropera, et al., Fundamentals of Heat and Mass Transfer, Wiley, seventh edition, 2011.

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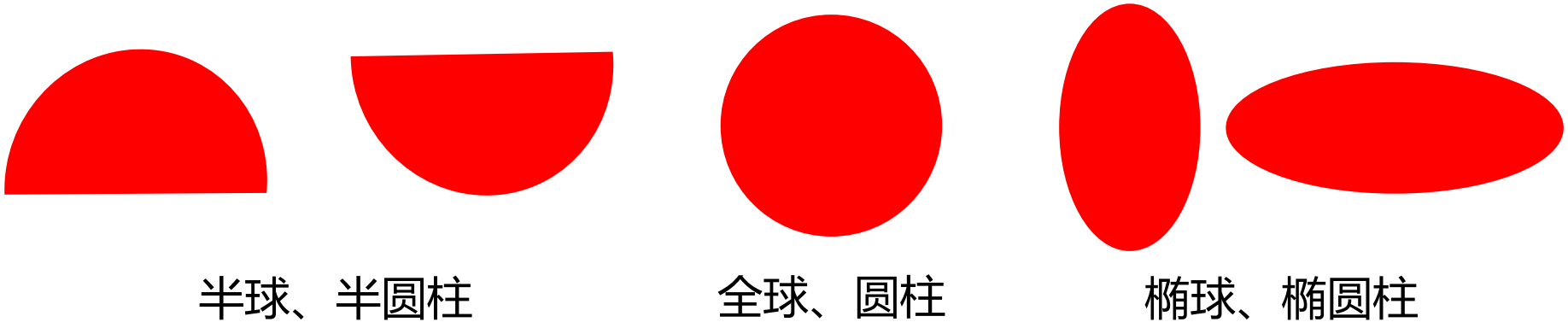

半球、半圆柱　　全球、圆柱　　椭球、椭圆柱

[2] C. Sasmal, R. P. Chhabra, Laminar free convection in power-law fluids from a heated hemisphere, J. Thermophysics Heat Transfer 28 (2014) 750-763.
[3] A.K. Tiwari, R.P. Chhabra, Laminar natural convection in power-law liquids from a heated semi-circular cylinder with its flat side oriented downward, Int. J. Heat Mass Transfer 58 (2013) 553-567.
[4] A. Chandra, R.P. Chhabra, Laminar free convection from a horizontal semi-circular cylinder to power-law fluids, Int. J. Heat Mass Transfer 55 (2012) 2934-2944.
[5] A. Prhashanna, R.P. Chhabra, Free convection in power-law fluids from a heated sphere, Chem. Eng. Sci. 65 (2010) 6190-6205.
[6] Prhashanna, R.P. Chhabra, Laminar natural convection from a horizontal cylinder in power-law fluids, Ind. Eng. Chem. Res. 50 (2011) 2424-2440.
[7] A.K. Gupta, C. Sasmal, M. Sairamu, R.P. Chhabra, Laminar and steady free convection in power-law fluids from a heated spheroidal particle: A numerical study, Int. J. Heat Mass Transfer 75 (2014) 592-609.
[8] C. Sasmal, R.P. Chhabra, Effect of aspect ratio on natural convection in power-law liquids from a heated horizontal elliptic cylinder, Int. J. Heat Mass Transfer 55 (2012) 4886-4899.

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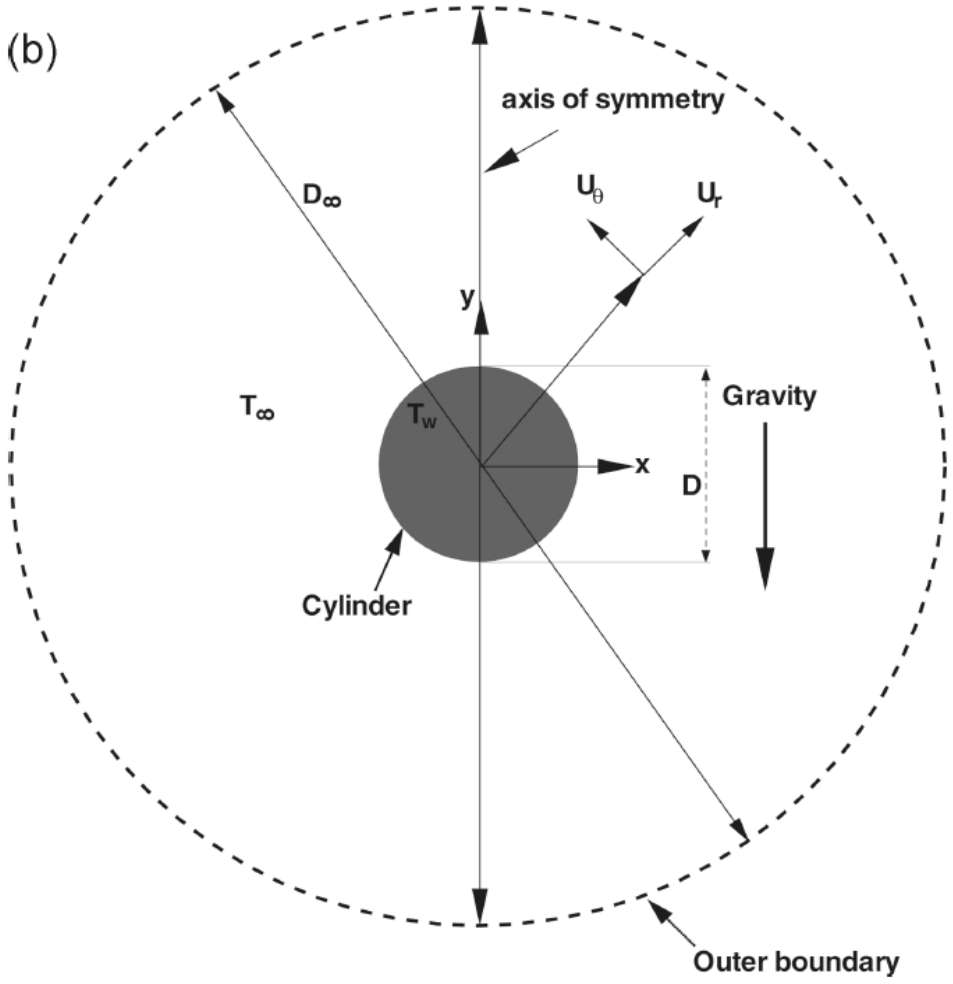

