



# Numerical Heat Transfer

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



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# 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



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# 第 13 章 求解流动换热问题的Fluent软件基础应用举例

13.1 Heat transfer with source term

13.2 Unsteady cooling process of a steel ball

13.3 Lid-driven flow and heat transfer

13.4 Flow and heat transfer in a micro-channel

13.5 Flow and heat transfer in chip cooling

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 有内热源的导热问题**

**导热问题**

**13.2 非稳态圆球冷却问题**

**13.3 顶盖驱动流动换热问题**

**混合对流问题**

**13.4 微通道内流动换热问题**

**13.5 芯片冷却流动换热问题**

**微通道问题**

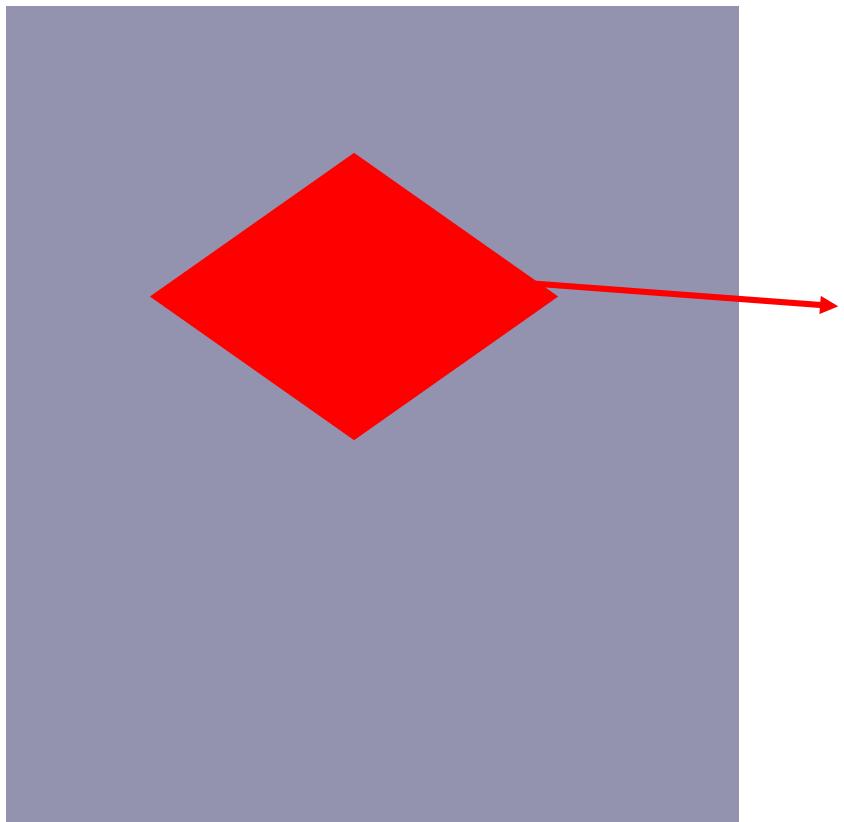
**13.6 肋片强化相变材料融化**

**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

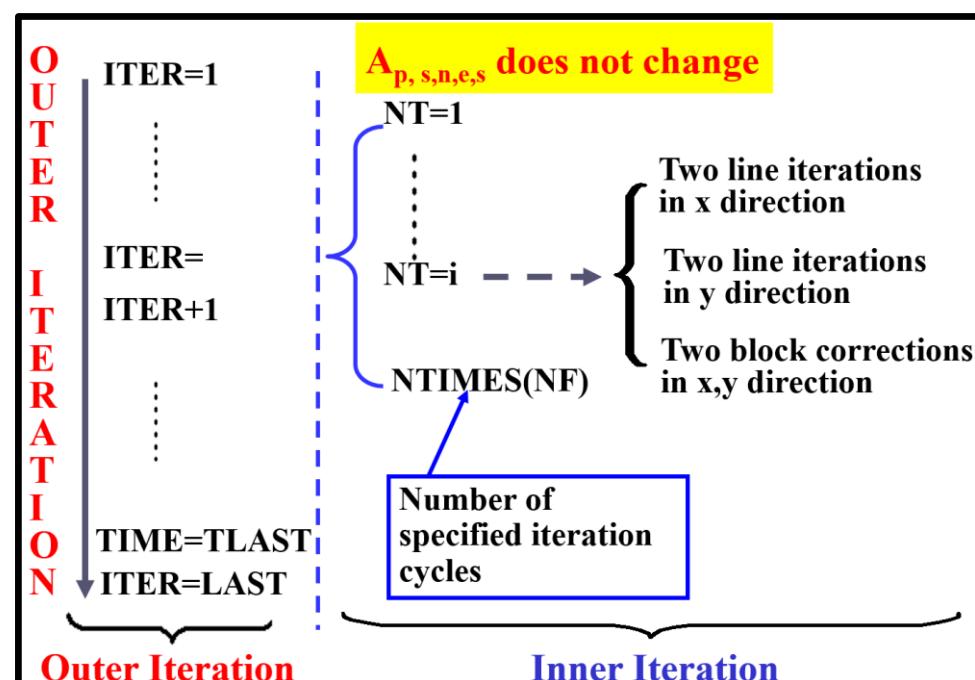
Outer iteration

## Time stepping method

Fixed

Adaptive method

## Teaching code





For fully implicit scheme,  $\Delta t$  does not affect stability, but will affect the accuracy of the simulation results.

