



PPS 2024

30 Sept.-03 Oct. | Ferrol · Spain

Introduction to OpenFOAM® Computational Library and Viscoelastic Fluid Flow Simulation

P4 - Case studies: Viscoelastic fluid flow solvers

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University of Minho
School of Engineering



Outline

9:00 – 10:30	Introduction to OpenFOAM (P1)
10:30 – 12:00	Mesh generation and post-processing (P2)
12:00 – 13:00	Lunch break
13:00 – 14:30	Case studies: Single- and two-phase flow solvers (P3)
14:30 – 16:00	Case studies: Viscoelastic fluid flow solvers (P4)



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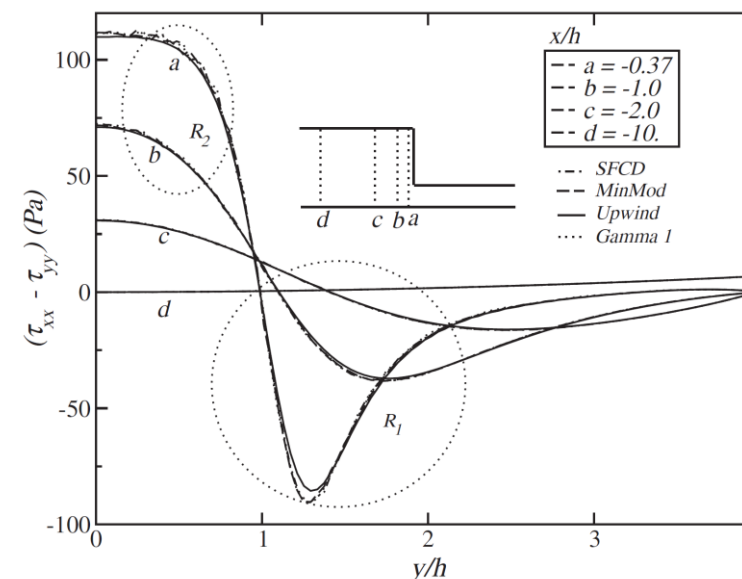
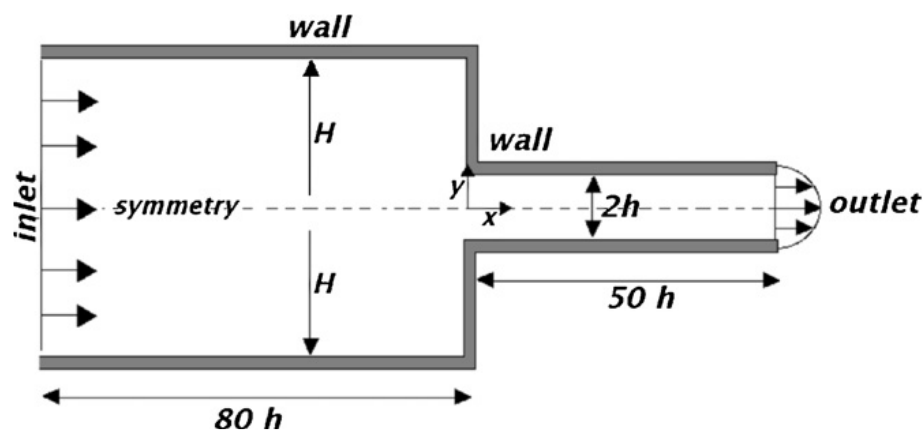
Differential viscoelastic flow solvers in OpenFOAM

Multi mode constitutive models

Maxwell
Oldroyd-B
White Metzner

(L,E, Feta) PTT
Giesekus
Leonov

FENE-(P,CR)
(S,D) XPP
DCPP



JL Favero et al. (Computer Aided Chemical Engineering, **2009**, **2010** / Journal of non-Newtonian Fluid Mechanics, **2010** / Computers & Chemical Engineering, **2010**)



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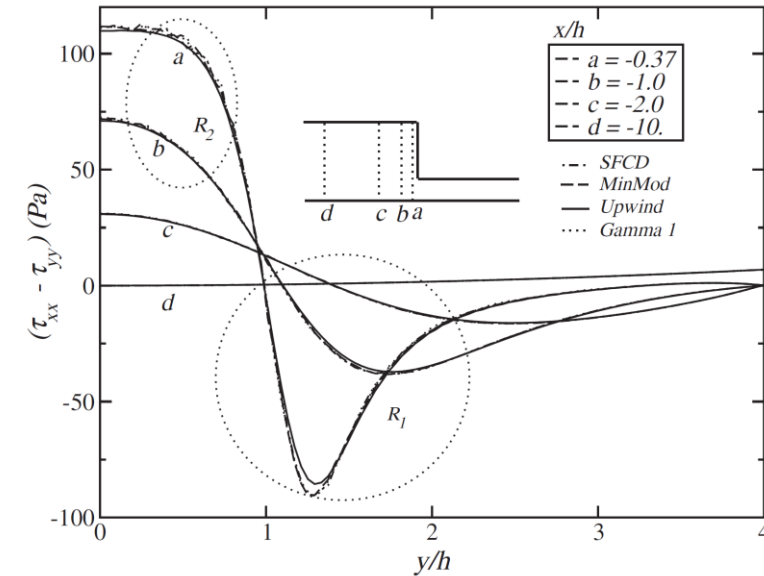
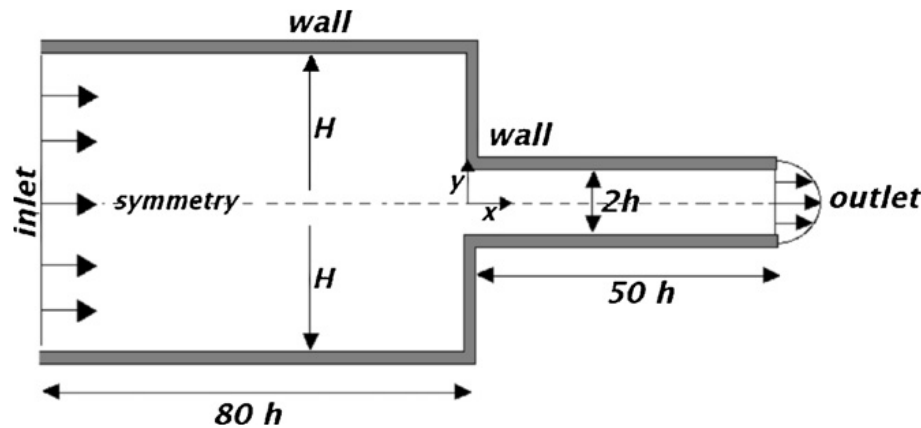
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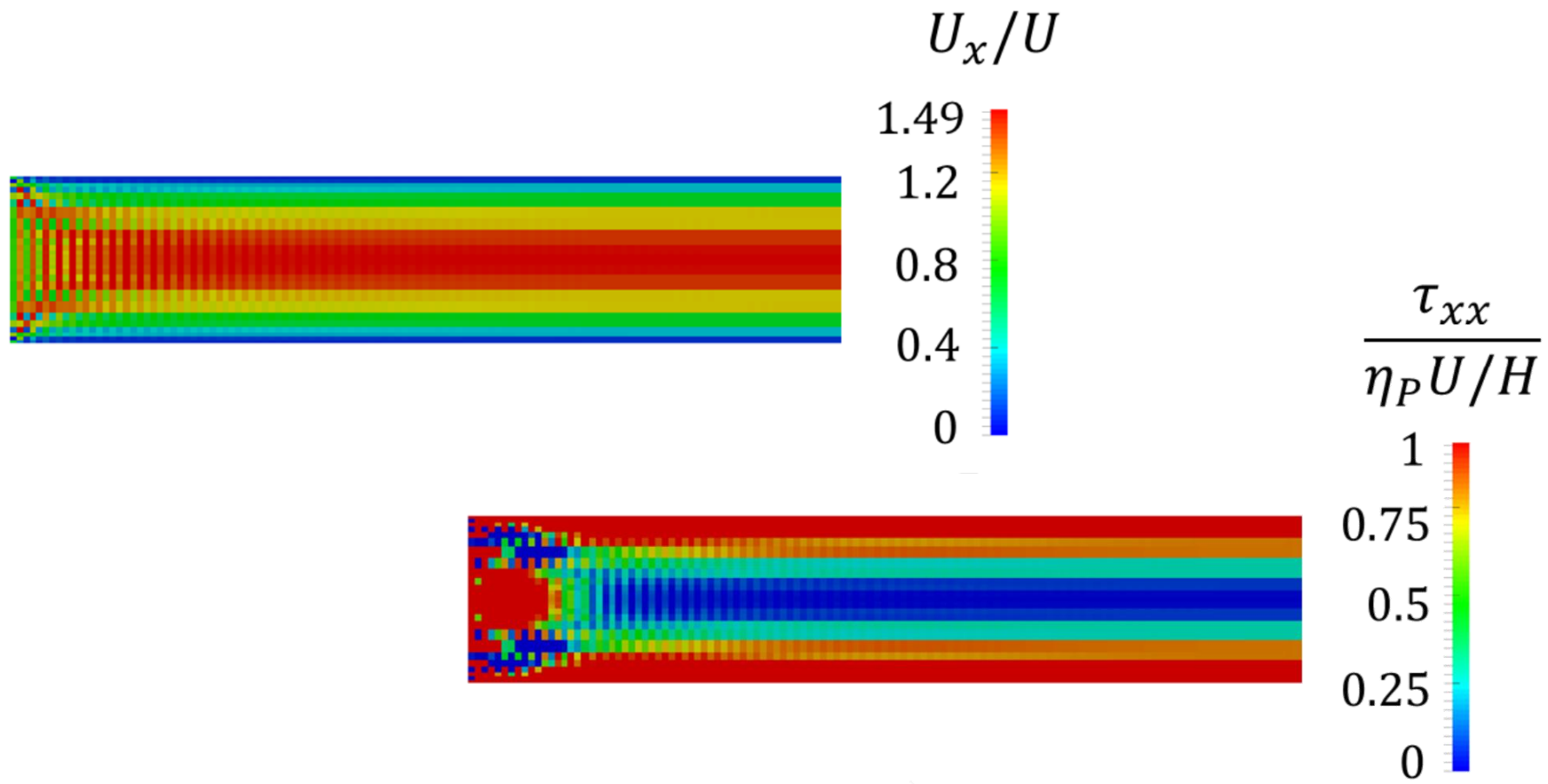
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Improved Both Sides Diffusion

Poiseuille Flow + UCM (Oldroyd-B $\eta_s=0$)

Re=0.01, De=1





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Improved Both Sides Diffusion

foam-extend 5.0

The iBSD – Improved Both-Sides-Diffusion

Conservation

```
fvm::div(phi, U)
```

Original

```
- fvm::laplacian(etaStr/rho, U) )  
==
```

BSD

```
fvm::div(phi, U)  
- fvm::laplacian(etaStr/rho, U) )  
==
```

iBSD

```
- fvc::grad(p)  
+ fvc::div(tau/rho)  
- fvc::div((etaStr/rho) * fvc::grad(U) )
```

$$\nabla \cdot (\rho \mathbf{U} \mathbf{U}) - \eta * \nabla^2 \mathbf{U} = -\nabla p + \nabla \cdot \boldsymbol{\tau} - \nabla \cdot (\eta * \nabla \mathbf{U})$$