[6] Prhashanna, R.P. Chhabra, Laminar natural convection from a horizontal cylinder in power-law fluids, Ind. Eng. Chem. Res. 50 (2011) 2424-2440.

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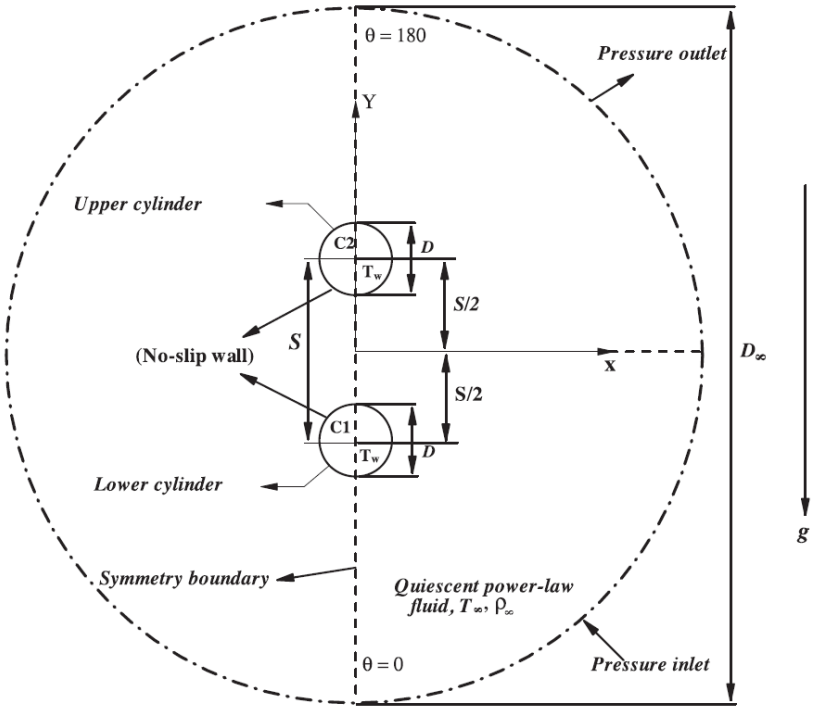

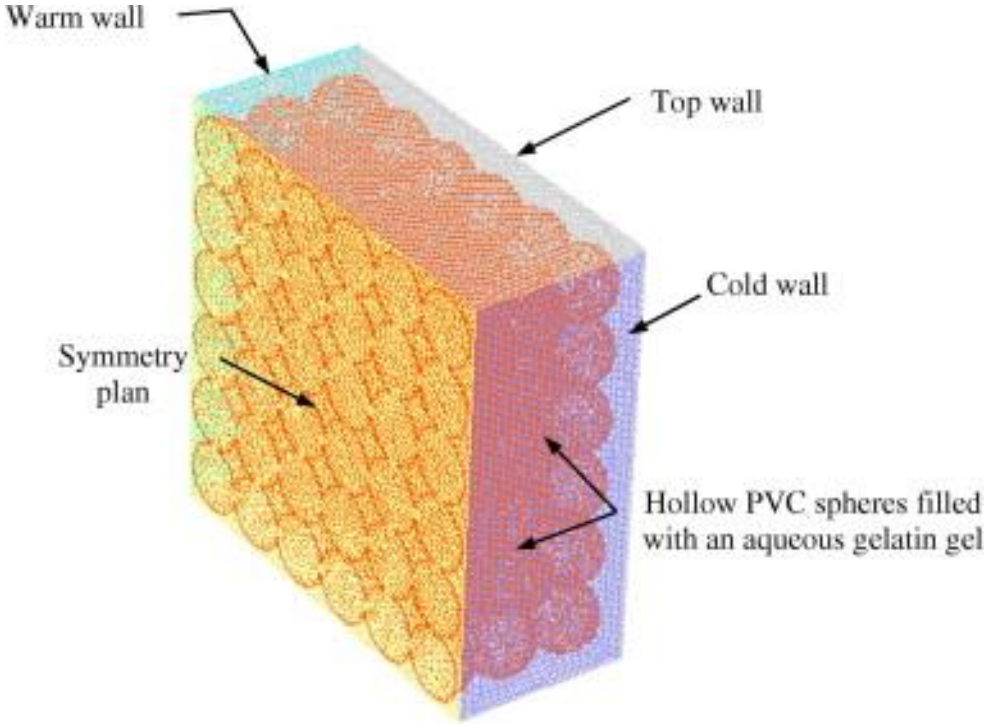

Schematic representation of the flow and computational domain

[9] R. Shyam, C. Sasmal, R.P. Chhabra, Natural convection heat transfer from two vertically aligned circular cylinders in power-law fluids, Int. J. Heat Mass Transfer 64 (2013) 1127-1152.

