

**L. H. CARNEVALE**  
G. R. ANJOS

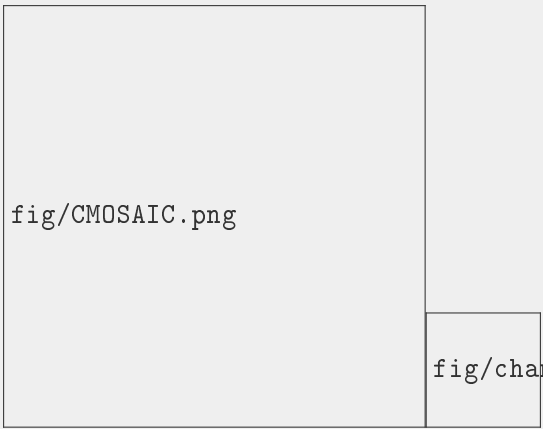
fig/uerj.png

30/07/2018





## Arrefecimento simultâneo de microprocessadores empilhados<sup>1</sup> com diferentes geometrias



fig/CMOSAIC.png

fig/channels\_67.jpg

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<sup>1</sup>figures from Prof. John Thome, Laboratoire de Transfert de Chaleur et de Masse (LTCM), EPFL, <https://ltdcm.epfl.ch>

## Corrente-Vorticidade

$$\frac{\partial \omega_z}{\partial t} + \mathbf{v} \cdot \nabla \omega_z = \frac{1}{Re} \nabla^2 \omega_z \quad (1)$$

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = \omega_z \quad (2)$$

$$\frac{\partial \psi}{\partial y} = v_x, \quad \frac{\partial \psi}{\partial x} = -v_y \quad (3)$$

## Transporte de Calor

$$\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T = \frac{1}{RePr} \nabla^2 T \quad (4)$$

## Condições de Contorno e Iniciais

$$\omega_z = \frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y} \quad (5)$$

$$\psi = \psi_0 \quad (6)$$

fig/triang.png

### Coeficientes da Função de Forma

$$a_i = x_j y_k - x_k y_j ; b_i = y_j - y_k ; c_i = x_k - x_j$$

$$a_j = x_k y_i - x_i y_k ; b_j = y_k - y_i ; c_j = x_i - x_k$$

$$a_k = x_i y_j - x_j y_i ; b_k = y_i - y_j ; c_k = x_j - x_i$$

$$\mathbf{M} = \frac{A}{12} \begin{bmatrix} 2 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 2 \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} B_x \\ B_y \end{bmatrix} = \frac{1}{2A} \begin{bmatrix} b_i & b_j & b_k \\ c_i & c_j & c_k \end{bmatrix}$$

$$\mathbf{G}_x = \frac{1}{6} \begin{bmatrix} b_i & b_j & b_k \\ b_i & b_j & b_k \\ b_i & b_j & b_k \end{bmatrix}$$

$$\mathbf{G}_y = \frac{1}{6} \begin{bmatrix} c_i & c_j & c_k \\ c_i & c_j & c_k \\ c_i & c_j & c_k \end{bmatrix}$$

$$\mathbf{K} = \mathbf{B}^T \mathbf{B}$$

$$A = a_i + a_j + a_k$$

## Corrente-Vorticidade

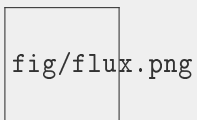
$$\left( \frac{\mathbf{M}}{\Delta t} + \frac{1}{Re} \mathbf{K} + v_x \mathbf{G}_x + v_y \mathbf{G}_y \right) \omega_z^{n+1} = \left( \frac{\mathbf{M}}{\Delta t} \right) \omega_z^n + \frac{\mathbf{f}}{Re}$$

$$\mathbf{K}\psi = \mathbf{M}\omega_z^{n+1} + \mathbf{f}$$

$$v_x = \mathbf{G}_y \psi \quad , \quad v_y = -\mathbf{G}_x \psi$$

## Transport de Calor


$$\left( \frac{\mathbf{M}}{\Delta t} + \frac{1}{RePr} \mathbf{K} + v_x \mathbf{G}_x + v_y \mathbf{G}_y \right) T^{n+1} = \left( \frac{\mathbf{M}}{\Delta t} \right) T^n + \frac{\mathbf{f}}{RePr}$$







## Caso de Validação



fig/poi.png



images/mesh-poi.png

## Parâmetros

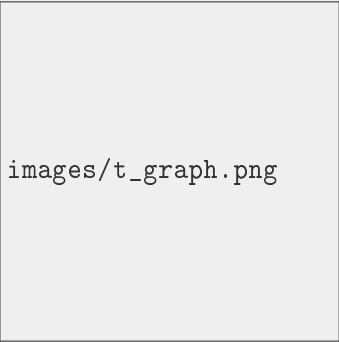
$Re = 10$  ,  $Pr = 1$  ,  $\Delta t = 0.1$  , 100 iterações

images/temp.png

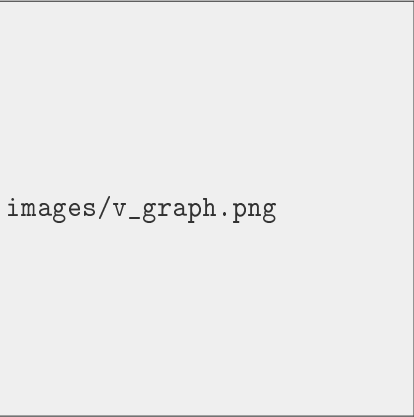
(a) Temperatura

images/vel.png

(b) Velocidade



images/t\_graph.png



images/v\_graph.png

Solução analítica:

$$T = \frac{-15}{48}q + \frac{2}{Re(-\partial P/\partial x)}qx + 3q \left( \frac{y^2}{2} - \frac{y^4}{3} \right)$$

$$u = 6y(1 - y)$$

- Condições de contorno similares ao caso anterior
- Fluxo de calor  $q = 1$  definido apenas nas regiões retangulares
- Mesmo número de Reynolds e Prandtl

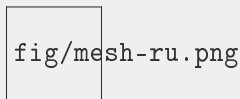
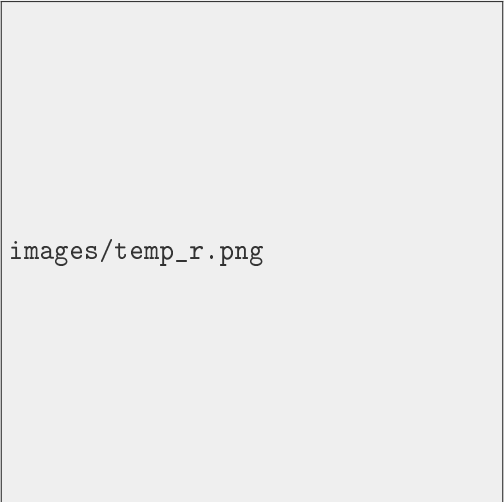
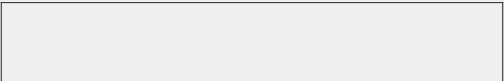


Figure: Malha não estruturada obtida com o software Gmsh



`images/temp_r.png`

(a) Temperatura



- Boa aplicação com a equação do transporte de calor
- Necessário aprimorar a metodologia para acomodar valores mais elevados de  $Re$
- Formulação é melhor aplicada à casos 2D

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**Figure:** Resultados preliminares de um problema de troca de calor conjugado

Obrigado!

fig/uerj.png