Larger Stencil



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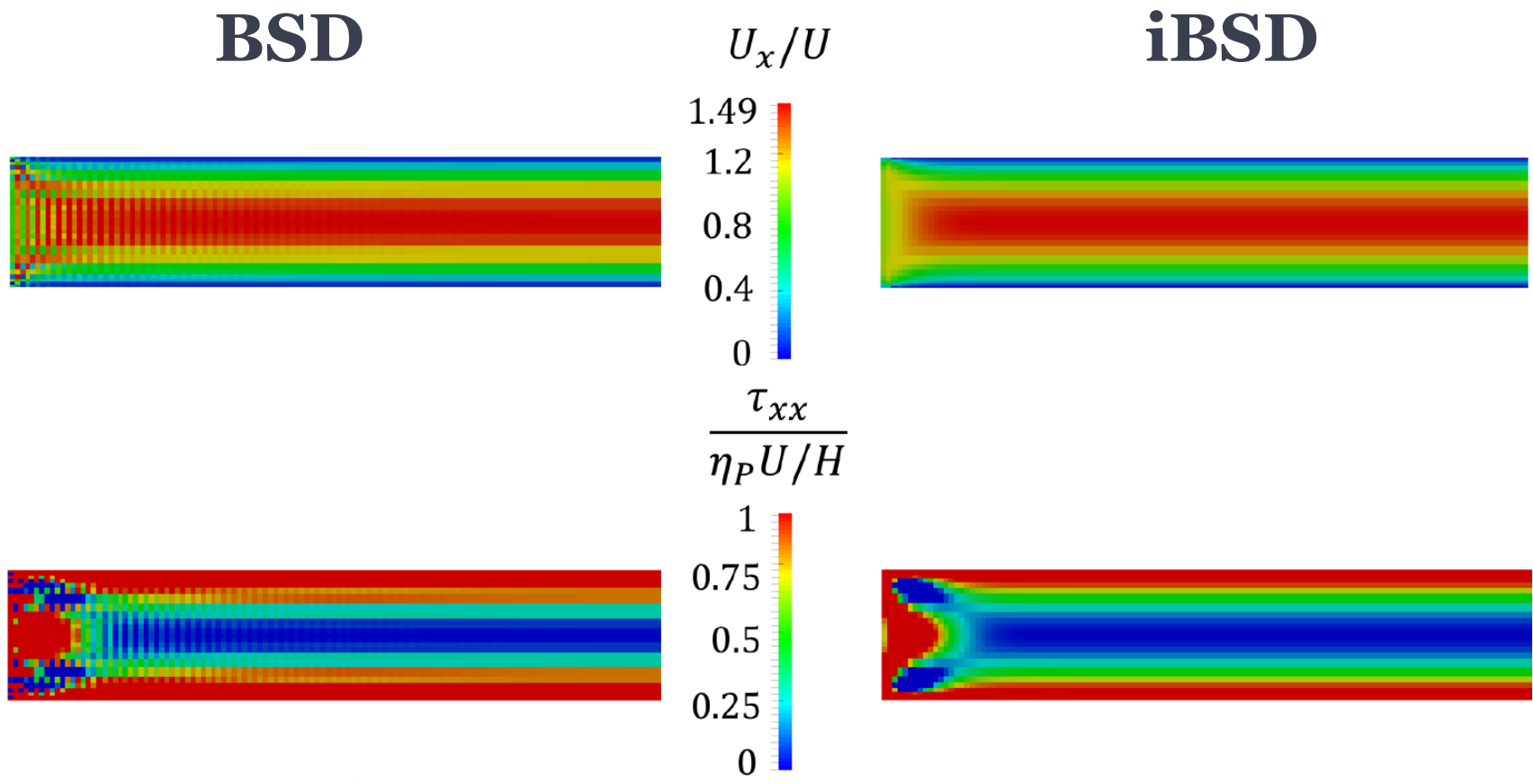




Improved Both Sides Diffusion

Poiseuille Flow + UCM (Oldroyd-B $h_s=0$)

Re=0.01, De=1





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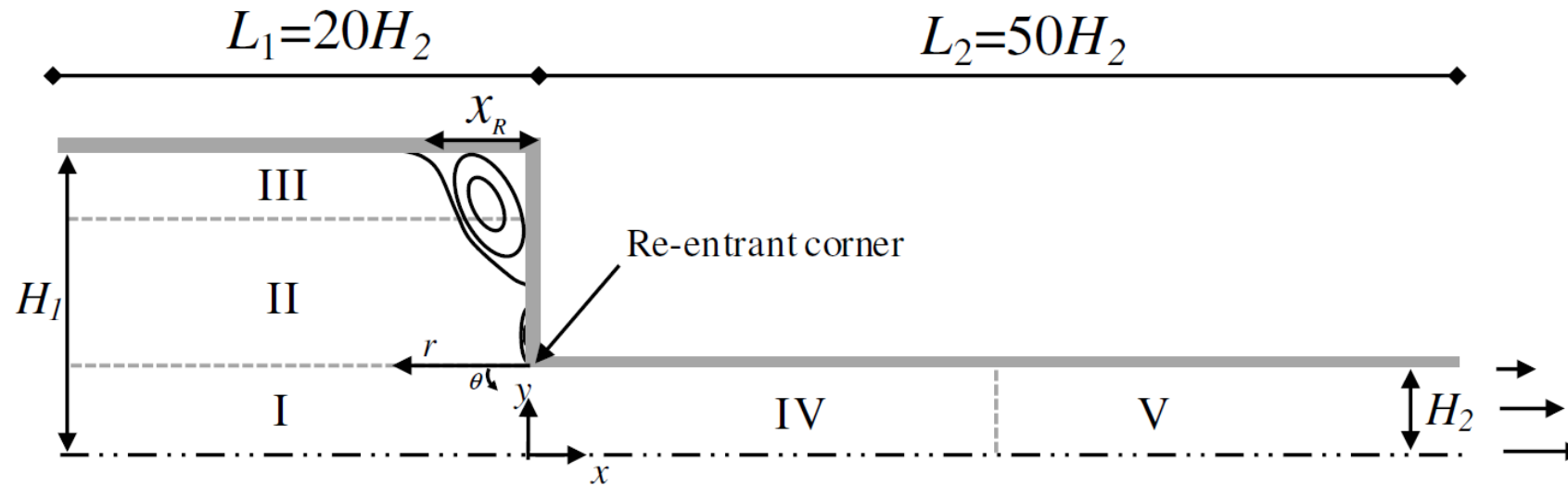
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Improved Both Sides Diffusion

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Case Study 1 – 4:1 Contraction (UCM)



Meshes

M1 – 228 Cells

...

M5 – 228128 Cells

Re = 0.01

De = {0,1,2,3,4,5}



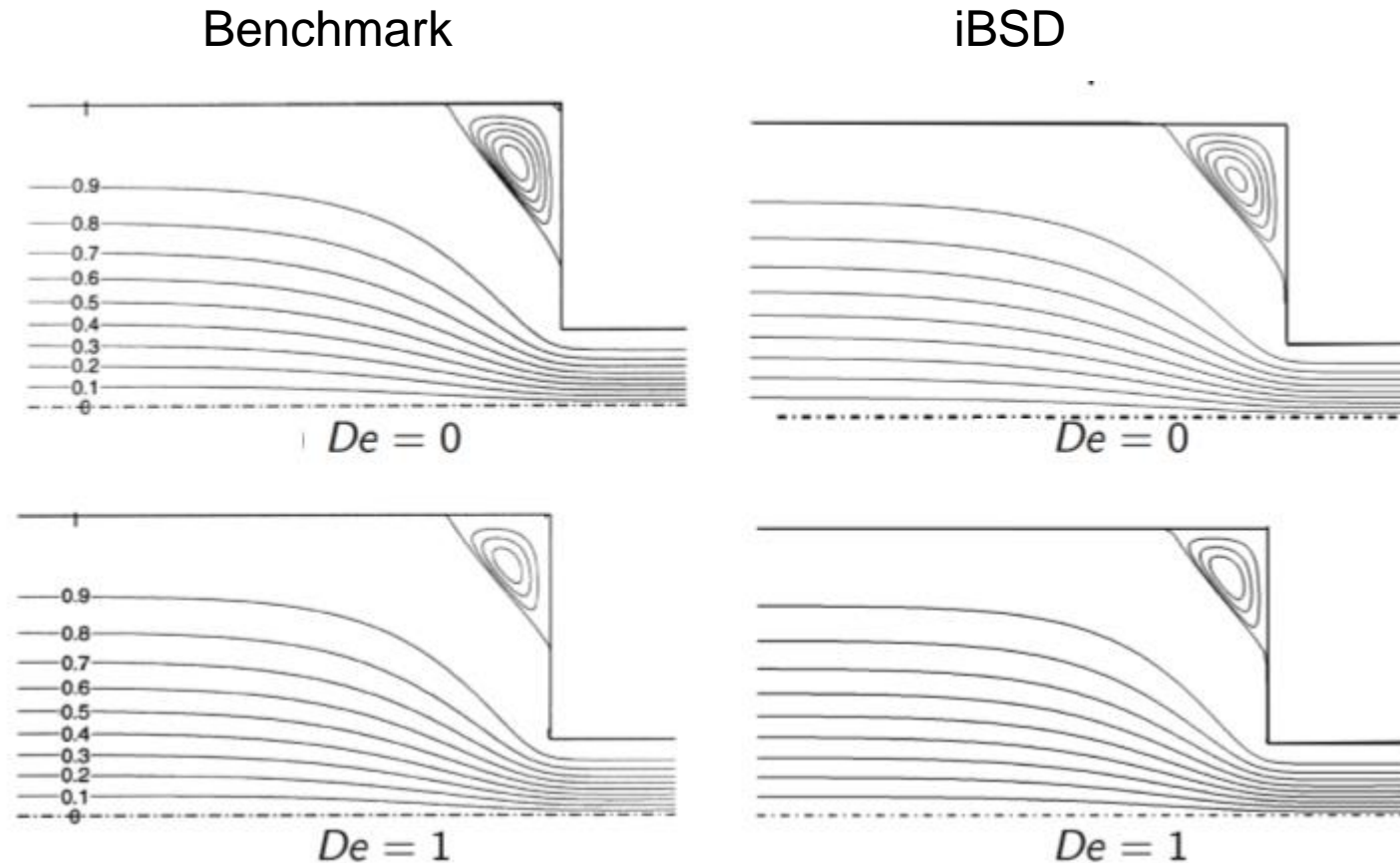
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Case Study 1 – 4:1 Contraction (UCM)