[10] O. Laguerre, S.B. Amara, G. Alvarez, D. Flick, Transient heat transfer by free convection in a packed bed of spheres: Comparison between two modelling approaches and experimental results, Appl. Therm. Eng. 28 (2008) 14–24.

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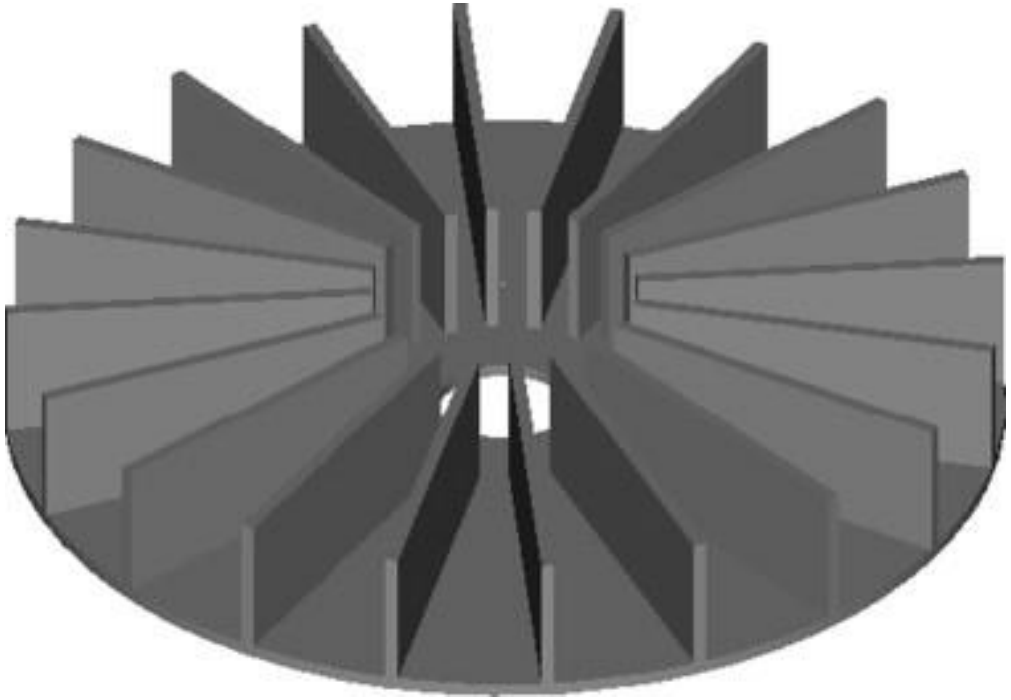
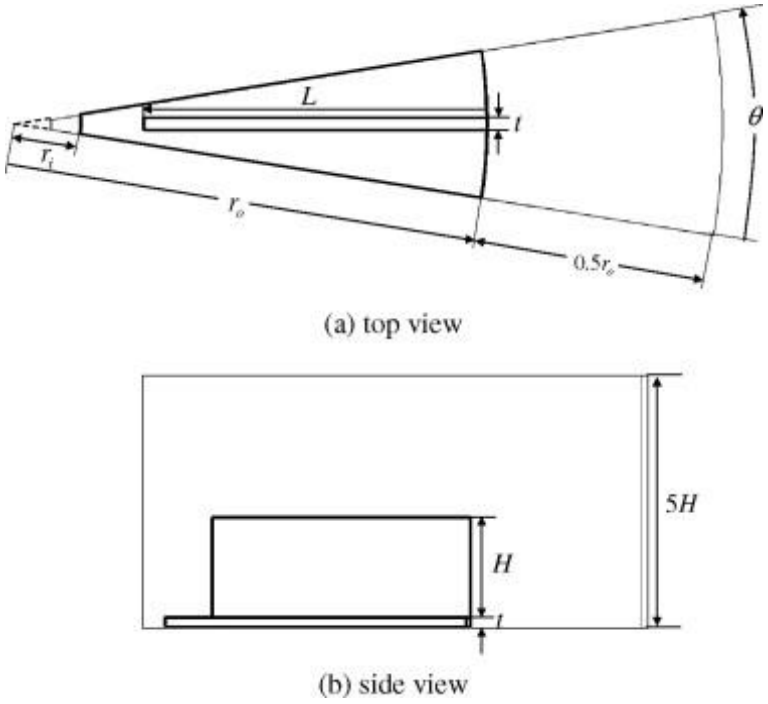


