

Numerical Heat Transfer

Chapter 13 Application examples of fluent for basic flow and heat transfer problems



Instructor Wen-Quan Tao; Qinlong Ren; Li Chen

CFD-NHT-EHT Center
Key Laboratory of Thermo-Fluid Science & Engineering
Xi'an Jiaotong University
Xi'an, 2021-Dec.-29

数值传热学

第 13 章 求解流动换热问题的Fluent软件基础应用举例



主讲 陶文铨

辅讲 任秦龙, 陈 黎

西安交通大学能源与动力工程学院
热流科学与工程教育部重点实验室

2021年12月29日, 西安

第 13 章 求解流动换热问题的Fluent软件基础应用举例

13.1 Conductive heat transfer in a heat sink

13.2 Unsteady cooling process of a steel ball

13.3 Flow and heat transfer in a micro-channel

13.4 Flow and heat transfer in chip cooling

13.5 Liquid cooling of photovoltaic panel

13.6 Phase change material melting with fins

第 13 章 求解流动换热问题的Fluent软件基础应用举例

13.1 散热装置导热问题

导热问题

13.2 非稳态圆球冷却问题

13.3 微通道内流动换热问题

13.4 芯片冷却流动换热问题

对流传热问题

13.5 太阳能光伏板水冷问题

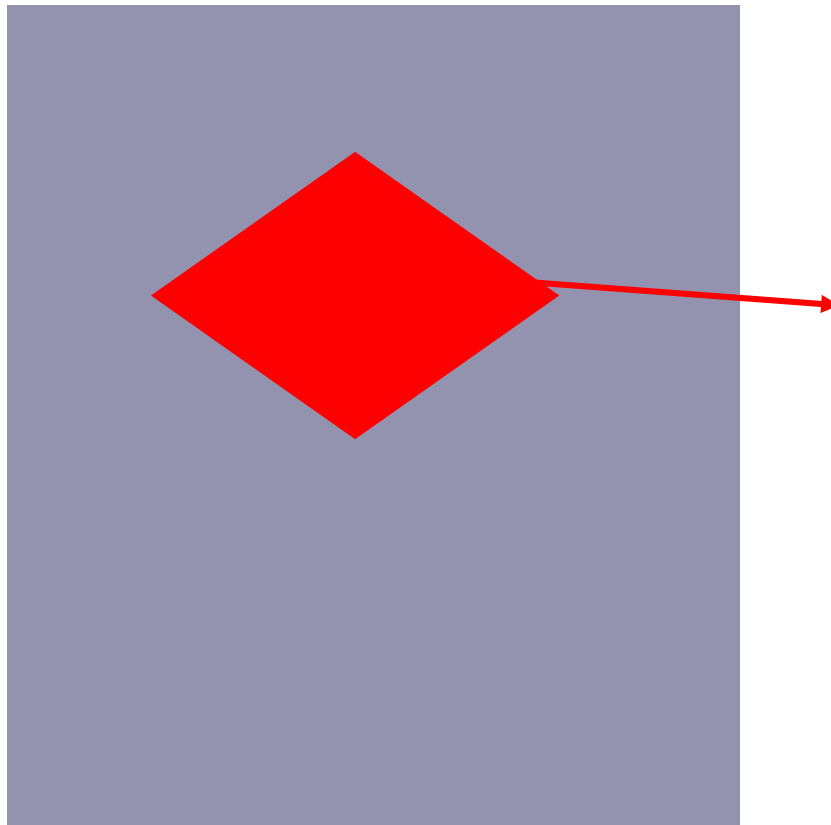
13.6 肋片强化相变材料融化

相变传热

Review

Example 2

Patching (修补) Values in Selected Cells



Domain

Sub-region need to Patch

- 1. Define the sub-region**
- 2. Use Patch to specify related variables.**

For transient problem you have to

time stepping method, time step size, the max iteration per time step

Max iteration per time step

Inner iteration times

Time step size

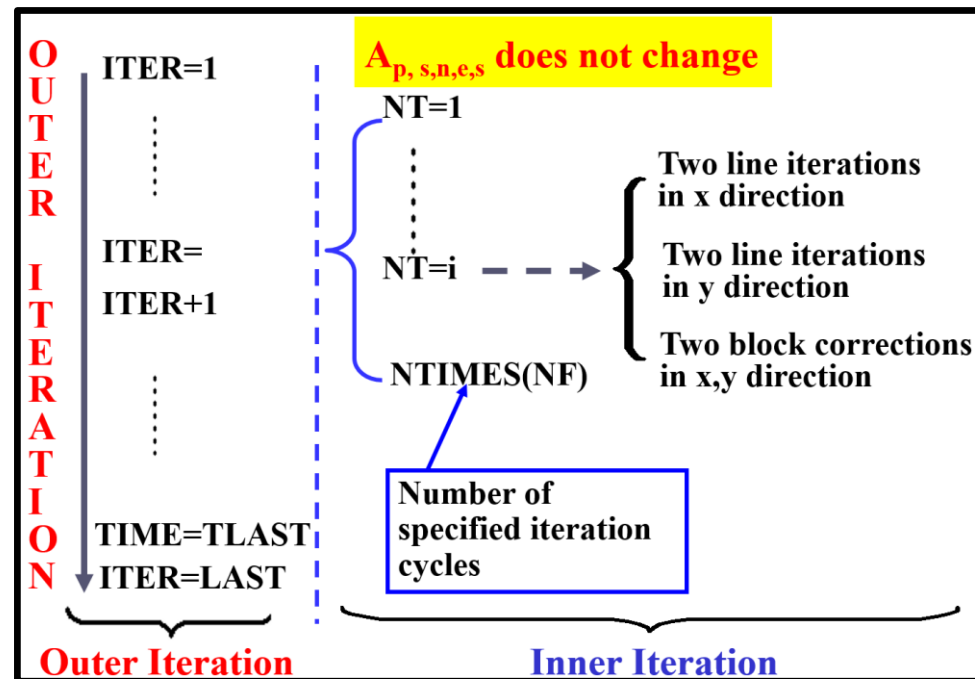
Outer iteration

Time stepping method

Fixed

Adaptive method

Teaching code



For fully implicit scheme, Δt does not affect stability, but will affect the accuracy of the simulation results.

The following way is recommended by Fluent to set

Δt :

1. At each time step, the ideal iteration number is 5-10.

2. If Fluent needs more inner iteration step (>10) for convergence at each time step, Δt is too large.

3. If Fluent needs only a few iteration steps, Δt is too small.

13.6 Phase change material melting with fins

肋片强化相变材料融化传热问题

Focus: compared with previous examples, the focus of this example is solid-liquid phase change heat transfer.