Streamlines



MM Alves, FT Pinho, PJ Oliveira, J. Non-Newtonian Fluid Mech., 93, 2000

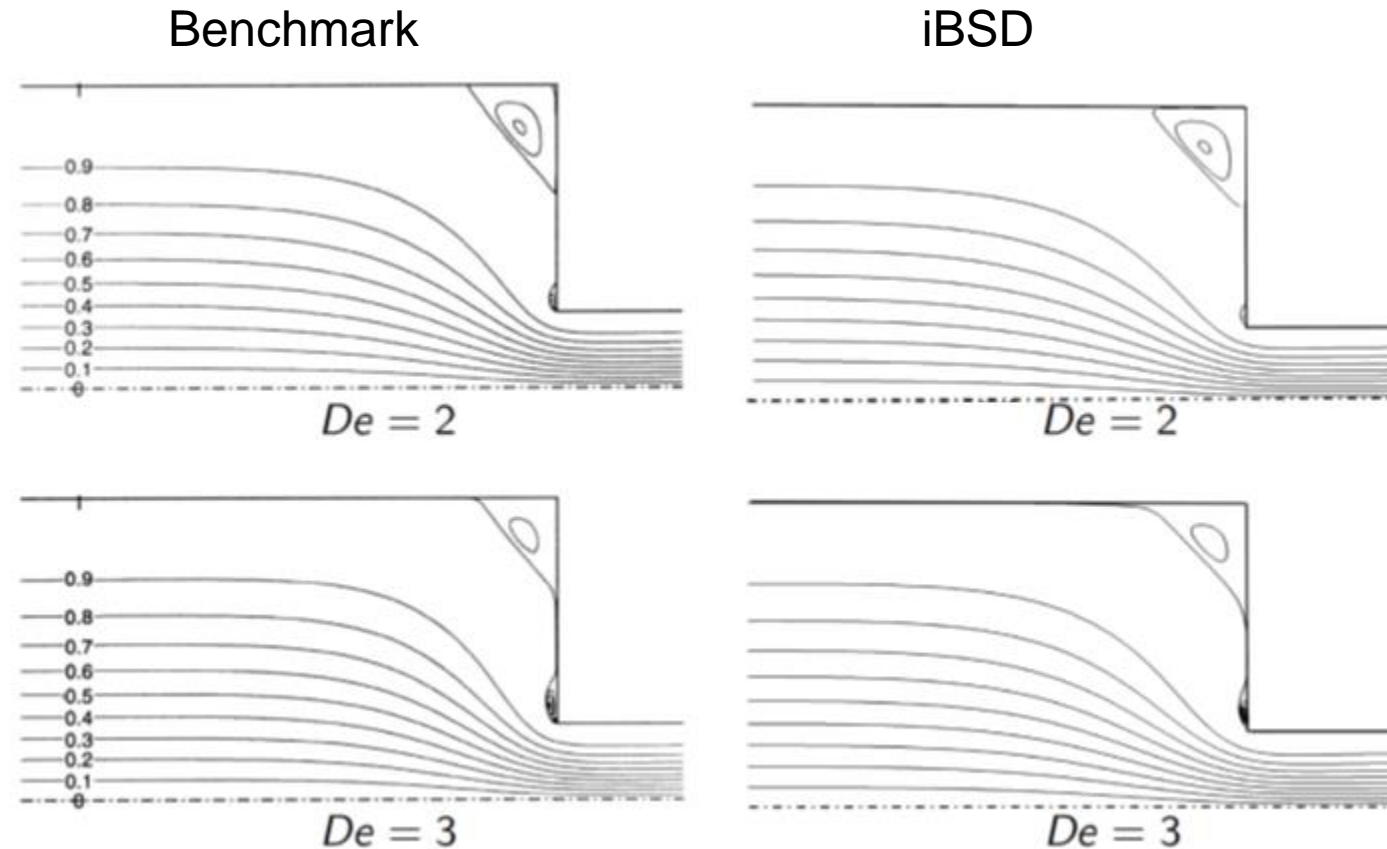
© Fernandes et al., Improved Both Sides Diffusion (iBSD): a new and straightforward stabilization approach for viscoelastic fluid flows, JNNFM, 249, 63-78, 2017

Improved Both Sides Diffusion

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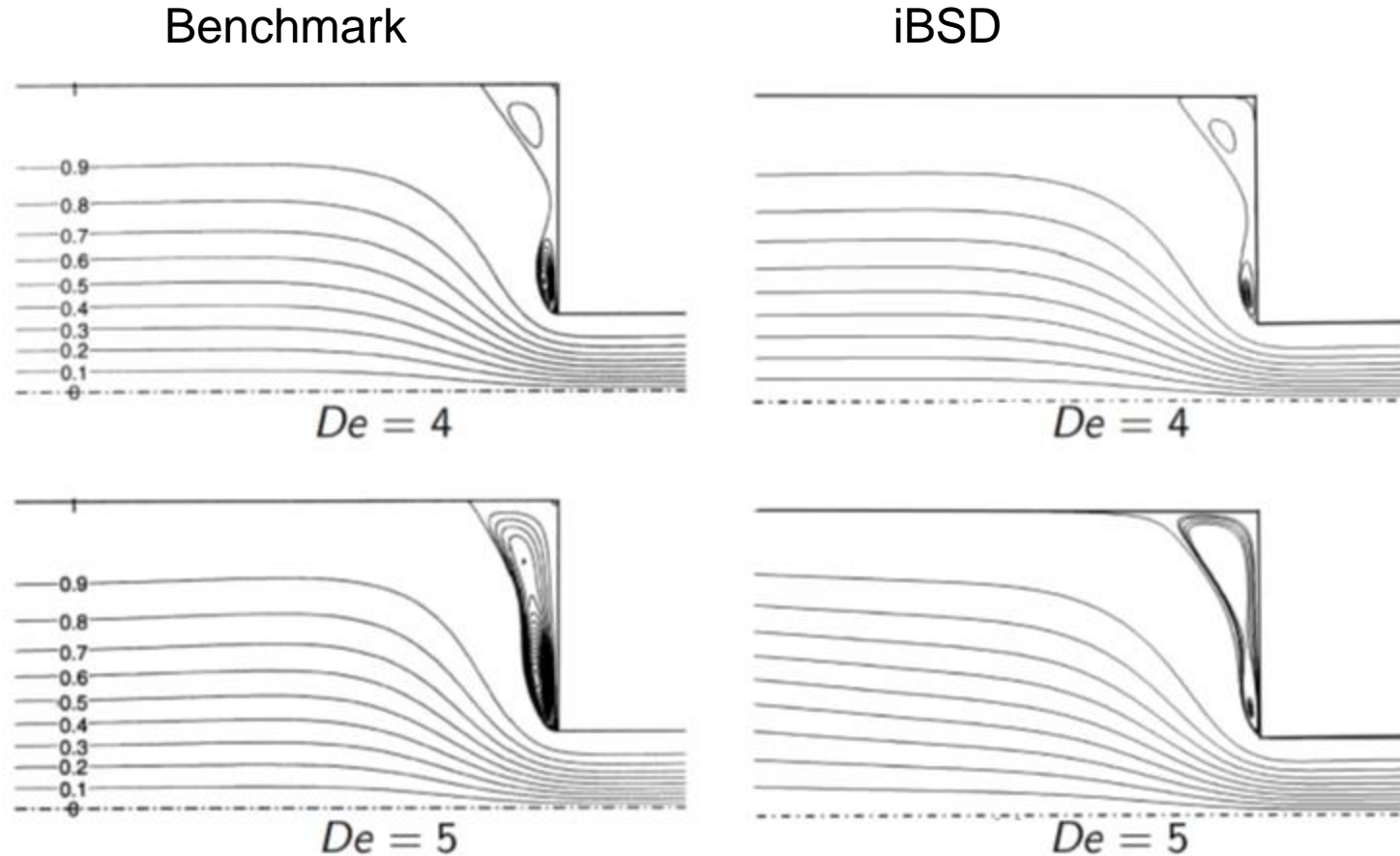
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Improved Both Sides Diffusion

foam-extend 5.0

Case Study 1 – 4:1 Contraction (UCM)

Primary vortex length ($X_r = x_r/H_2$)

Developed code in <i>OpenFOAM</i> [®]							
De	Mesh 1	Mesh 2	Mesh 3	Mesh 4	Mesh 5	Extrapolated	Difference (%)
0	1.438	1.479	1.492	1.495	1.496	1.4965	0.03
1	1.293	1.336	1.326	1.32711	1.32696	1.32694	0.002
2	1.207	1.200	1.130	1.101	1.091	1.0857	0.5
3	1.333	1.118	0.958	0.900	0.885	0.880	0.6
4	1.391	1.088	0.845	0.75	0.732	0.728	0.6
5	1.469	1.101	0.758	0.636	0.617	0.613	0.6

Alves et al. (2000)						
De	Mesh 1	Mesh 2	Mesh 3	Mesh 4	Extrapolated	Difference (%)
0	1.472	1.488	1.494	1.495	1.496	0.1
1	1.349	1.371	1.349	1.339	1.335	0.3
2	1.631	1.259	1.154	1.118	1.105	1.2
3	1.517	1.266	1.014	0.946	0.923	2.5
4	1.644	1.337	0.987	–	0.87	13.4
5	1.687	1.517	1.127	–	0.997	13

MM Alves, FT Pinho, PJ Oliveira, J. Non-Newtonian Fluid Mech., 93, 2000



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Integral Viscoelastic Solver

$$\boldsymbol{\tau}_p = \int_{-\infty}^t M(t-t') f(\mathbf{B}_{t'}) dt'$$

$$M(t-t') = \sum_k \frac{a_k}{\lambda_k} e^{-\frac{(t-t')}{\lambda_k}}$$

$$f(\mathbf{B}_{t'}) = \begin{cases} \mathbf{B}_{t'} & \text{- UCM} \\ \frac{\alpha}{\alpha + \beta I_1 + (1-\beta) I_2} \mathbf{B}_{t'} & \text{- K-BKZ (PSM)} \end{cases}$$

Deformation Fields approach

$$\frac{\partial \mathbf{B}_i}{\partial t} + \nabla \cdot (\mathbf{U} \mathbf{B}_i) - ((\nabla \mathbf{U})^T \cdot \mathbf{B}_i + \mathbf{B}_i \cdot \nabla \mathbf{U}) = 0$$



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Araujo, MSB., et al., "A stable numerical implementation of integral viscoelastic models in the OpenFOAM® computational library. Computers & Fluids, 2018

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Integral Viscoelastic Solver

Stress Tensor Field Calculation

- Define **cutoff time** (s_{max}) and **number of deformation fields** (nf)
- At each time step t :
 1. Update velocity and pressure fields (PISO)
 2. Transport all the previously created deformation fields ($\mathbf{B}_{i=1,nf}$)

$$\frac{\partial \mathbf{B}_i}{\partial t} + \nabla \cdot (\mathbf{U} \mathbf{B}_i) - ((\nabla \mathbf{U})^T \cdot \mathbf{B}_i + \mathbf{B}_i \cdot \nabla \mathbf{U}) = 0$$

3. Create a new deformation field ($\mathbf{B}_t = \mathbf{I}$)
4. If required redistribute/interpolate the deformation fields
5. Compute the stress field



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OpenFOAM Code:

```
volTensorField L = fvc::grad(U);

for (int fieldI = 0; fieldI <= nActFields ; fieldI++)
{
    volTensorField SB = B[fieldI] & L;
    fvSymmTensorMatrix BEqn
    (
        fvm::ddt(B[fieldI])
        + fvm::div(phi, B[fieldI], "div(phi,B)")
        ==
        twoSymm(SB)
    );
    BEqn.solve(mesh.solutionDict().solver("B"));
}
```

$$\frac{\partial \mathbf{B}_i}{\partial t} + \nabla \cdot (\mathbf{U} \mathbf{B}_i) - ((\nabla \mathbf{U})^T \cdot \mathbf{B}_i + \mathbf{B}_i \cdot \nabla \mathbf{U}) = 0$$