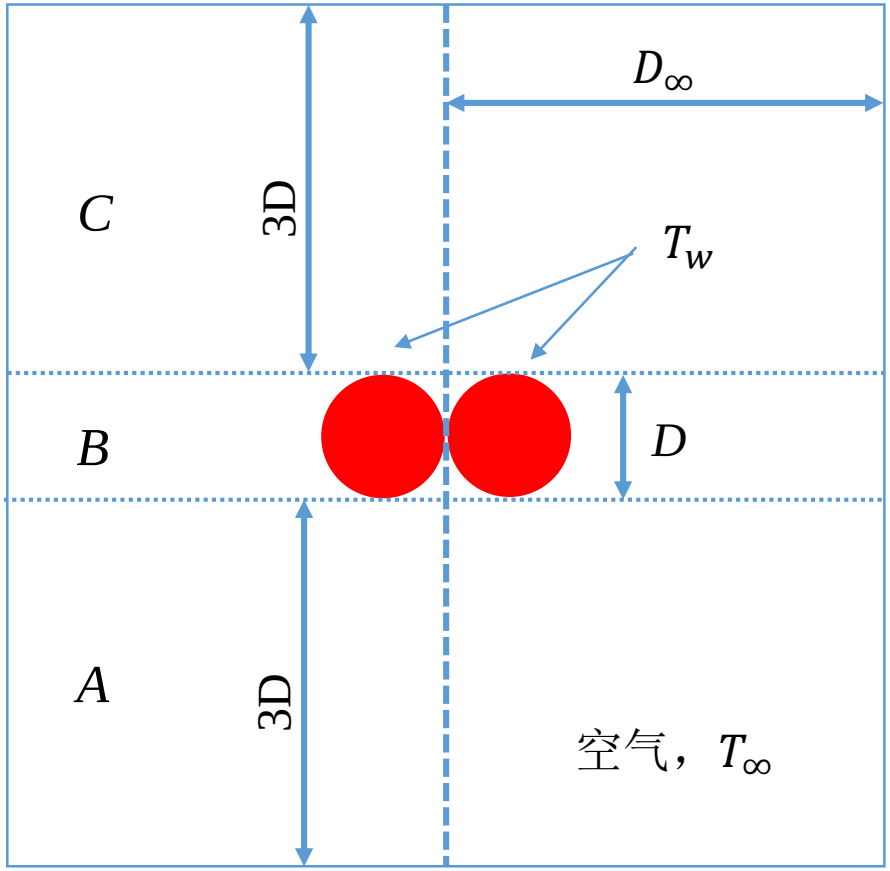
Radial heat sink with a circular base and rectangular fins.

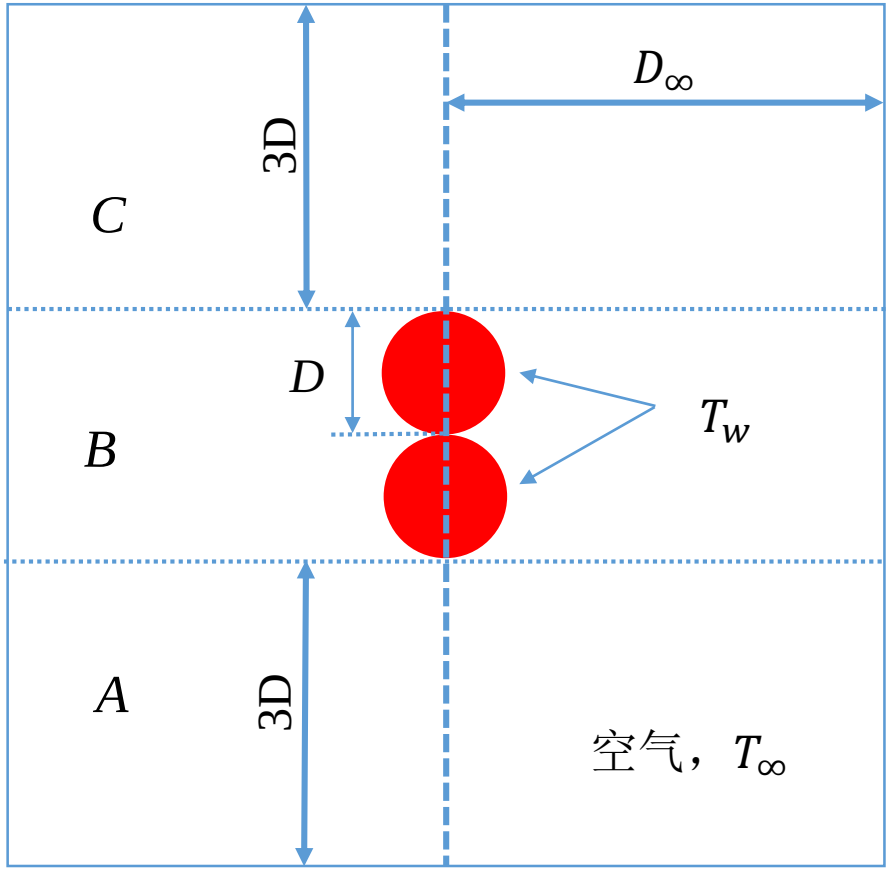


Computational domain and dimensions

[11] S.H. Yu, K.S. Lee, S.J. Yook, Natural convection around a radial heat sink, Int. J. Heat Mass Transfer 53 (2010) 2935–2938.

Fluent 进行接触双圆管自然对流研究的相关结果





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流动假设：

二维，稳态，不可压缩（除y方向），热物性恒定（除y方向动量方程），忽略粘性耗散和辐射

Y方向密度变化通过布西涅斯克近似（Boussinesq approximation）简化，即：

$$(\rho_\infty - \rho) \approx \rho\beta(T - T_\infty)$$

控制方程：

连续性方程:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

动量方程：

x 方向: $u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \vartheta\nabla^2 u$

y 方向: $u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \vartheta\nabla^2 v + g\beta(T - T_\infty)$

能量方程:

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\nabla^2 T$$

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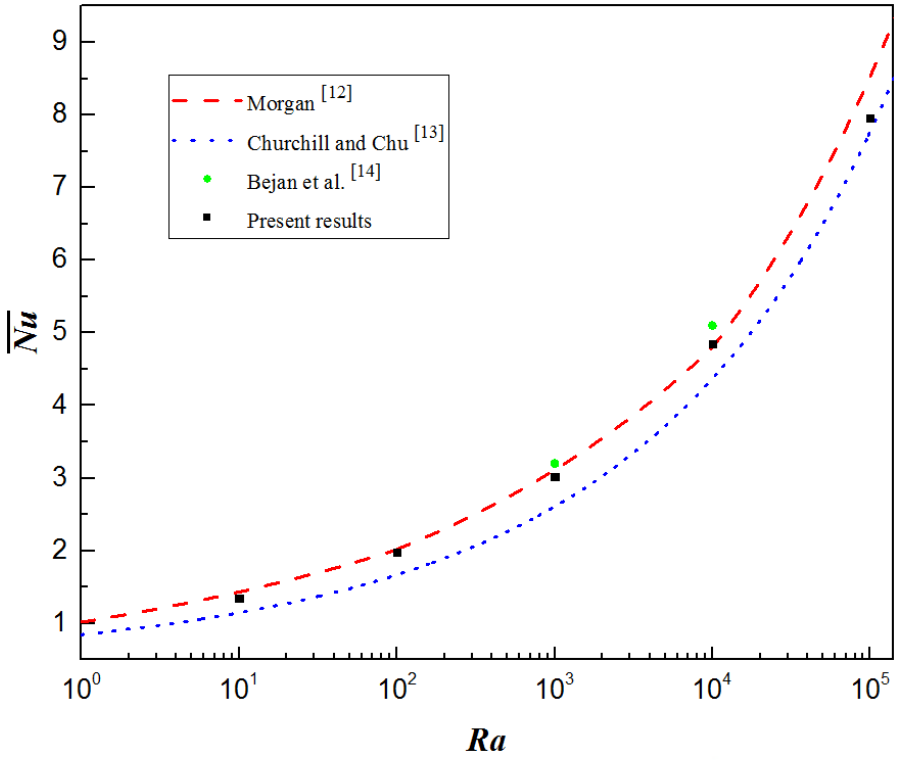
数值结果验证：



[12] V.T. Morgan, The overall convective heat transfer from smooth circular cylinders, Adv. Heat Transfer 11 (1975) 199-210.
[13] S.W Churchill, H.S. Chu, Correlating equations for laminar and turbulent free convection from a horizontal cylinder, Int. J. Heat Mass Transfer 18 (1975) 1049-1053.
[14] A. Bejan, A.J. Fowler, G. Stanescu, The optimal spacing between horizontal cylinders in a fixed volume cooled by natural convection, Int. J. Heat Mass Transfer 38 (1995) 2047-2055.

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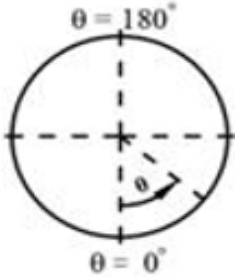

数值结果验证：

Ra		Nu_θ						
		$\theta = 0°$	30°	60°	90°	120°	150°	180°
10^3	Present	3.788	3.752	3.636	3.366	2.863	1.954	1.219
	Corcione [15]	3.789	3.755	3.640	3.376	2.841	1.958	1.210
	Kuehn and Goldstein [16]	3.890	3.850	3.720	3.450	2.930	2.010	1.220
	Wang et al. [17]	3.860	3.820	3.700	3.450	2.930	1.980	1.200
10^5	Present	9.792	9.691	9.334	8.783	7.970	5.898	2.015
	Corcione [15]	9.694	9.595	9.297	8.749	7.871	5.848	1.989
	Kuehn and Goldstein [16]	10.150	10.030	9.650	9.020	7.910	5.290	1.720
	Wang et al. [17]	9.800	9.690	9.480	8.900	8.000	5.800	1.940

[15] M. Corcione, Correlating equations for free convection heat transfer from horizontal isothermal cylinders set in a vertical array, Int. J. Heat Mass Transfer 48 (2005) 3660-3673.
[16] T.H. Kuehn, R.J. Goldstein, Numerical solution to the Navier-Stokes equations for laminar natural convection about a horizontal isothermal circular cylinder, Int. J. Heat Mass Transfer 23 (1980) 971-979.
[17] P. Wang, R. Kahawita, T.H. Nguyen, Numerical computation of the natural convection flow about a horizontal cylinder using splines, Num. Heat Transfer 17 (1990) 191-215.

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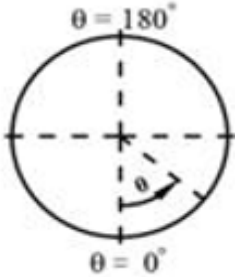

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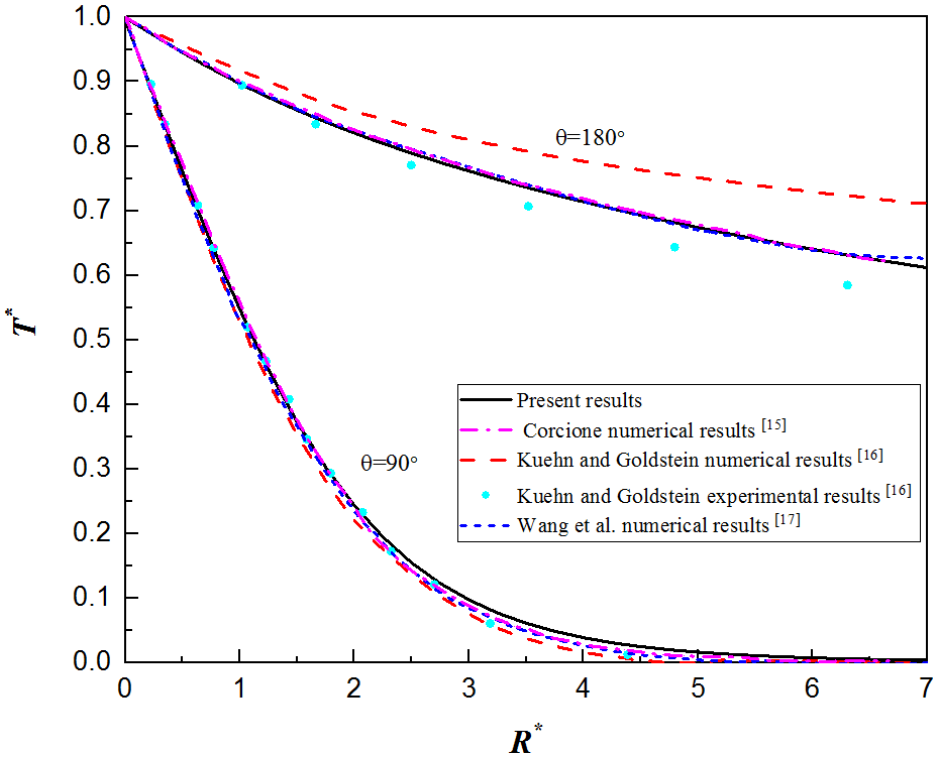