13.6 Phase change material melting with fins

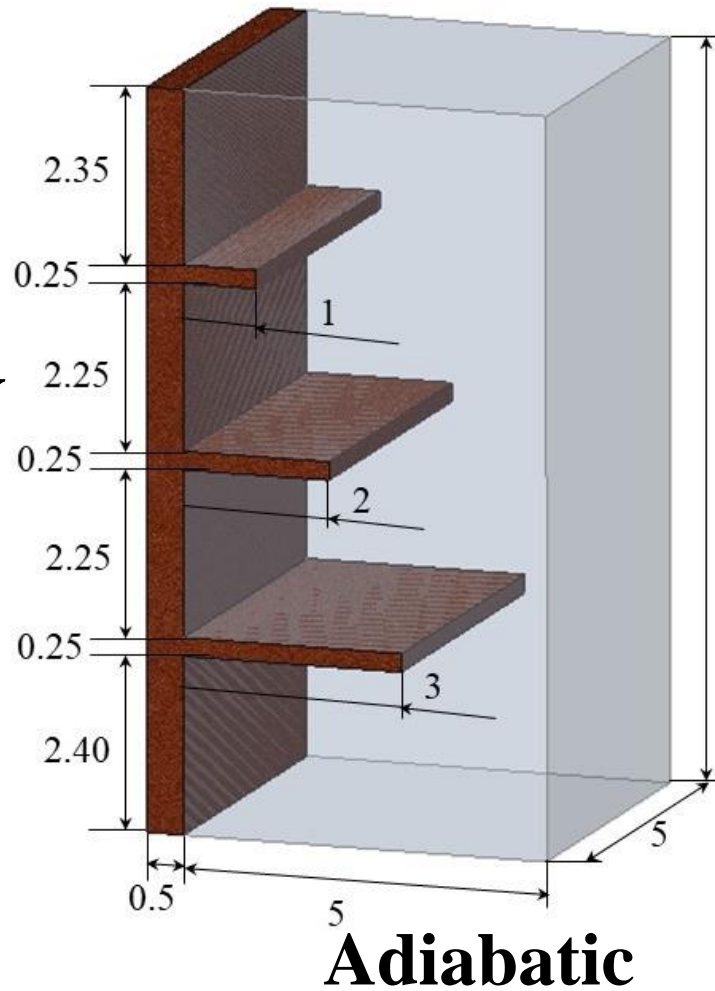
Known: Paraffin RT50 is used as the phase change material, and internal copper fins are used to enhance the solid-liquid phase change inside the 3D square cavity.

Property	Copper	RT50
ρ [kg/m^3]	8954	880
C_p [$J/kg \cdot K$]	383	2000
k [$W/m \cdot K$]	400	0.2
β [K^{-1}]	–	1×10^{-3}
μ [$Pa \cdot s$]	–	0.0275
L [kJ/kg]	–	168
T_m [K]	–	322

Assumption: (1) laminar flow, (2) incompressible fluid, (3) constant fluid properties except the density ρ , (4) negligible radiation heat transfer

Adiabatic

$T_l = 330\text{ K}$



10 **Adiabatic**

Initial temperature

$T_i = 321.9\text{ K}$

Adiabatic

Fig.1 Computational domain (mm)

Find: Temperature distribution and liquid fraction distribution in the domain.

Governing equations:

Continuity equation:

$$\frac{\partial u_i}{\partial x_i} = 0$$

Momentum equations:

$$\rho \frac{D(u_i)}{Dt} = -\frac{\partial p}{\partial x_i} + \mu \frac{\partial^2 u_i}{\partial x_j \partial x_j} + F_i$$

Energy equation for PCM:

$$\frac{\partial(\rho h)}{\partial t} + \frac{\partial(u_i \rho c_{pf} T_f)}{\partial x_i} = k_f \left(\frac{\partial^2 T_f}{\partial x_i^2} \right)$$

Where h is the enthalpy, T_f is the PCM temperature, c_{pf} is PCM specific heat and, k_f is PCM thermal conductivity.

Energy equation for the fins:

$$\rho_s c_{ps} \frac{\partial T_s}{\partial t} = k_s \left(\frac{\partial^2 T_s}{\partial x_i^2} \right)$$

where T_s is fin temperature and k_s is fin thermal conductivity

**拥有了ANSYS FLUENT 是否还需要学习数值方法？
是否还需要编写流动传热计算程序？**

YES! ! ! !

**发展具有独立知识产权的流动传热计算代码和软件，
是实现我国能源科技强国的必要条件！**

**即是打破西方技术封锁的基本保障，也是维护国家安
全的迫切需求！**

需要思考的两个问题：

**自主发展的计算代码是否可以实现ANSYS FLUENT的
基本模块功能？ ？ ？**

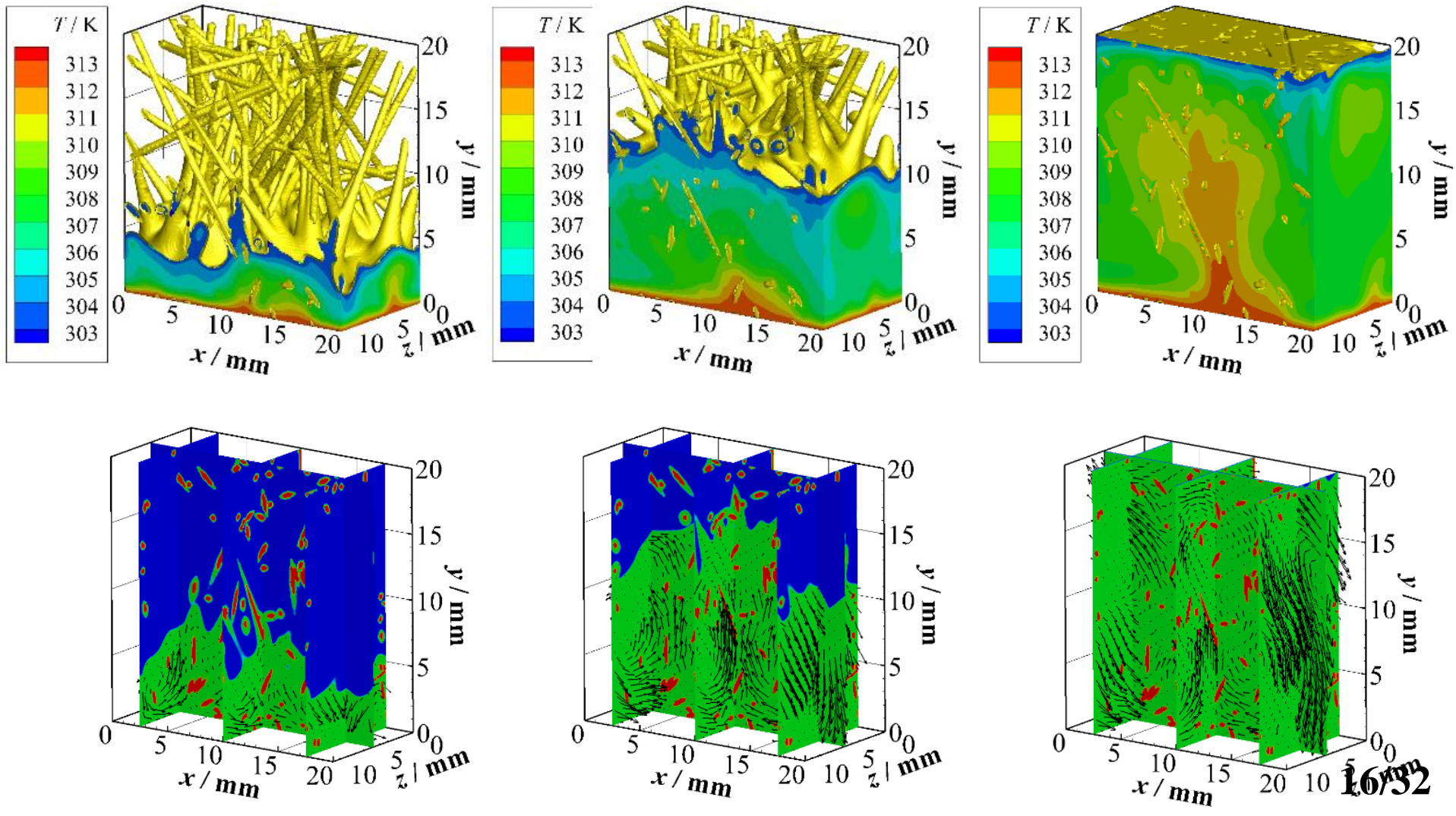
**自主发展的计算代码的功能性是否可以比ANSYS
FLUENT更强大？ ？**

Of Course! ! ! ! !