3. Create a new deformation field ($\mathbf{B}_t = \mathbf{I}$)
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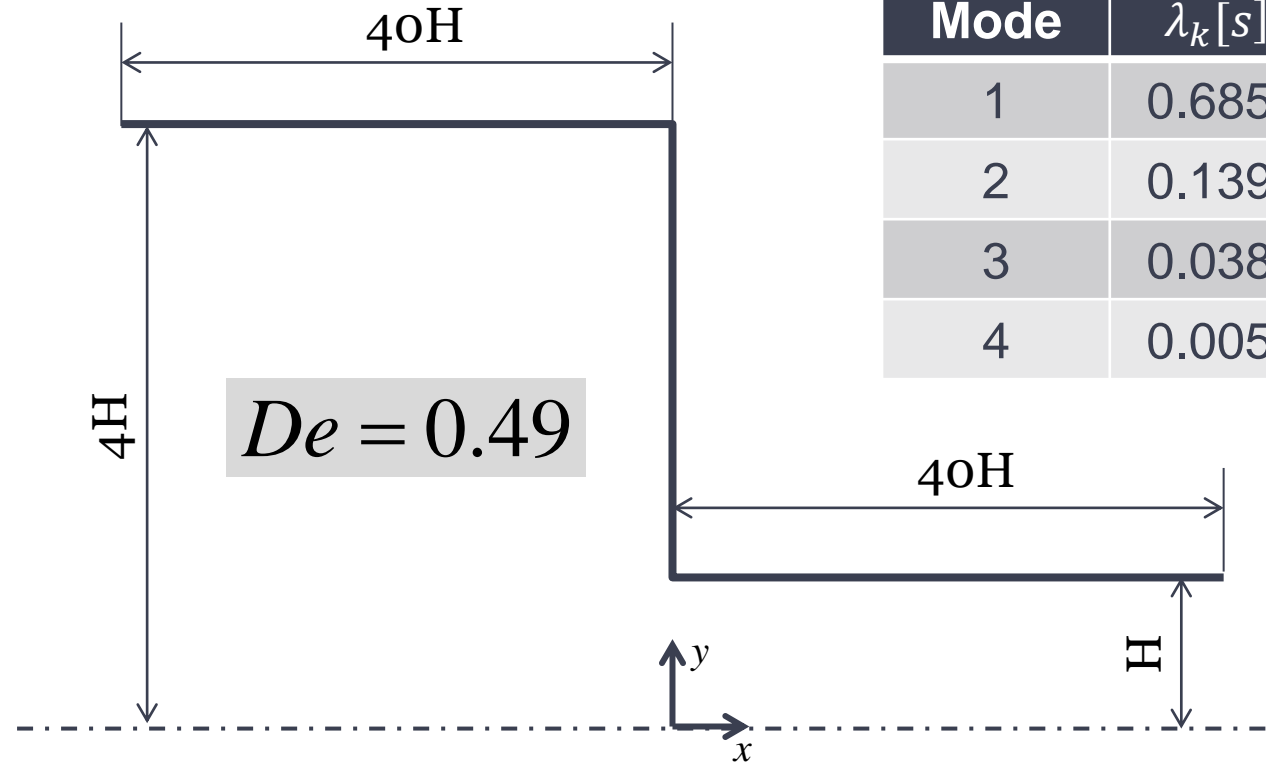
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Integral Viscoelastic Solver

Case Study - 4:1 Abrupt Planar Contraction - K- BKZc

Solution of 5% wt. polyisobutylene (PIB) in Tetradecane(C14)

$$S_{\max} = 1.5 \text{ s}$$
$$n_f = 150$$



Mode	$\lambda_k[s]$	$a_k[Pa]$
1	0.6855	0.0584
2	0.1396	1.6648
3	0.0389	14.5604
4	0.0059	99.1525

$$\alpha = 10$$

$$\beta = 0.7$$

$$\theta = 0$$

- LM Quinzani, RC Armstrong, RA Brown, Journal non-Newtonian Fluid Mechanics, 52, 1994
- E Mitsoulis, Journal of Rheology, 37, 1993

Araujo, MSB., et al., "A stable numerical implementation of integral viscoelastic models in the OpenFOAM® computational library. Computers & Fluids, 2018



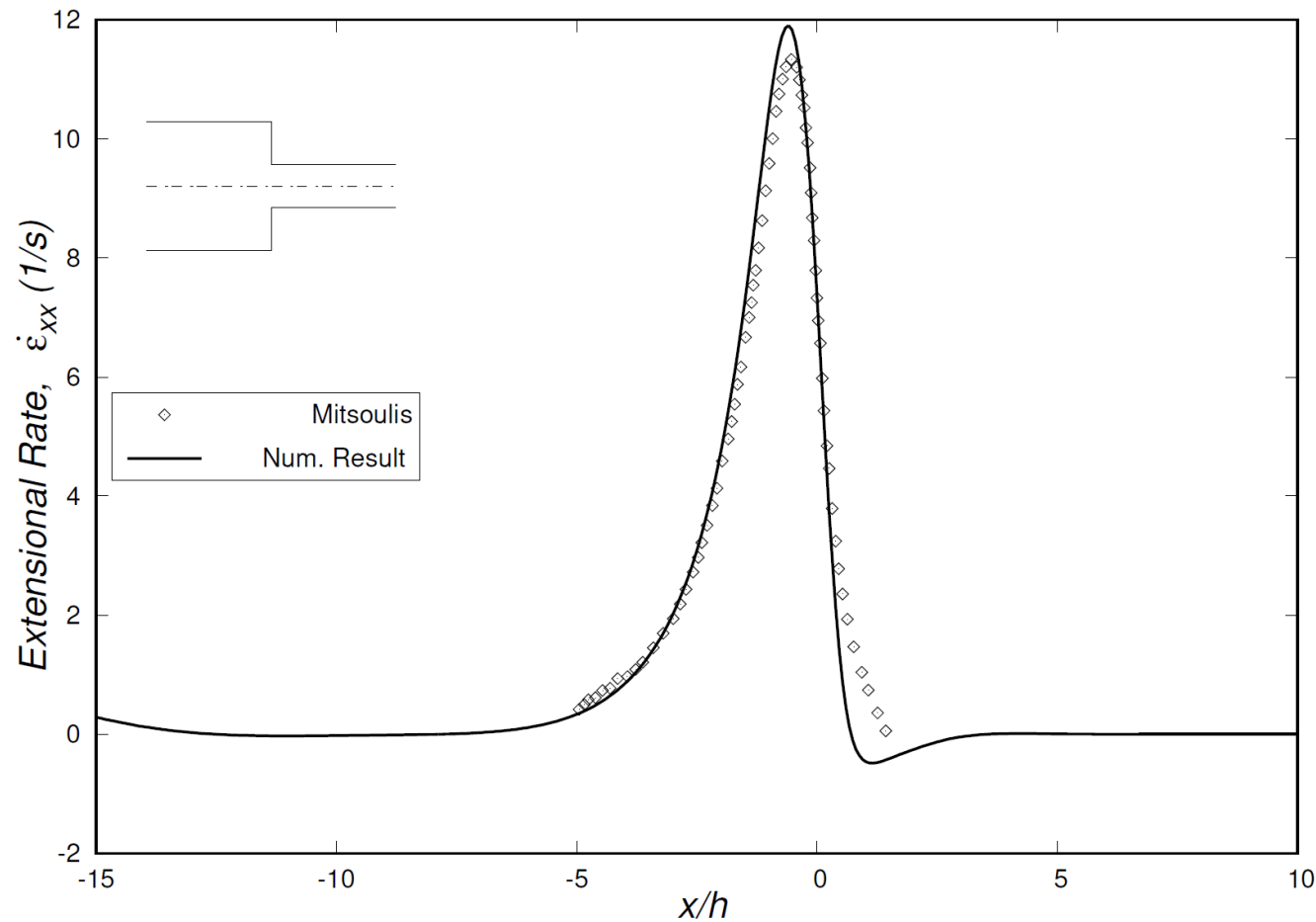
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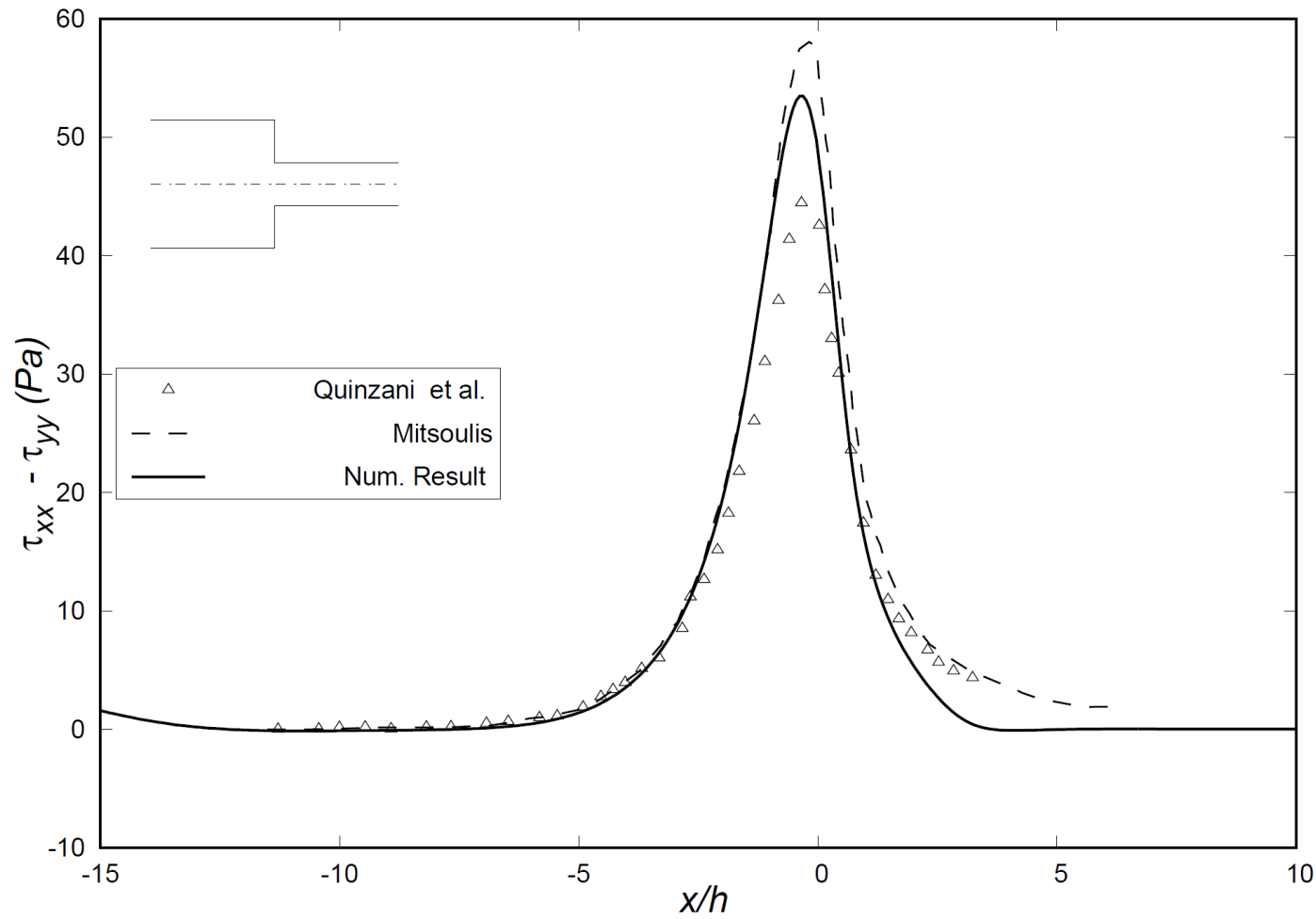
Integral Viscoelastic Solver