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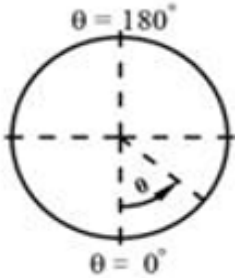

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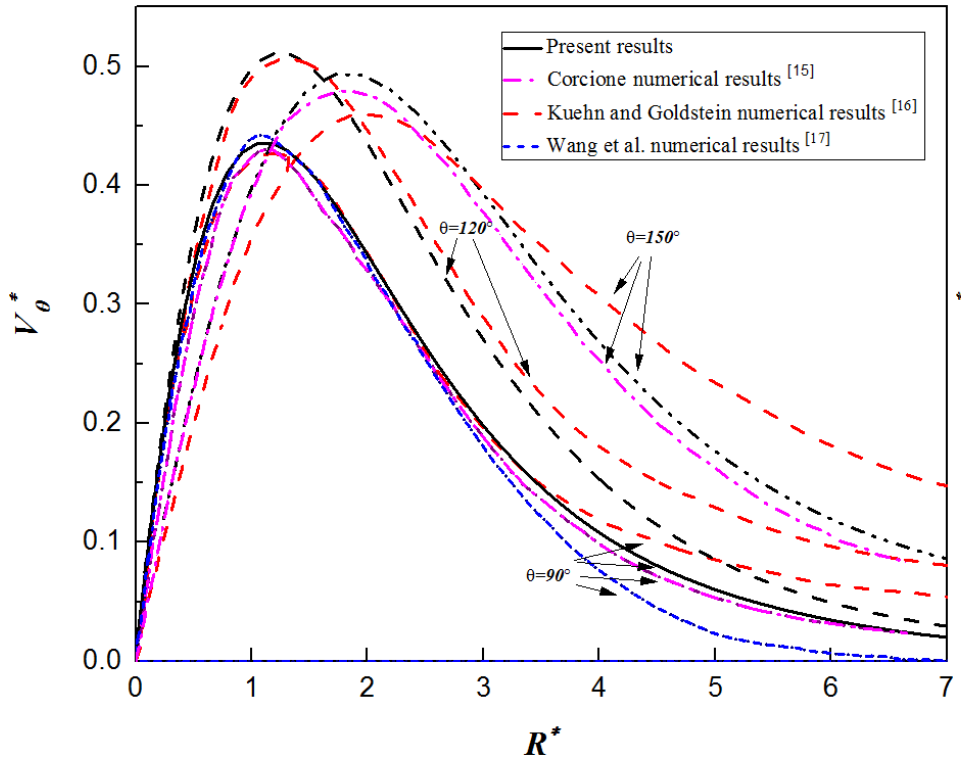