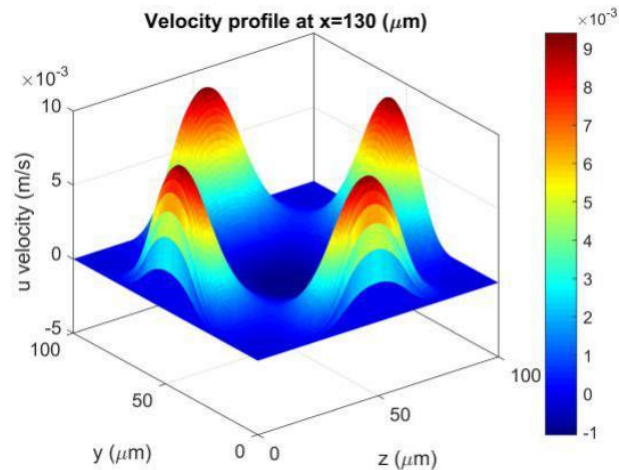
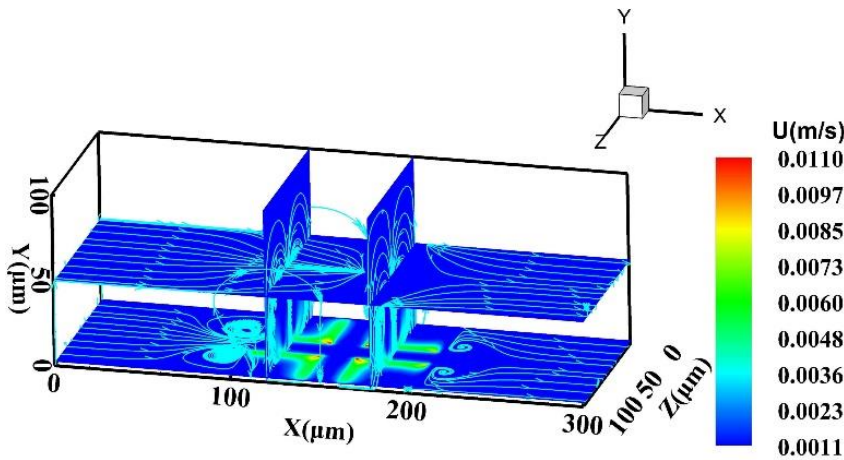
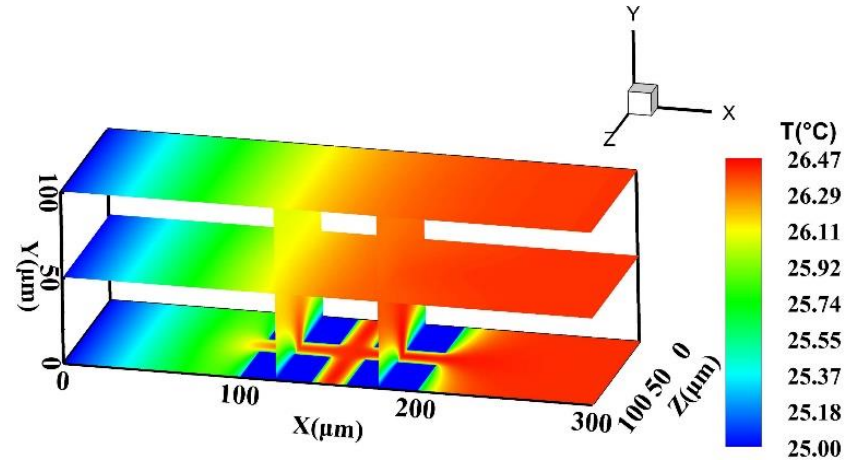
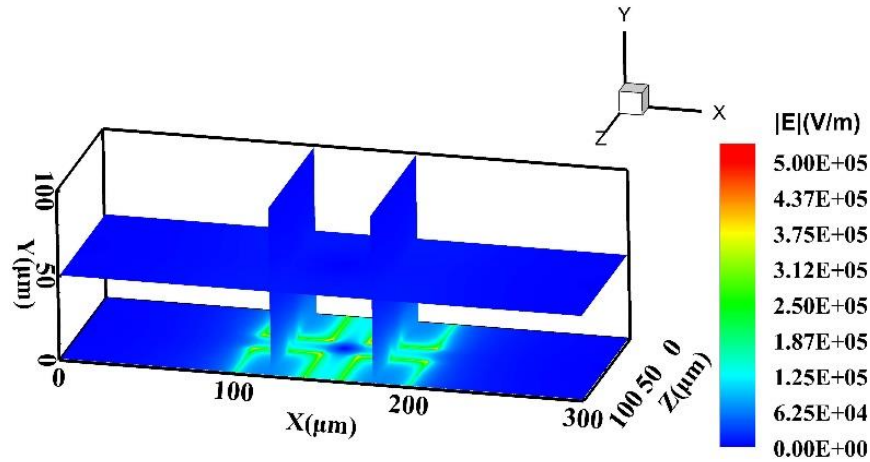
自主代码与国外软件性能对比

类别	ANSYS FLUENT	COMSOL	自主代码
计算方法	有限容积法	有限元法	格子玻尔兹曼法
并行效率	一般	一般	强
复杂结构处理	困难	容易	容易
多场耦合性能	一般	强	强
稳定性	强	一般	一般