Case Study - 4:1 Abrupt Planar Contraction - K- BKZ



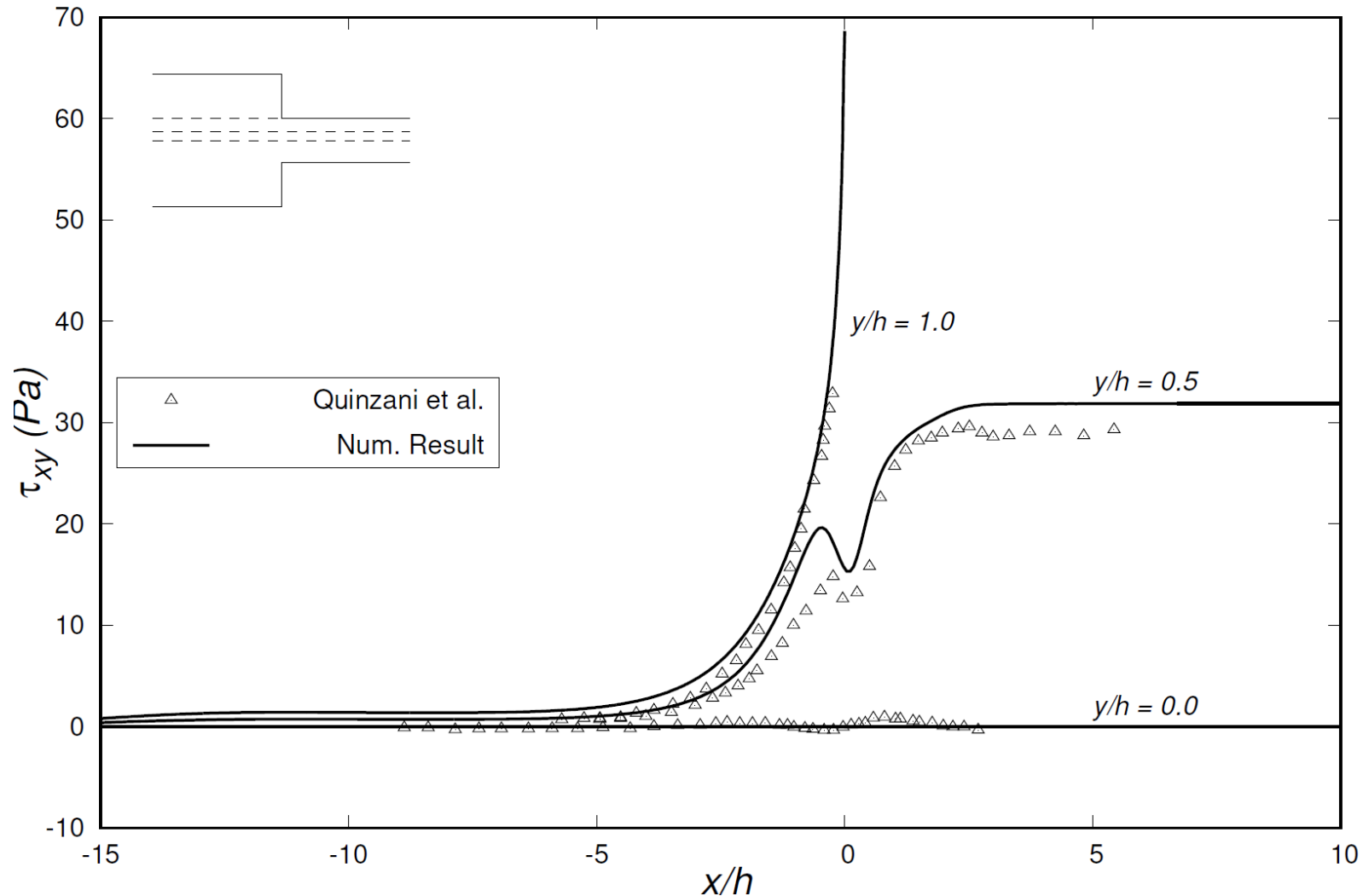
Integral Viscoelastic Solver

Case Study - 4:1 Abrupt Planar Contraction - K- BKZ



Integral Viscoelastic Solver

Case Study - 4:1 Abrupt Planar Contraction - K- BKZ



Araujo, MSB., et al., "A stable numerical implementation of integral viscoelastic models in the OpenFOAM® computational library. Computers & Fluids, 2018

Coupled Approaches - Viscoelastic Semi-coupled solver

exaFOAM

$$\begin{pmatrix} \mathbf{A}_u & \nabla \\ \nabla \cdot & -\nabla \cdot (\mathbf{\Gamma}_u^{-1} \nabla) \end{pmatrix} \begin{bmatrix} \mathbf{u} \\ p \end{bmatrix} = \begin{bmatrix} b_u \\ b_p \end{bmatrix}$$

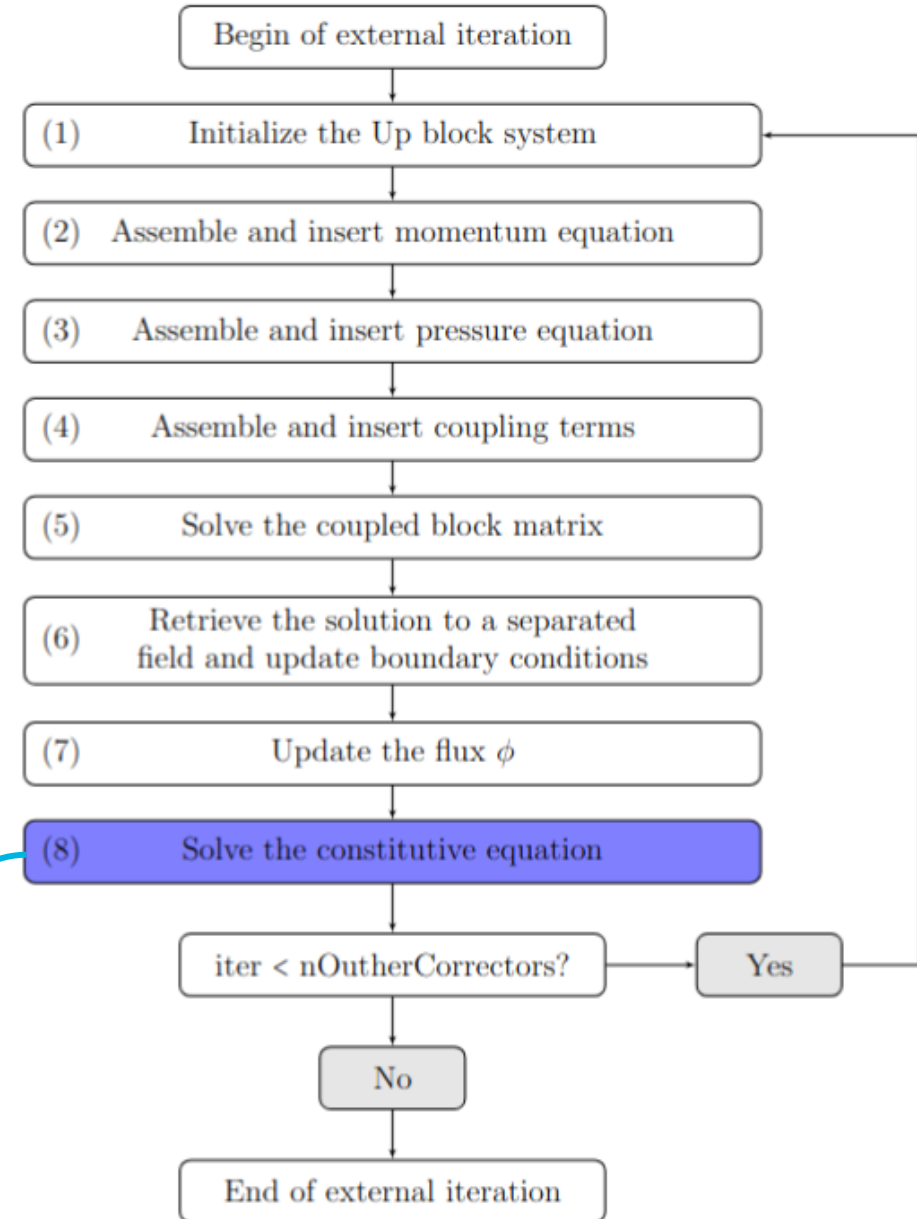
$$\frac{\partial(\rho \mathbf{u})}{\partial t} + \nabla \cdot (\rho \mathbf{u} \mathbf{u}) - \nabla^2 \left[\left(\eta_S + \sum_{m=1}^{N_m} \eta_{Stab_m} \right) \mathbf{u} \right] = -\nabla p$$

$$+ \sum_{m=1}^{N_m} (\nabla \cdot \boldsymbol{\tau}_{P_m}) - \nabla \cdot \left[\nabla \left(\sum_{m=1}^{N_m} \eta_{Stab_m} \mathbf{u} \right) \right]$$

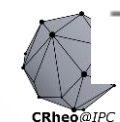
$$\nabla \cdot \mathbf{u} - \nabla \cdot [(a_{ii}^u)^{-1} \nabla p] = -\nabla \cdot [(\overline{a_{ii}^u})^{-1} \nabla p_f],$$

• For each mode:

$$\frac{\partial \boldsymbol{\tau}_P}{\partial t} + \nabla \cdot (\mathbf{u} \boldsymbol{\tau}_P) - \boldsymbol{\tau}_P (\nabla \mathbf{u})^T - \nabla \mathbf{u} \boldsymbol{\tau}_P = \frac{\eta_P}{\lambda} (\nabla \mathbf{u} + (\nabla \mathbf{u})^T) - g_R(\boldsymbol{\tau}_P)$$



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Coupled Approaches - Viscoelastic fully-coupled solver

exaFOAM

$$\begin{pmatrix} \mathbf{A}_u & \nabla & \nabla \cdot \\ \nabla \cdot & -\nabla \cdot [\mathbf{\Gamma}_u^{-1} \nabla] & 0 \\ \nabla \cdot (\boldsymbol{\tau}^{*0}) & 0 & \mathbf{A}_\tau \end{pmatrix} \begin{bmatrix} \mathbf{u} \\ p \\ \boldsymbol{\tau}^* \end{bmatrix} = \begin{bmatrix} b_u \\ b_p \\ b_{\tau^*} \end{bmatrix}$$

$$\frac{\partial(\rho \mathbf{u})}{\partial t} + \nabla \cdot (\rho \mathbf{u} \mathbf{u}) - \nabla^2 \left[\left(\eta_S + \sum_{m=1}^{N_m} \eta_{Stab_m} \right) \mathbf{u} \right] = -\nabla p$$

$$+ (\nabla \cdot \boldsymbol{\tau}^*) + \sum_{\substack{m=1 \\ m \neq m_C}}^{N_m} (\nabla \cdot \boldsymbol{\tau}_{P_m}) - \nabla \cdot \left[\nabla \left(\sum_{m=1}^{N_m} \eta_{Stab_m} \mathbf{u} \right) \right]$$

$$\nabla \cdot \mathbf{u} - \nabla \cdot [(a_{ii}^u)^{-1} \nabla p] = -\nabla \cdot [(\overline{(a_{ii}^u)^{-1}} \nabla p_f)],$$