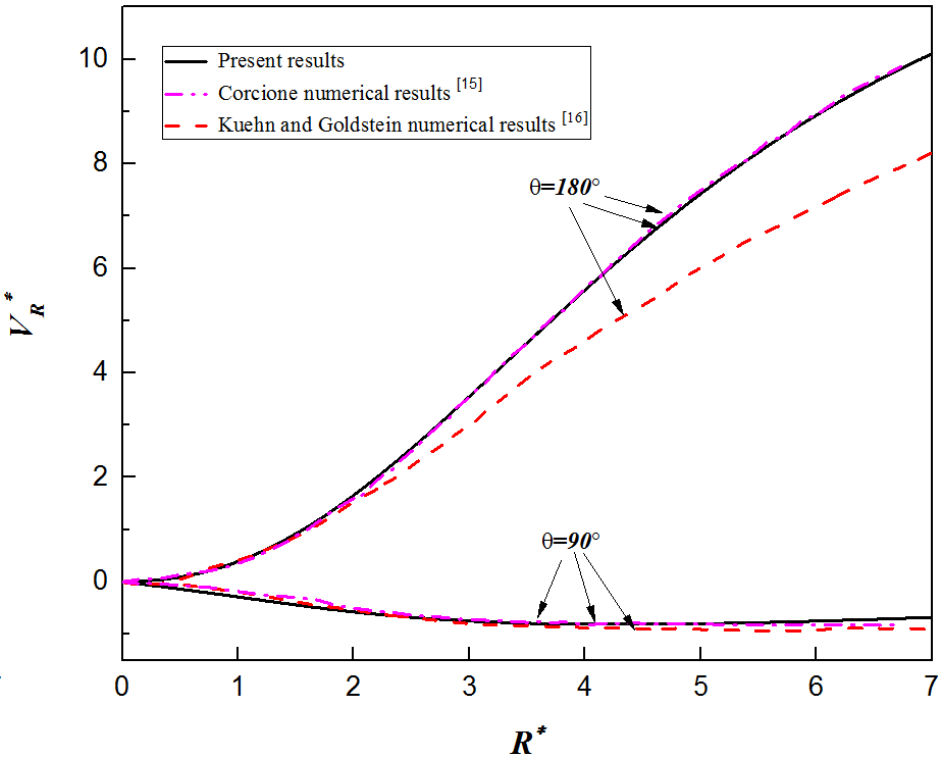

[15] M. Corcione, Correlating equations for free convection heat transfer from horizontal isothermal cylinders set in a vertical array, Int. J. Heat Mass Transfer 48 (2005) 3660-3673.
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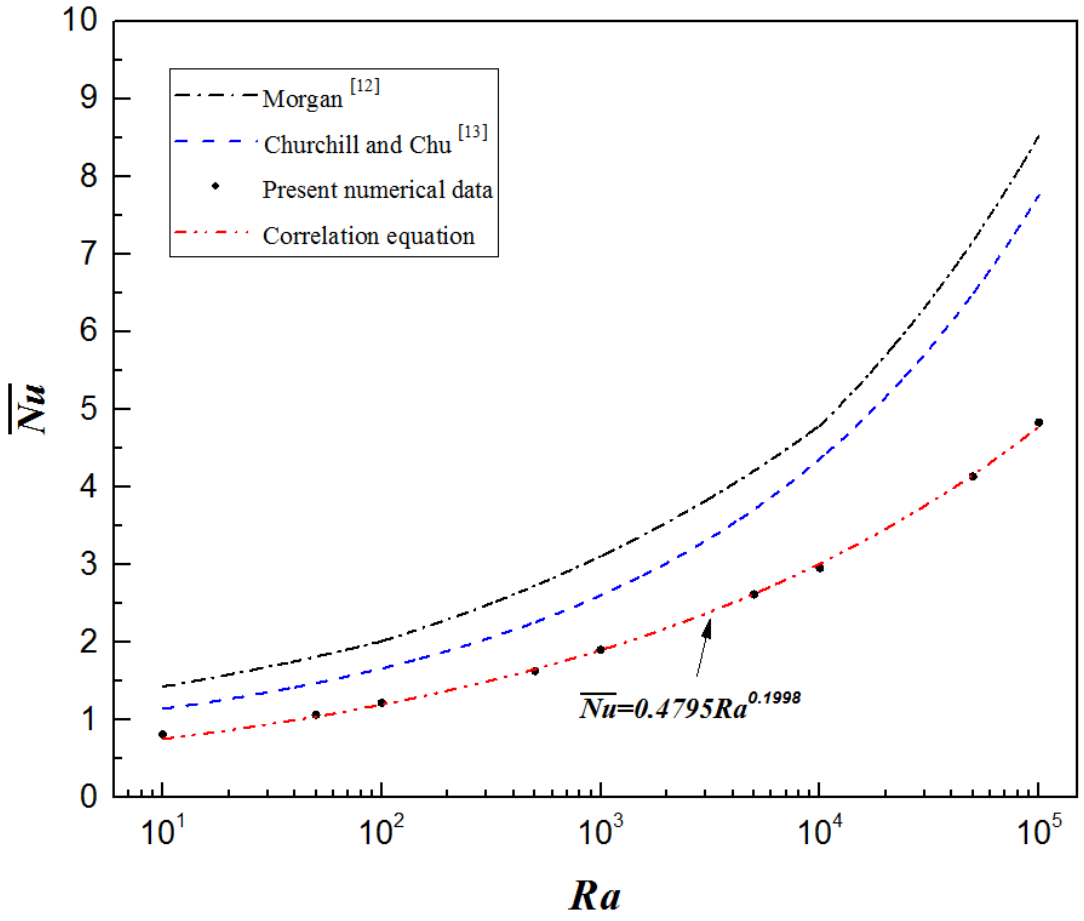
两水平圆柱水平紧密接触的数值结果：