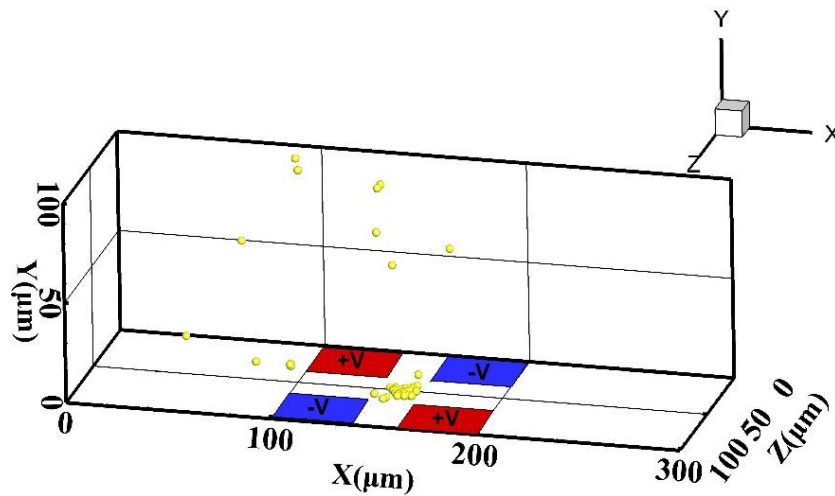
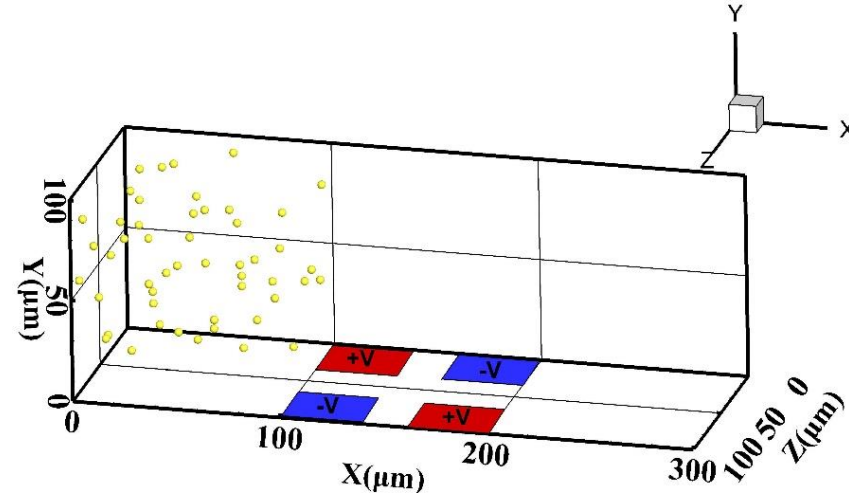
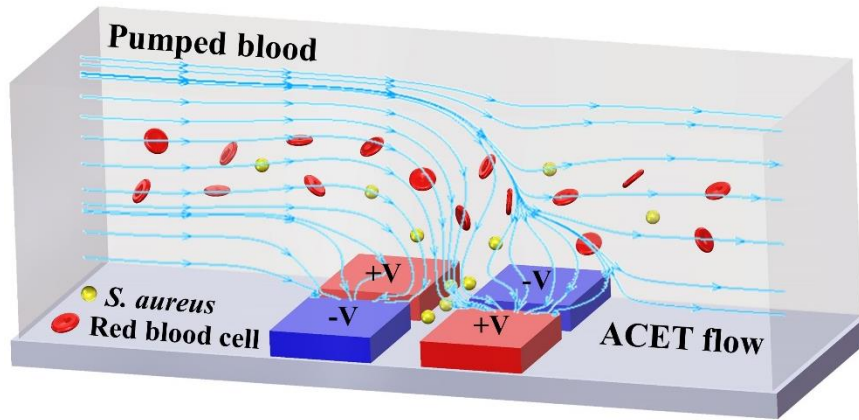
三维多孔金属纤维内固液相变传热 (GPU加速LBM)



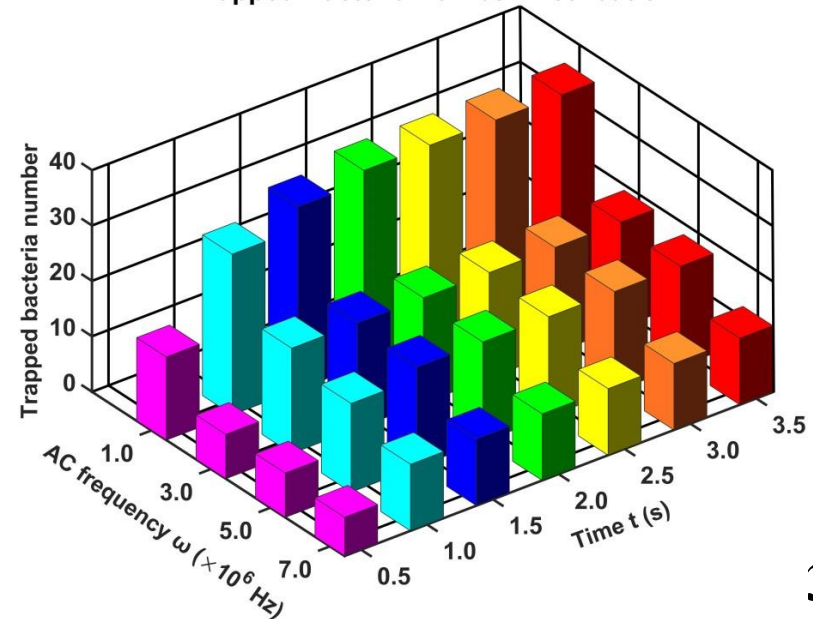
三维多场耦合非牛顿血液电热流动 (GPU加速LBM)



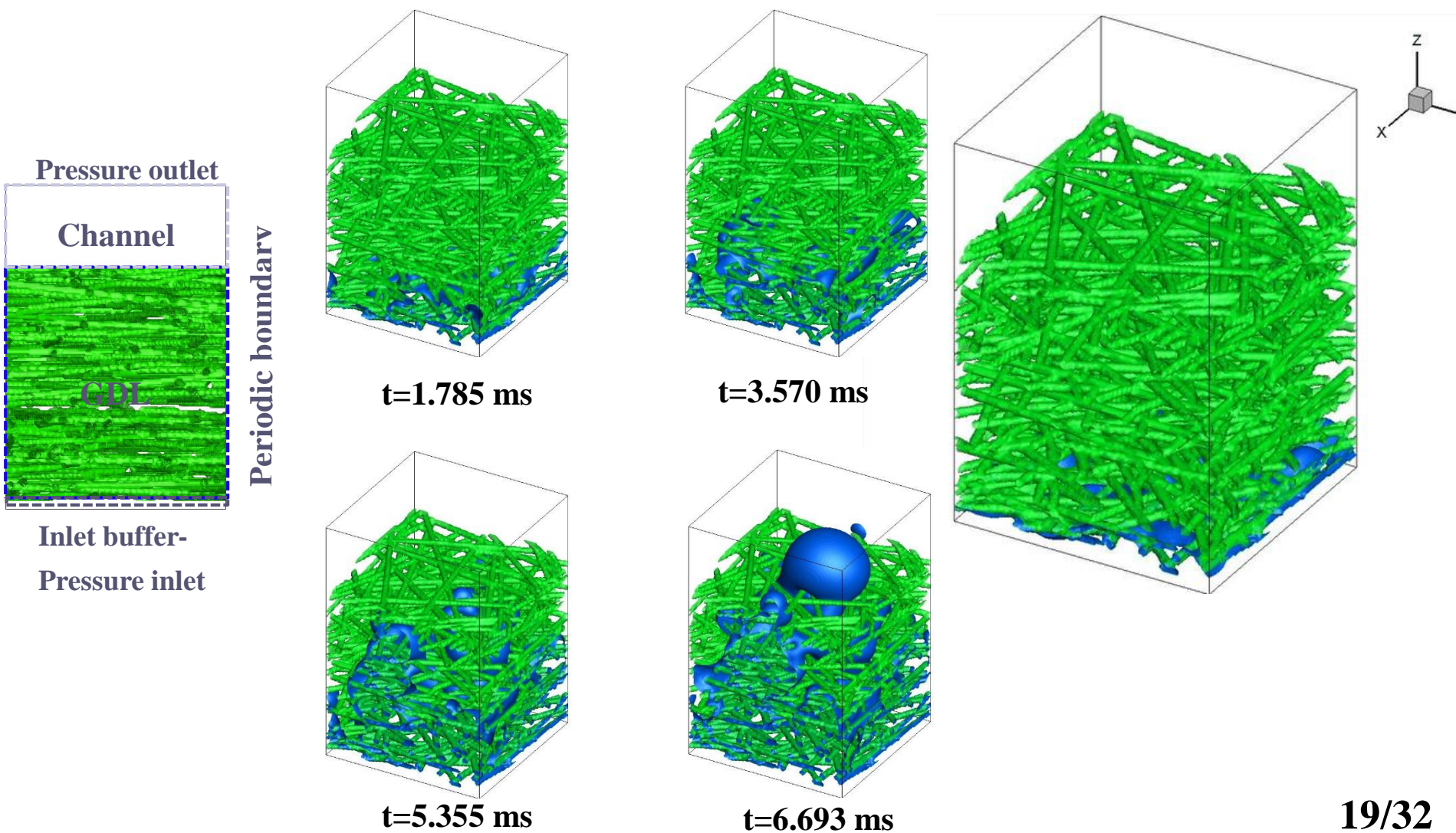
三维微流控芯片血液细菌富集 (GPU加速LBM)