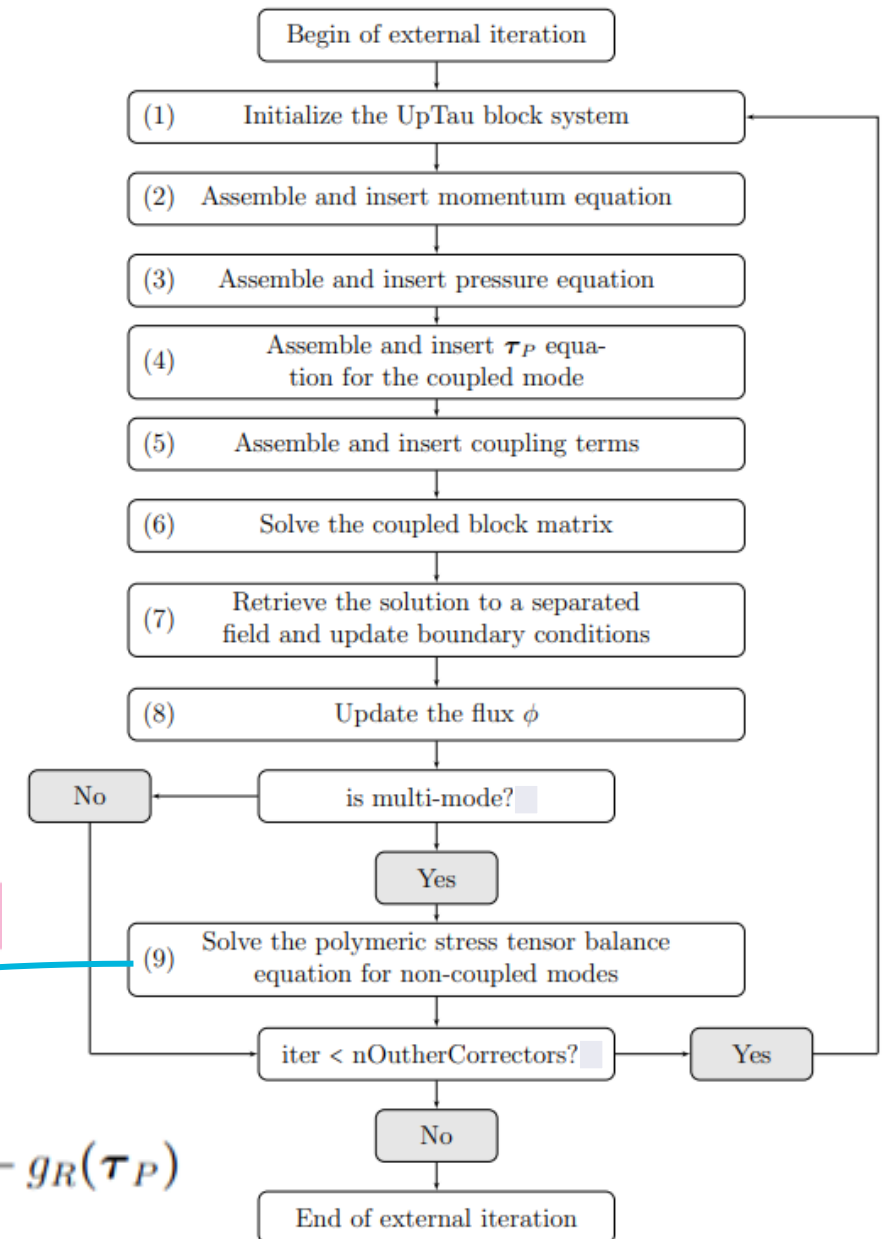
- For the **coupled** mode:

$$\frac{\partial \boldsymbol{\tau}_P}{\partial t} + \nabla \cdot (\mathbf{u}^0 \boldsymbol{\tau}_P^n) - \nabla \cdot (\mathbf{u}^0 \boldsymbol{\tau}_P^0) + \nabla \cdot (\mathbf{u}^n \boldsymbol{\tau}_P^0)$$

$$-\boldsymbol{\tau}_P (\nabla \mathbf{u})^T - \nabla \mathbf{u} \boldsymbol{\tau}_P = \frac{\eta_P}{\lambda} (\nabla \mathbf{u} + (\nabla \mathbf{u})^T) - g_R(\boldsymbol{\tau}_P)$$

- For the other modes (decoupled):

$$\frac{\partial \boldsymbol{\tau}_P}{\partial t} + \nabla \cdot (\mathbf{u} \boldsymbol{\tau}_P) - \boldsymbol{\tau}_P (\nabla \mathbf{u})^T - \nabla \mathbf{u} \boldsymbol{\tau}_P = \frac{\eta_P}{\lambda} (\nabla \mathbf{u} + (\nabla \mathbf{u})^T) - g_R(\boldsymbol{\tau}_P)$$



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Coupled Approaches - Application cases

exaFOAM

Memory requirement

- Number of coupled variables:
 - Segregated: 0
 - Semi-coupled: 4 (p, U)
 - Fully-coupled: 10 (p, U, τ^*)

Solver	Number of cells [million]	Memory requirement [Gb]	Ratio to Segregated
Segregated	1	9.2	-
Semi-coupled	1	14.8	1.61
Fully-coupled	1	43.6	4.74
Segregated	20	173.9	-
Semi-coupled	20	561.6	3.23
Fully-coupled	20	845.6	4.86



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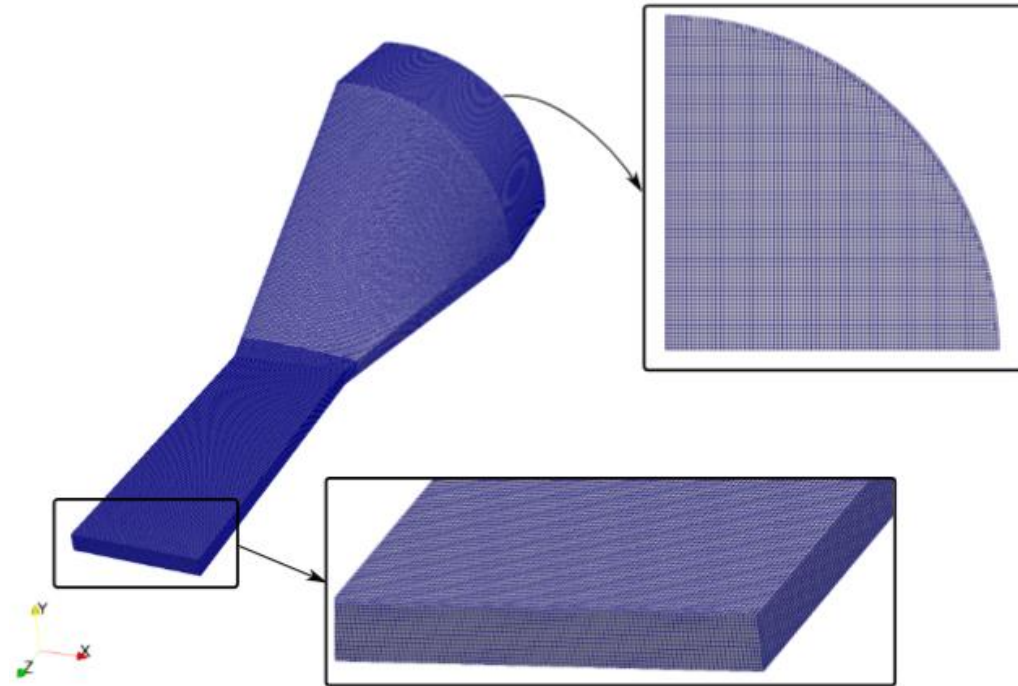
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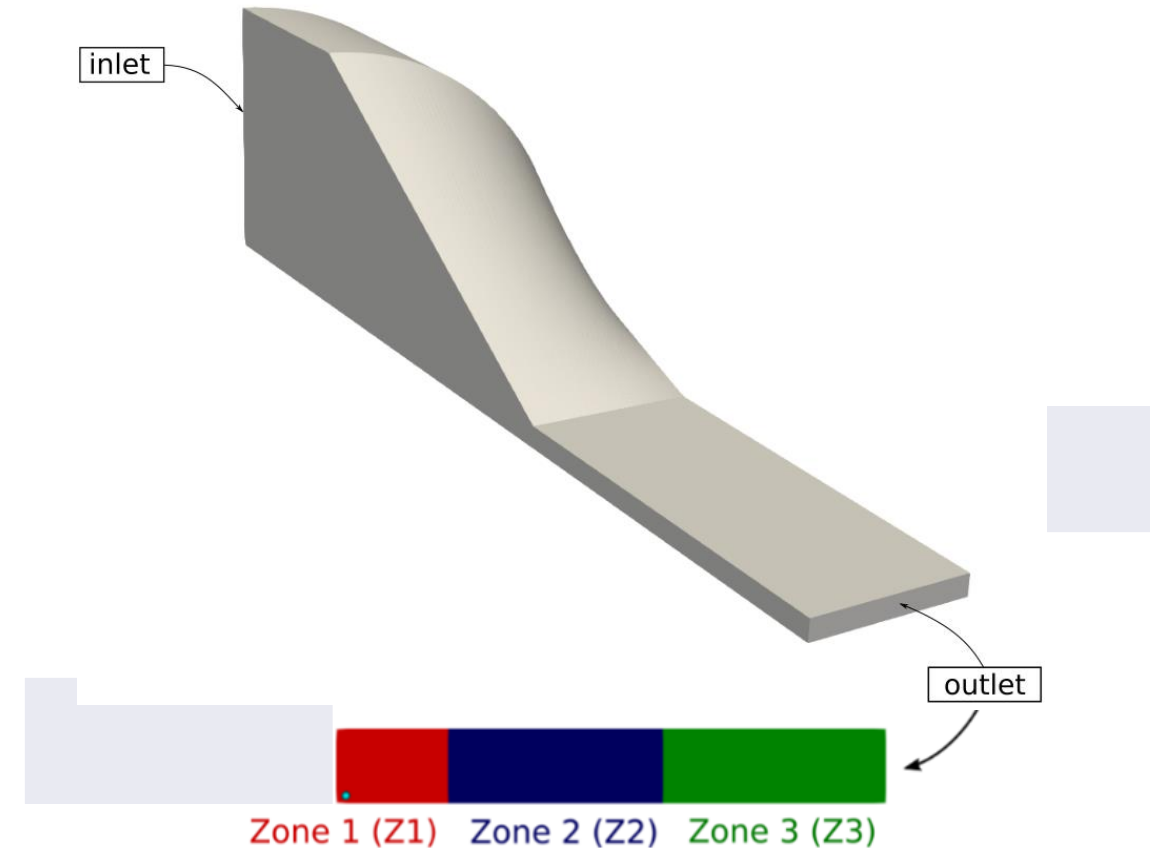
Coupled Approaches - Application case (MB19)

eXaFOAM

MB19 benchmark case: profile extrusion [4]