经验关系式：$\overline{Nu} = 0.4795Ra^{0.1998}$

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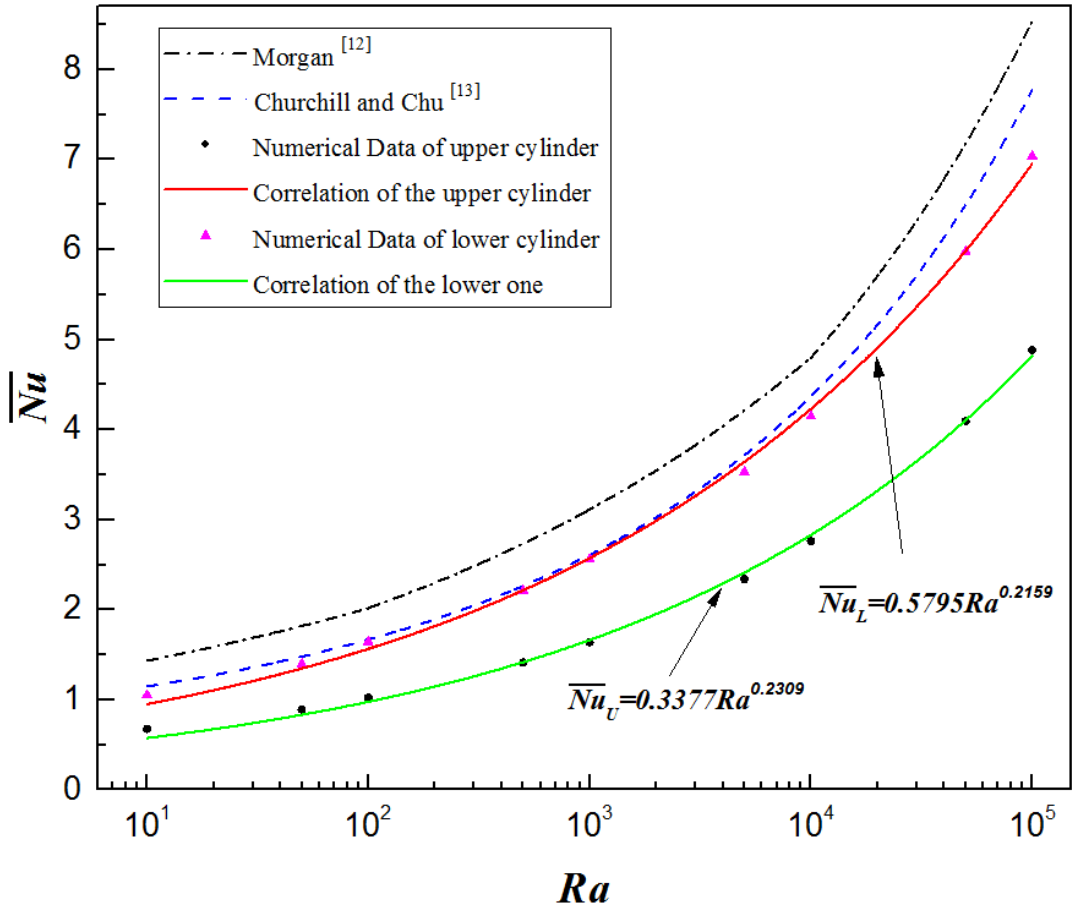
两水平圆柱竖直紧密接触的数值结果：



对于整体的经验关系式：$\overline{Nu} = 0.4579Ra^{0.2218}$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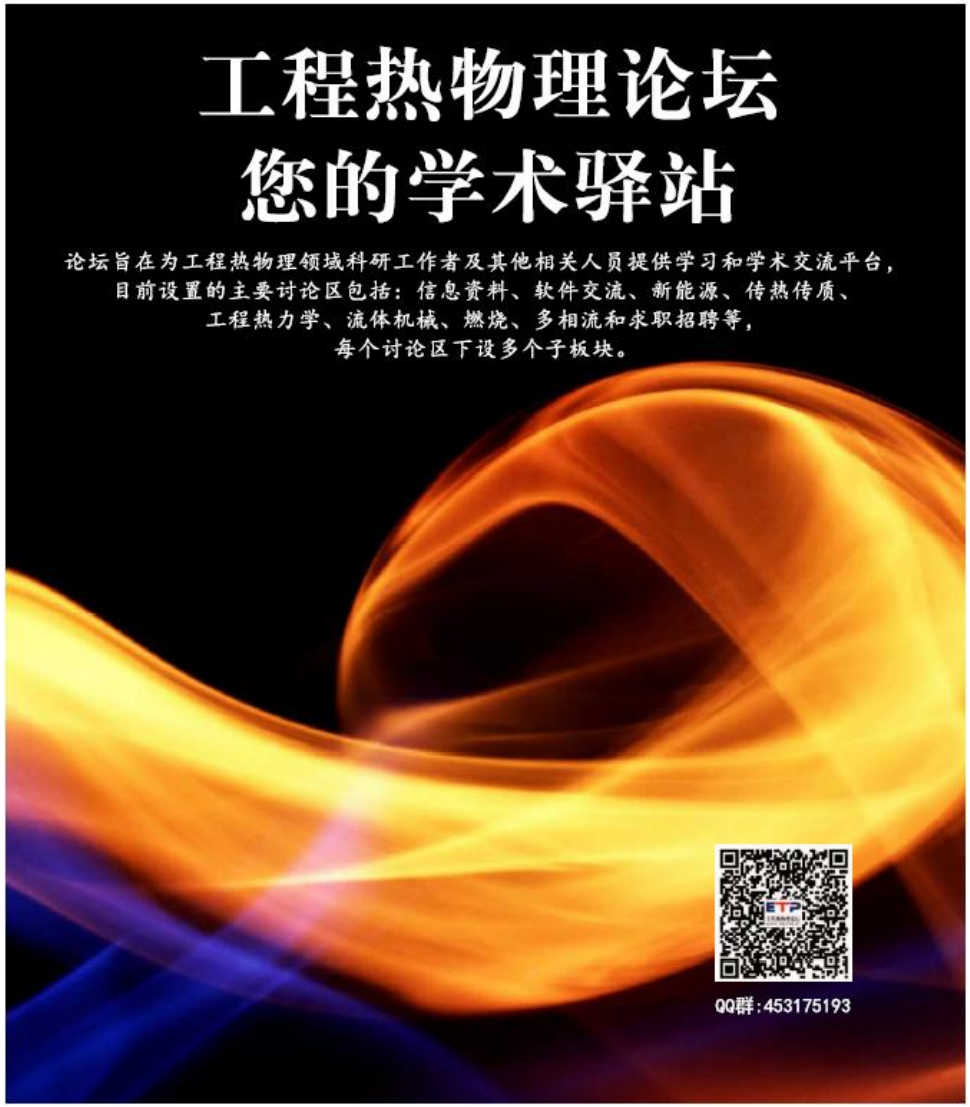

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