Trapped Bacteria Number Distribution



燃料电池扩散层内液态水突破过程 (GPU加速LBM)



CFD的软件开发是一项典型的 复杂工程



Prof. Kong Ling

$$\underbrace{\frac{\partial(\rho\phi\phi)}{\partial t}}_{\text{Transient}} + \underbrace{\nabla \cdot (\rho\phi\mathbf{u}\phi)}_{\text{Convection}} = \underbrace{\nabla \cdot (\Gamma_\phi \nabla \phi)}_{\text{Diffusion}} + \underbrace{s_\phi}_{\text{Source}}$$

有限容积法的通用输运方程

其实这些算子还可以进一步简化

直到形成这样的软件框架

应用层

特定工程问题求解模块

方法层

单一物理问题的求解算法与模型

离散层

控制方程各部分的离散及格式

框架层

计算网格、物理场、代数方程组

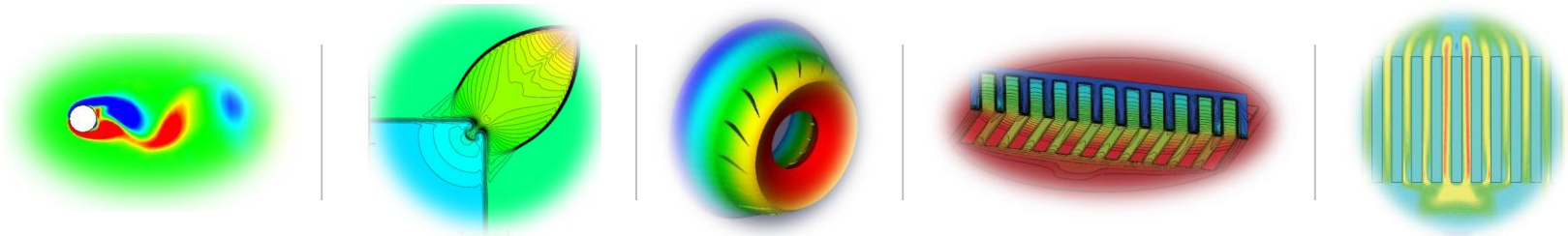
基础层

基本代数运算，几何单元

MHT

Multi- physics phase region scale

Heat Transfer



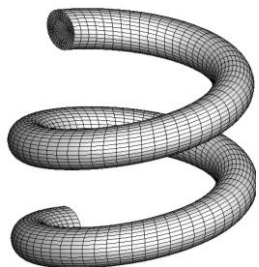
框架层功能：网格支持模块

非结构化网格

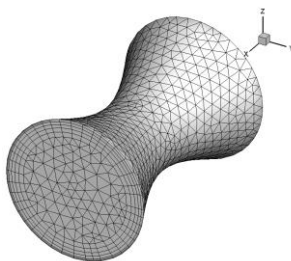
二维与三维统一

支持多种格式的网格文件

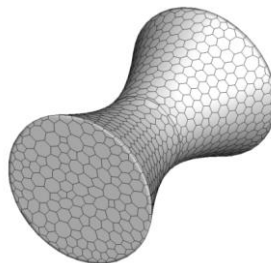
六面体网格



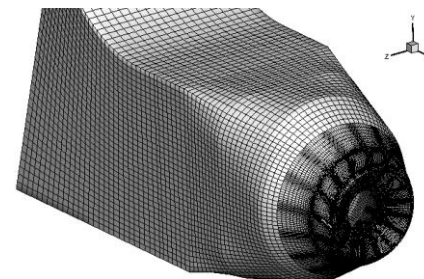
混合网格



多面体网格

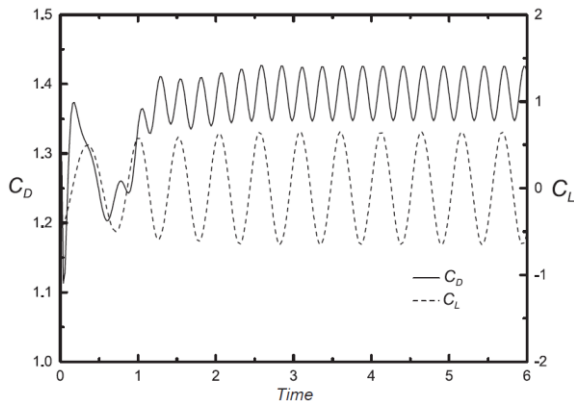
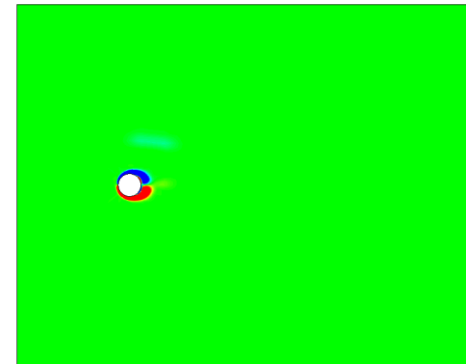
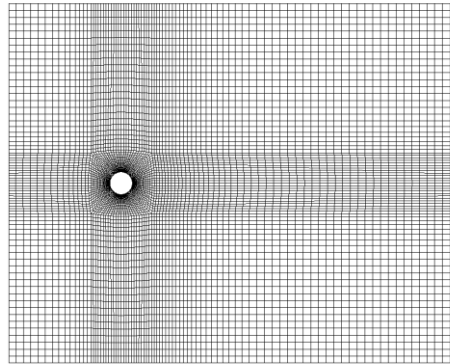
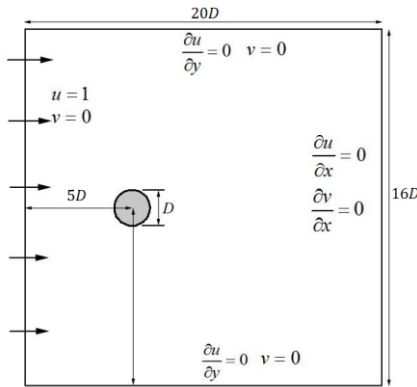