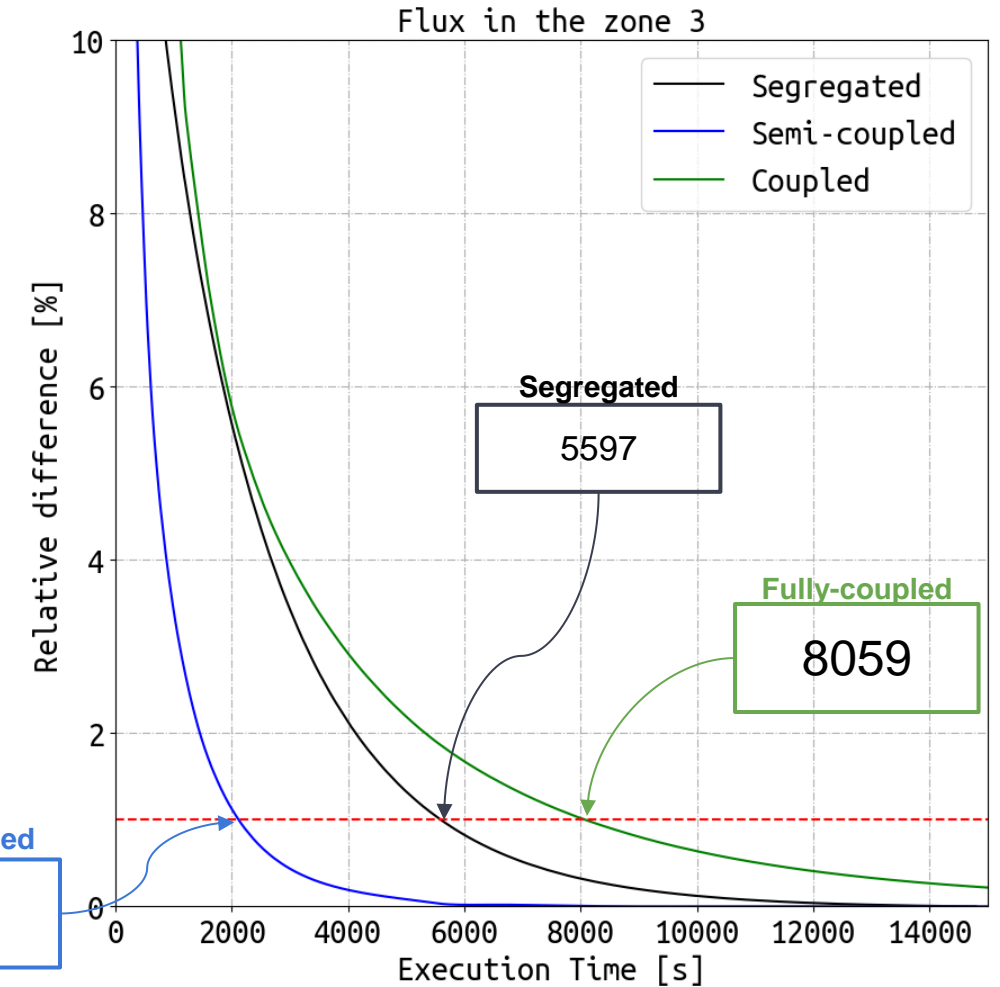
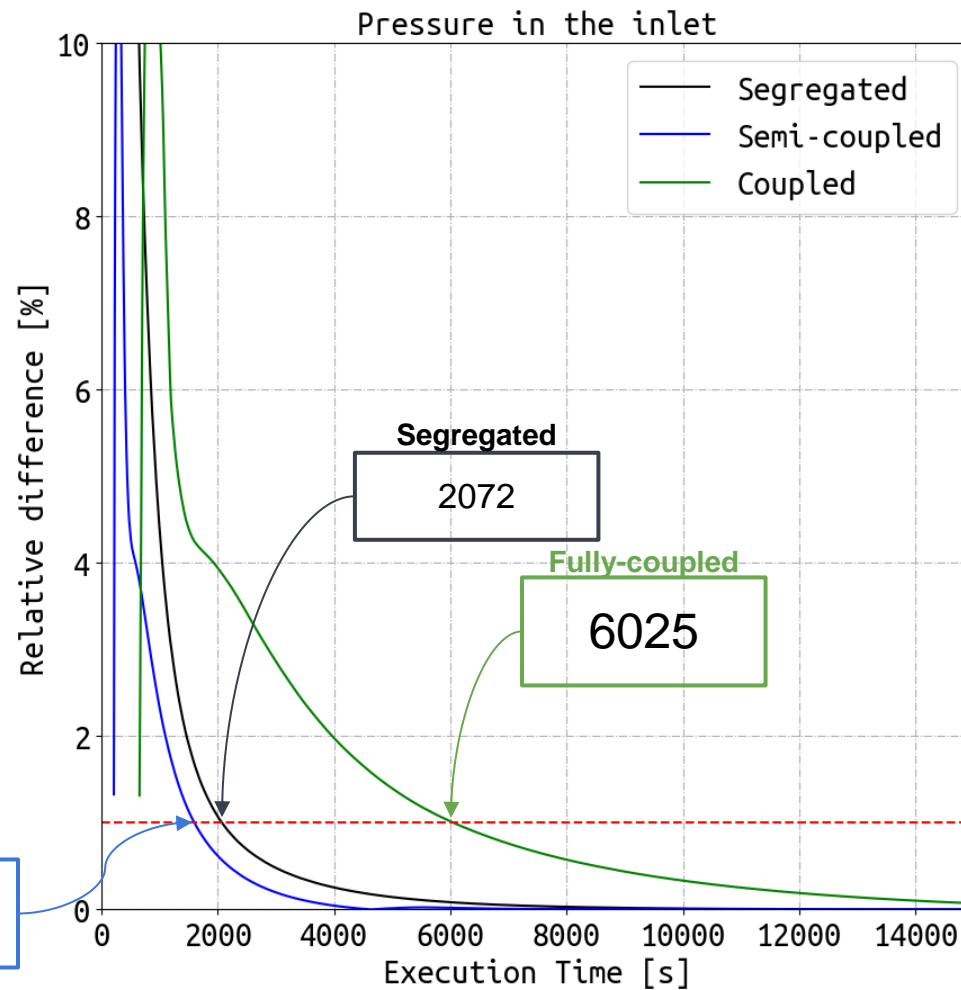


Mesh: 1 million cells



Coupled Approaches - Application case (MB19)

eXaFOAM



$$\text{TTS KPI} = \frac{5597}{2109} = 2.65 \quad \text{Semi-coupled}$$



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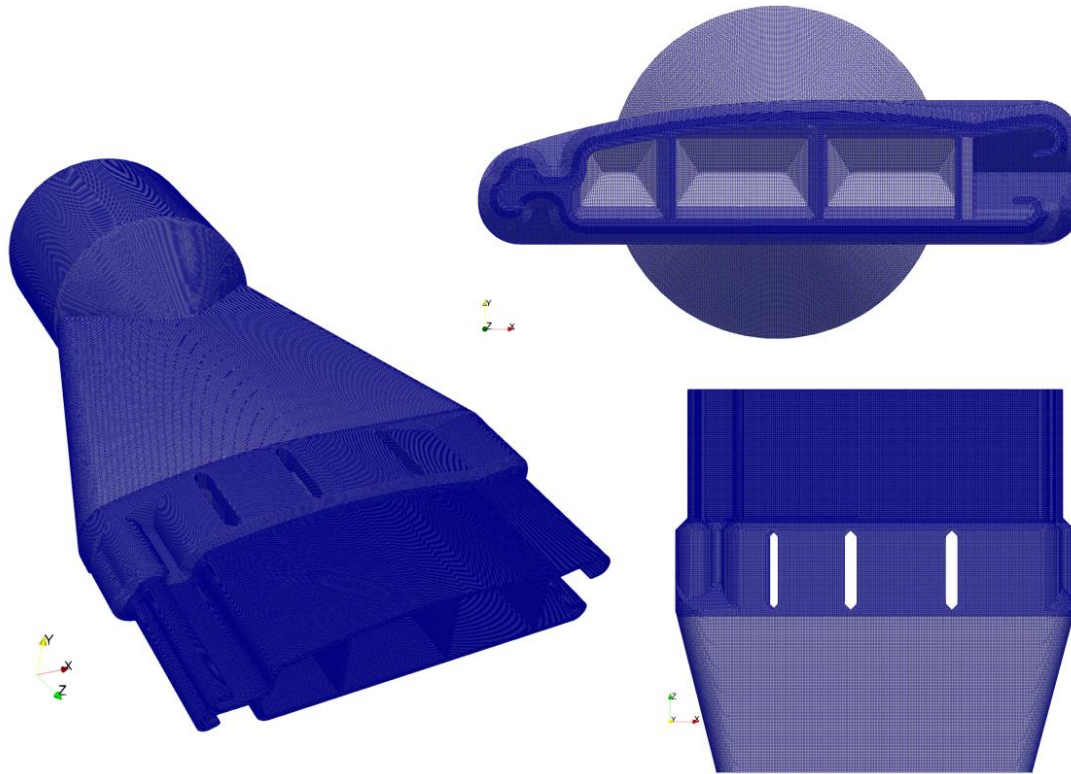


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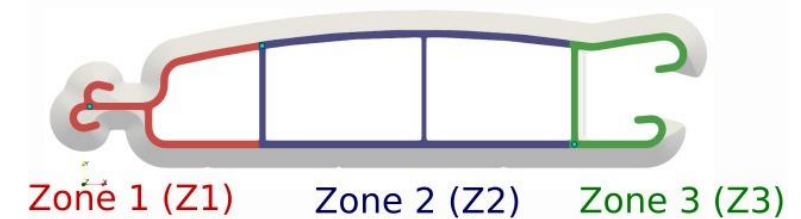
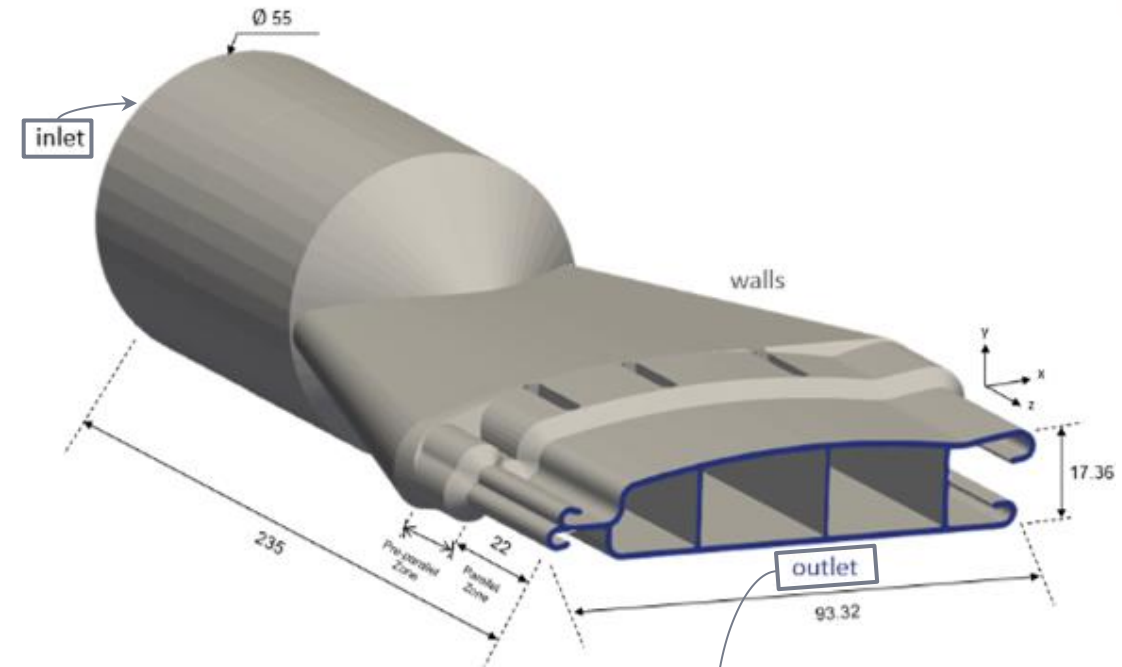
Coupled Approaches - Application case (B4)