The following way is recommended by Fluent to set

$\Delta t$ :

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,  $\Delta t$  is too large.
3. If Fluent needs only a few iteration steps,  $\Delta t$  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

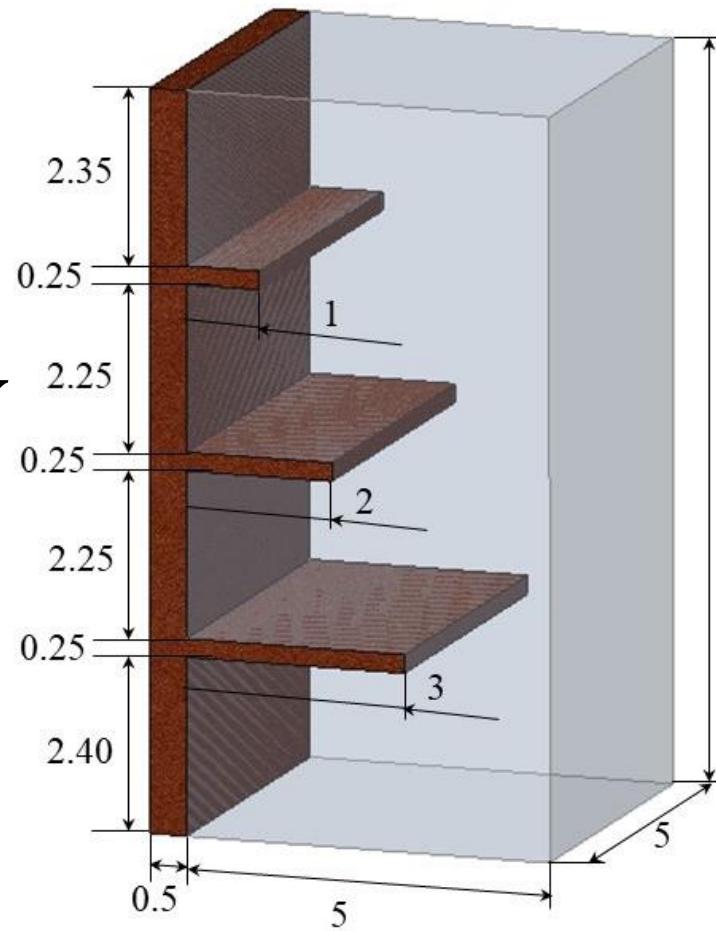
**Known:** Paraffin RT50 is used as the phase change material, and internal copper fins are used to enhance the solid-liquid phase change inside the 3D square cavity.

Property	Copper	RT50
$\rho [kg/m^3]$	8954	880
$C_p [J/kg \cdot K]$	383	2000
$k [W/m \cdot K]$	400	0.2
$\beta [K^{-1}]$	$1.67 \times 10^{-5}$	$1 \times 10^{-3}$
$\mu [Pa \cdot s]$	—	0.0275
$L [kJ/kg]$	—	168
$T_m [K]$	—	322

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

# Adiabatic

$T_l = 330 K$



10 Adiabatic

Initial temperature

$T_i = 321.9 K$

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:

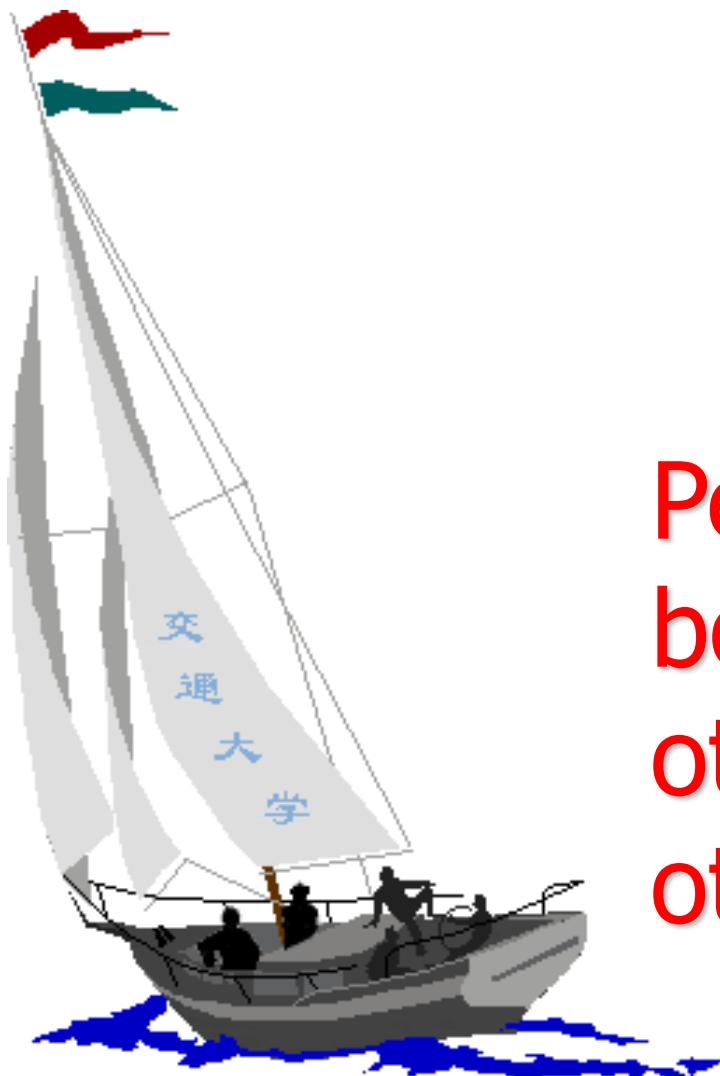
$$\frac{\partial(\rho h)}{\partial t} + \frac{\partial(u_i \rho c_{pf} T_f)}{\partial x_i} = k_f \left( \frac{\partial^2 T_f}{\partial x_i^2} \right)$$

Where  $h$  is the enthalpy,  $T_f$  is the PCM temperature,  $c_{pf}$  is PCM specific heat and  $k_f$  is fluid 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



同舟共济  
渡彼岸!

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