多区域网格



方法层功能：求解不可压缩流动的

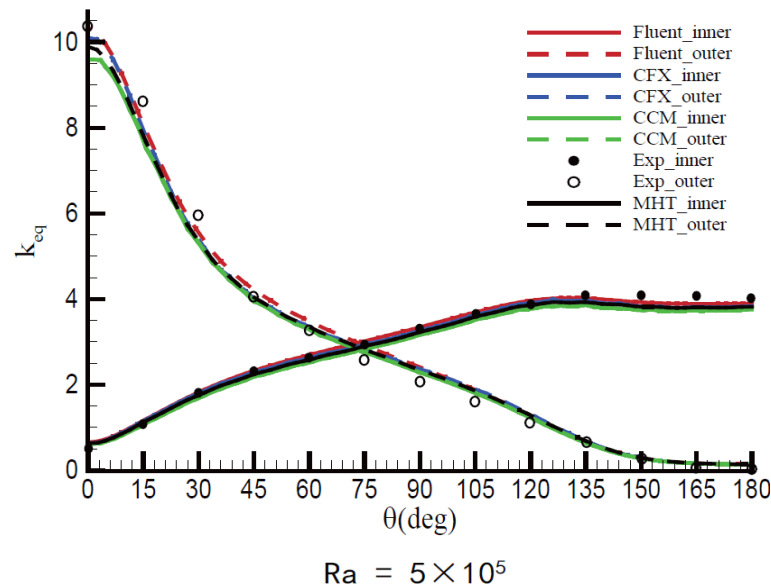
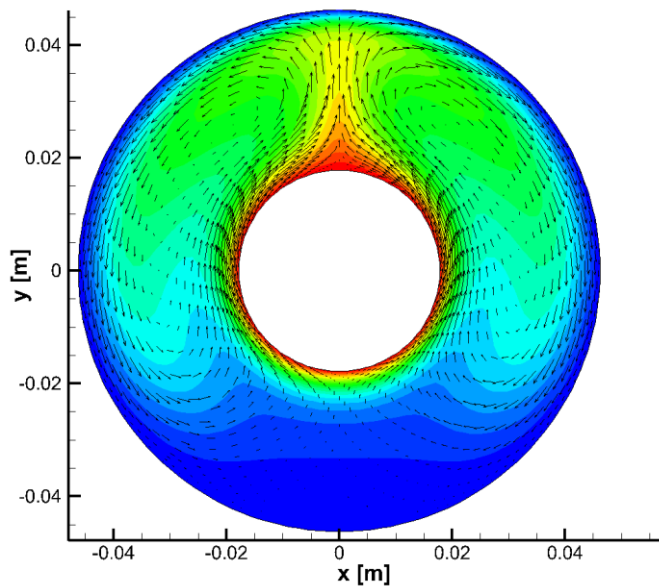
SIMPLE算法



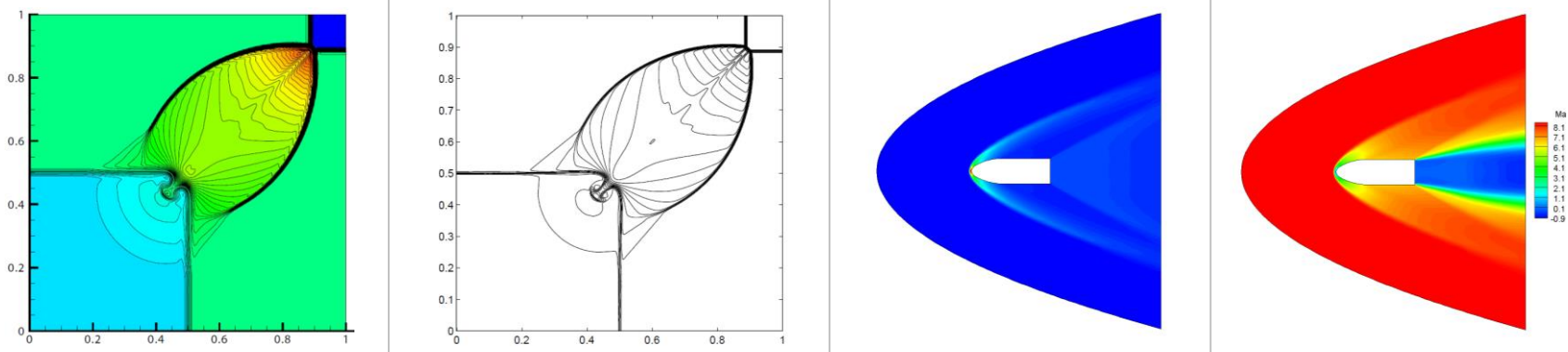
	C_D	C_L	St
	1.388 ± 0.041	± 0.65	0.192
$Re = 200$			
Authors	C_D	C_L	St
Rosenfeld et al. [47]	1.31 ± 0.04	± 0.65	0.20
Liu et al. [48]	1.31 ± 0.049	± 0.69	0.192
Wright and Smith [49]	1.33 ± 0.04	± 0.68	0.196
Calhoun [50]	1.17 ± 0.058	± 0.67	0.202
Russell and Wang [51]	1.29 ± 0.022	± 0.50	0.195
Stålberg et al. [52]	-	-	-
Choi et al. [45]	1.36 ± 0.048	± 0.64	0.191
Taira and Colonius [46]	1.34 ± 0.047	± 0.68	0.195
Present	1.37 ± 0.051	± 0.71	0.198

P.H. Chiu, R.K. Lin, Tony W.H. Sheu, A differentially interpolated direct forcing immersed boundary method for predicting incompressible Navier-Stokes equations in time-varying complex geometries, *Journal of Computational Physics*, 2010, 229, 4476-4500

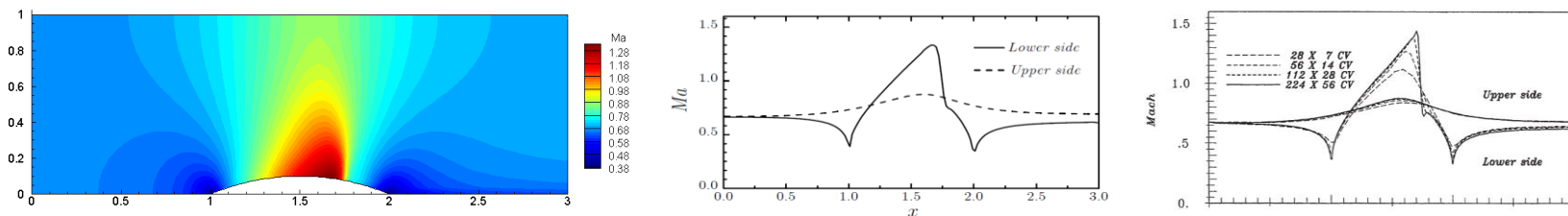
引入求解自然对流的Bossinisque假设



方法层功能：可压缩流动

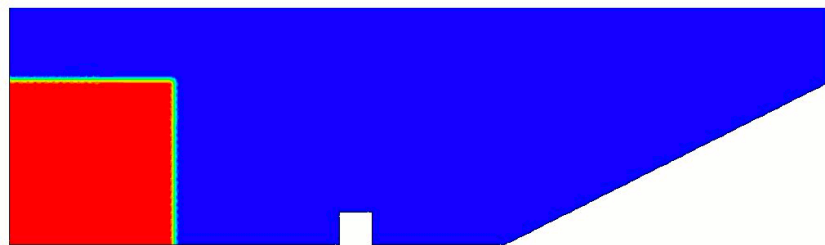


P.D. Lax, X.D. Liu, Solution of two-dimensional Riemann problems of gas dynamics by positive schemes, *SIAM J. Sci. Comput.*, 1998, 19(2), 319-340



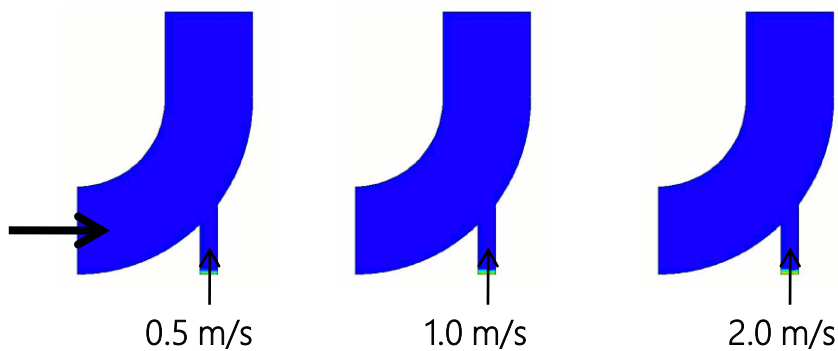
方法层功能：两相流

VOSET界面追踪算法

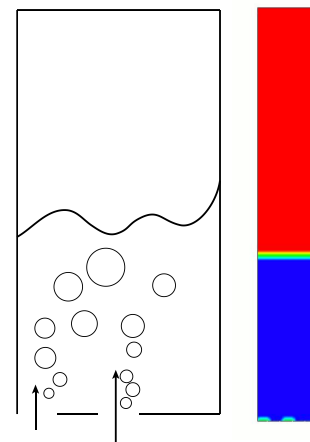


两流体模型

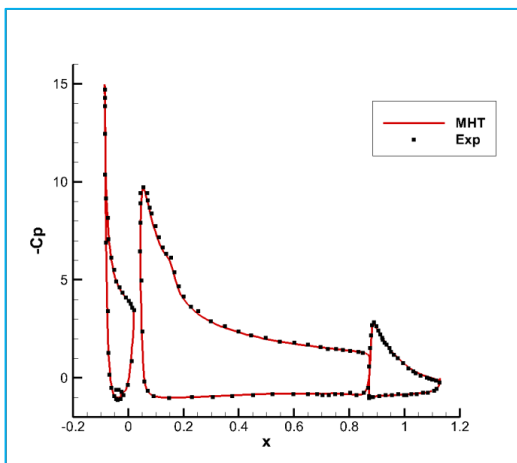
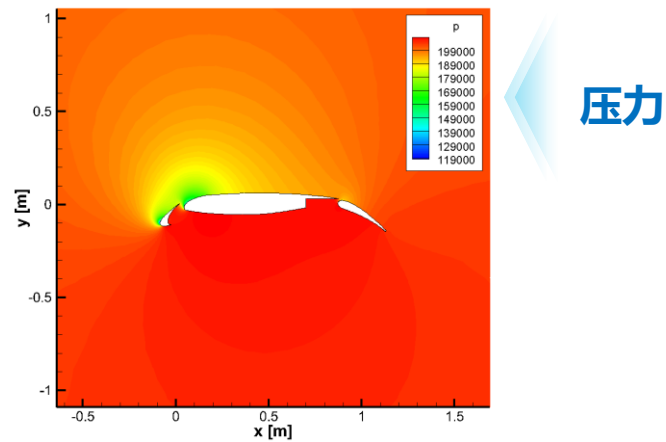
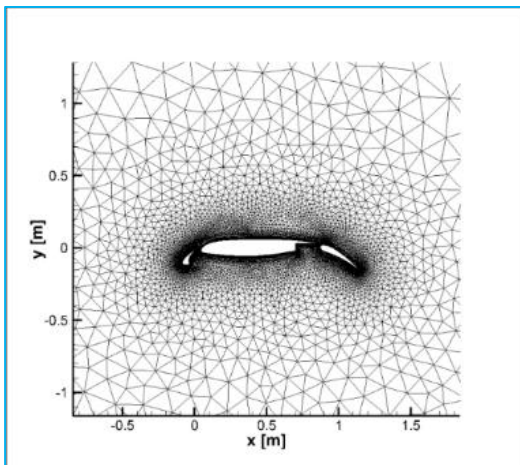
主支管两相混合



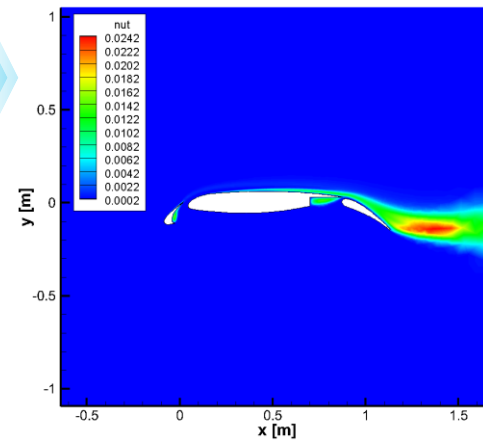
气泡上升流



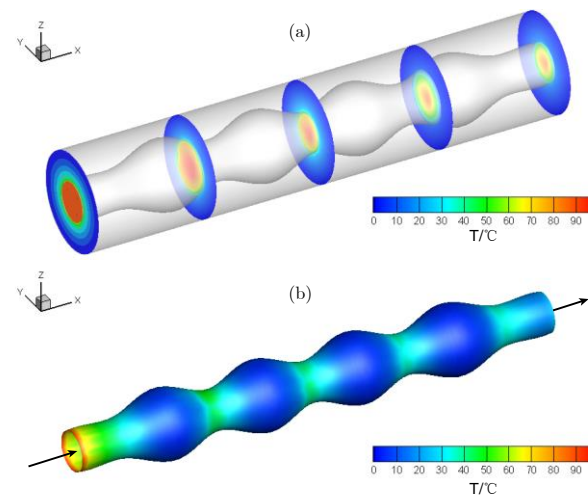
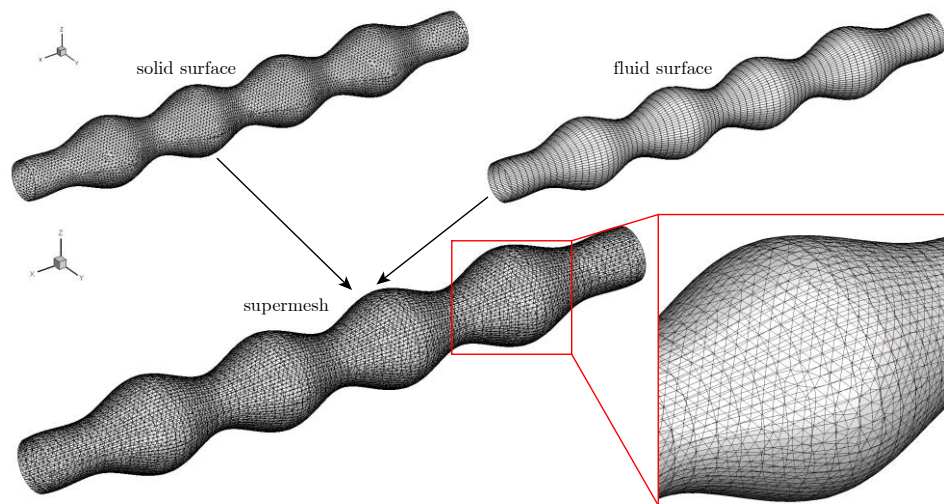
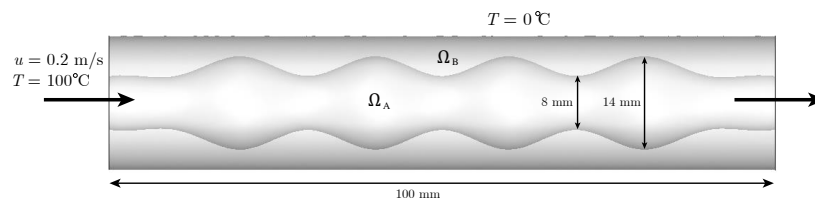
方法层功能：湍流模型



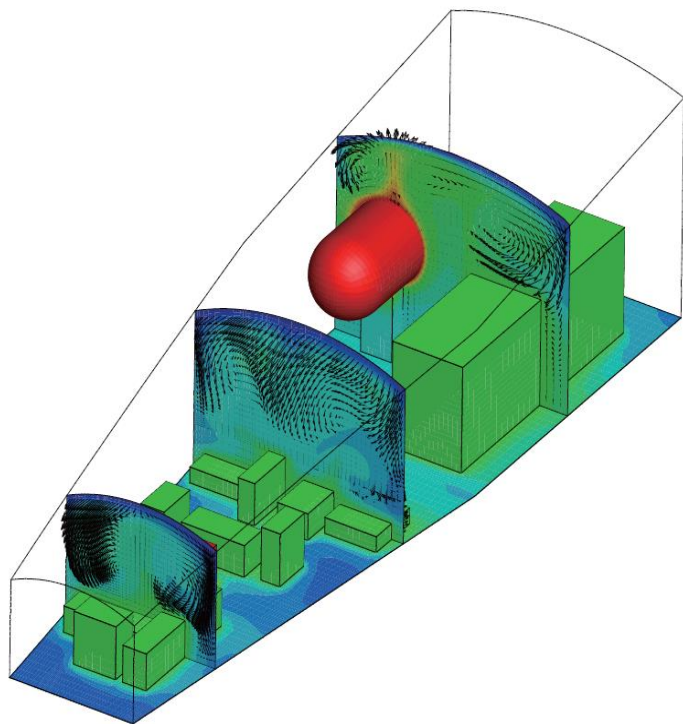
湍流粘性



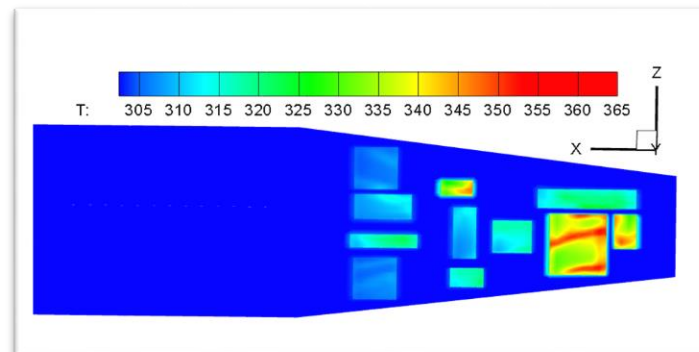
方法层功能：网格的非协调界面



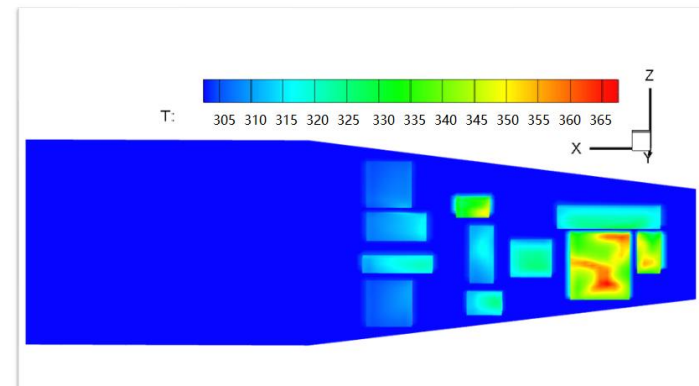
应用举例：某飞行器设备舱自然对流



流场与温度场



FLUENT



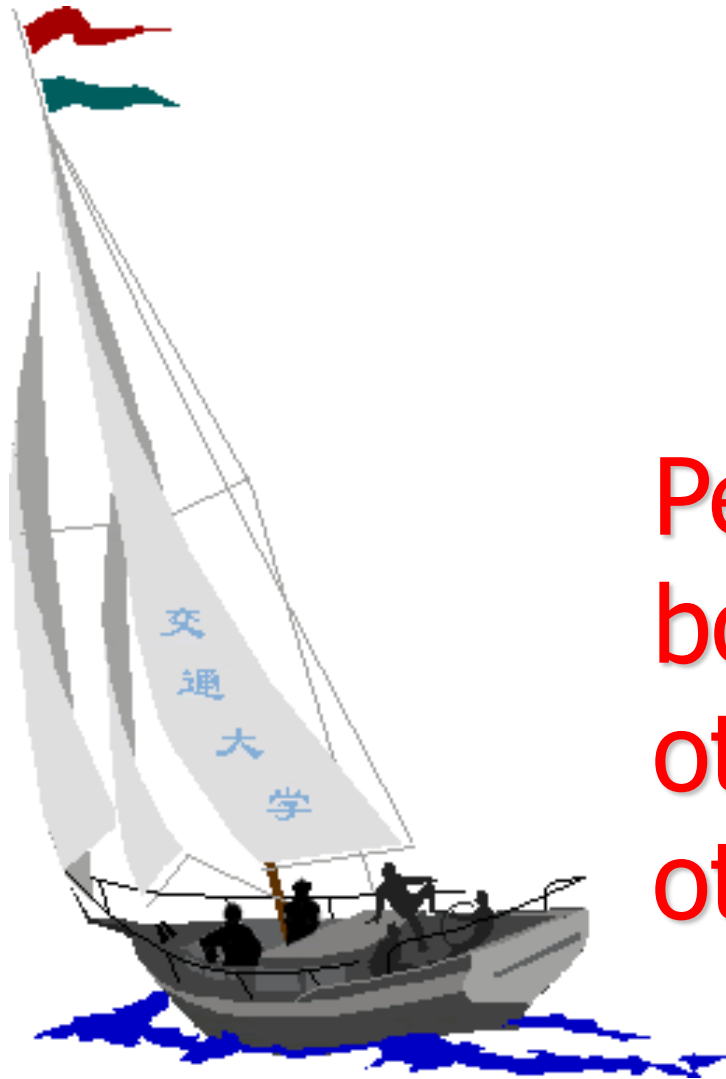
MHT

欢迎各位同学关注数峰信息科技有限公司微信公众号进行交流



数峰信息科技有限公司

SHUFENG TECHNOLOGICAL INFORMATION



同舟共济 渡彼岸!

People in the same
boat help each
other to cross to the
other bank, where....