B4 benchmark case: complex profile extrusion [4]

exaFOAM



Mesh: 20 million cells



Coupled Approaches

exaFOAM

CODE

<https://develop.openfoam.com/exafoam/wp4-development>

W wp4-development

master wp4-development / +

History Find file Edit Code

Merge branch 'UMinho' into 'master' Hrvoje authored 1 month ago 3bfbe924

Name	Last commit	Last update
foam-extend-5.0	UMinho developments for viscoel...	1 month ago
README.md	UMinho developments for viscoel...	1 month ago

README.md



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foam-extend 5.0

CASE Studies

<https://develop.openfoam.com/committees/hpc/-/tree/develop/viscoelastic/viscoelasticFluidFoam>

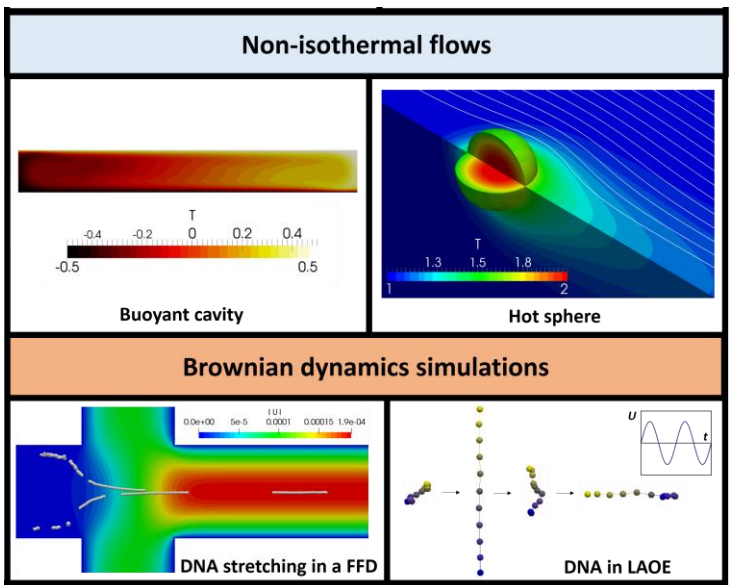
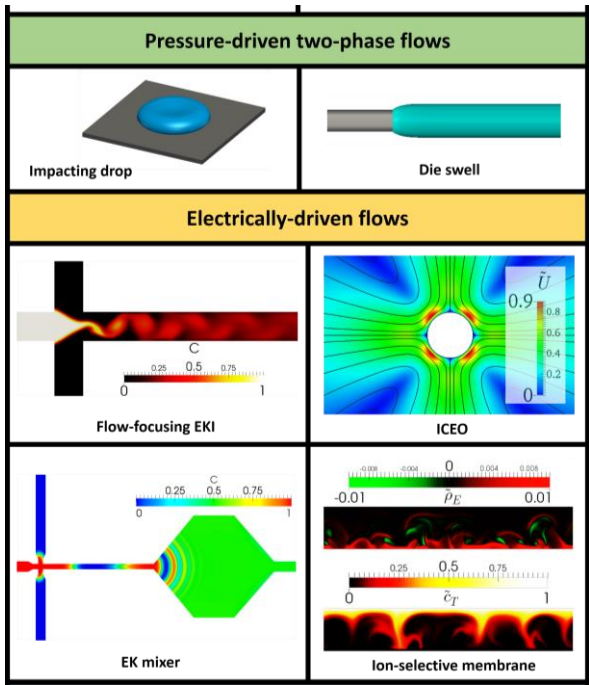
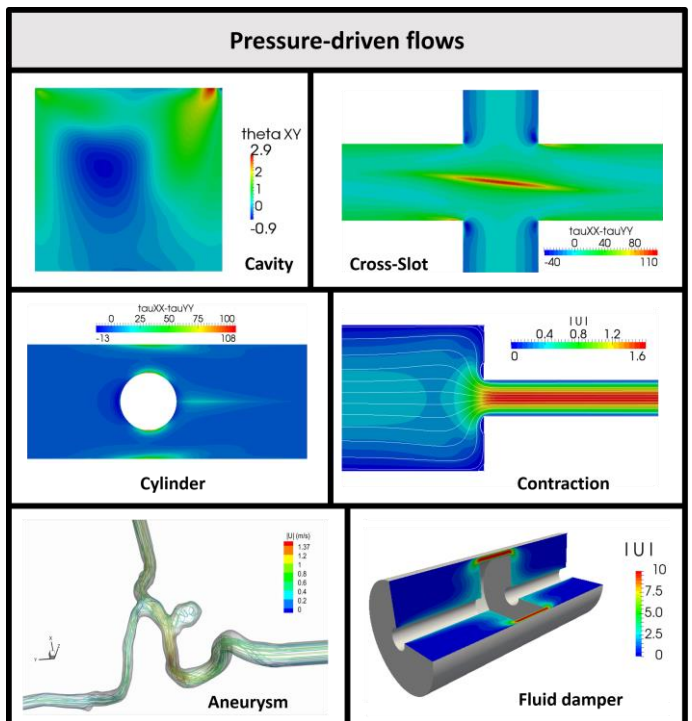
Name	Last commit
..	
complexProfile	Update README.md
complexProfileExtrusion	Changes to visco-elastic cases
lidDrivenCavity	Update README.md
profileExtrusion	Update README.md
testedCases	Changes to visco-elastic cases
README.md	Changes to visco-elastic cases
generateCase.sh	Changes to visco-elastic cases



RheoTool



<https://github.com/fppimenta/rheoTool>



foam-extend 4 / OpenFOAM 7 / OpenFOAM 9



Viscoelastic models solved in the standard extra-stress or conformation tensor variables

Model	TypeName	$\eta_s(\dot{\gamma})$	$\eta_p(\dot{\gamma})$	$\lambda(\dot{\gamma})$	Constitutive Equation
Oldroyd-B	<i>Oldroyd-B</i>	η_s	η_p	λ	$\boldsymbol{\tau} + \lambda \overset{\nabla}{\boldsymbol{\tau}} = \eta_p (\nabla \mathbf{u} + \nabla \mathbf{u}^T)$
WhiteMetzner (Carreau-Yasuda)	<i>WhiteMetznerCY</i>	η_s	$\eta_p [1 + (K\dot{\gamma})^a]^{\frac{n-1}{a}}$	$\lambda [1 + (L\dot{\gamma})^b]^{\frac{m-1}{b}}$	$\boldsymbol{\tau} + \lambda(\dot{\gamma}) \overset{\nabla}{\boldsymbol{\tau}} = \eta_p(\dot{\gamma}) (\nabla \mathbf{u} + \nabla \mathbf{u}^T)$
Giesekus	<i>Giesekus</i>	η_s	η_p	λ	$\boldsymbol{\tau} + \lambda \overset{\nabla}{\boldsymbol{\tau}} + \alpha \frac{\lambda}{\eta_p} (\boldsymbol{\tau} \cdot \boldsymbol{\tau}) = \eta_p (\nabla \mathbf{u} + \nabla \mathbf{u}^T)$
4PTT	<i>PTT</i>	η_s	η_p	λ	$f \boldsymbol{\tau} + \lambda \overset{\square}{\boldsymbol{\tau}} = \eta_p (\nabla \mathbf{u} + \nabla \mathbf{u}^T)$ where $f = \left[1 + \frac{\varepsilon \lambda}{\eta_p} \text{tr}(\boldsymbol{\tau}) \right]$ (linear), $f = \left[e^{\frac{\varepsilon \lambda}{\eta_p} \text{tr}(\boldsymbol{\tau})} \right]$ (exponential) or $f = \Gamma(\beta) E_{\alpha, \beta} \left(\frac{\varepsilon \lambda}{\eta_p} \text{tr}(\boldsymbol{\tau}) \right)$ (generalized)
FENE-CR	<i>FENE-CR</i>	η_s	η_p	λ	$\left[1 + \lambda \frac{D}{Dt} \left(\frac{1}{f} \right) \right] \boldsymbol{\tau} + \frac{\lambda}{f} \overset{\nabla}{\boldsymbol{\tau}} = \eta_p (\nabla \mathbf{u} + \nabla \mathbf{u}^T)$ where $f = \frac{L^2 + \frac{\lambda}{\eta_p} \text{tr}(\boldsymbol{\tau})}{L^2 - 3}$
FENE-P	<i>FENE-P</i>	η_s	η_p	λ	$\boldsymbol{\tau} + \frac{\lambda}{f} \overset{\nabla}{\boldsymbol{\tau}} = \frac{a \eta_p}{f} (\nabla \mathbf{u} + \nabla \mathbf{u}^T) - \frac{D}{Dt} \left(\frac{1}{f} \right) [\lambda \boldsymbol{\tau} + a \eta_p \mathbf{I}]$ where $f = \frac{L^2 + \frac{\lambda}{a \eta_p} \text{tr}(\boldsymbol{\tau})}{L^2 - 3}$ and $a = \frac{L^2}{L^2 - 3}$
5Rolie-Poly	<i>Rolie-Poly</i>	η_s	η_p	λ_D	$\lambda_D \overset{\nabla}{\mathbf{A}} = -(\mathbf{A} - \mathbf{I}) - 2k \frac{\lambda_D}{\lambda_R} \left(1 - \sqrt{3/\text{tr}(\mathbf{A})} \right) \left[\mathbf{A} + \beta \left(\frac{\text{tr}(\mathbf{A})}{3} \right)^\delta (\mathbf{A} - \mathbf{I}) \right]$ where $k = \frac{\left(3 - \frac{\chi^2}{\chi_{\max}^2} \right) \left(1 - \frac{1}{\chi_{\max}^2} \right)}{\left(1 - \frac{\chi^2}{\chi_{\max}^2} \right) \left(3 - \frac{1}{\chi_{\max}^2} \right)}$ and $\chi = \sqrt{\frac{\text{tr}(\mathbf{A})}{3}}$
eXtended Pom-Pom	<i>XPomPom</i>	η_s	η_p	λ_B	$f \boldsymbol{\tau} + \lambda_B \overset{\nabla}{\boldsymbol{\tau}} + \alpha \frac{\lambda_B}{\eta_p} (\boldsymbol{\tau} \cdot \boldsymbol{\tau}) + \frac{\eta_p}{\lambda_B} (f - 1) \mathbf{I} = \eta_p (\nabla \mathbf{u} + \nabla \mathbf{u}^T)$ where $f = 2 \frac{\lambda_B}{\lambda_S} e^{\frac{2}{\lambda} (A-1)} \left(1 - \frac{1}{A^{n+1}} \right) + \frac{1}{A^2} \left[1 - \frac{\alpha}{3} \frac{\text{tr}(\boldsymbol{\tau} \cdot \boldsymbol{\tau})}{(\eta_p / \lambda_B)^2} \right]$ and $A = \sqrt{1 + \frac{\text{tr}(\boldsymbol{\tau})}{3 \eta_p / \lambda_B}}$

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‡Viscoelastic models solved with the log-conformation approach

Model	TypeName	$\Theta \rightarrow \tau$	^{6,7} Constitutive Equation
⁸ Oldroyd-B	<i>Oldroyd-BLog</i>	$\tau = \frac{\eta_p}{\lambda} (e^\Theta - \mathbf{I})$	$\Upsilon = \frac{1}{\lambda} (e^{-\Theta} - \mathbf{I})$
⁹ WhiteMetzner (Carreau-Yasuda)	<i>WhiteMetznerCYLog</i>	$\tau = \frac{\eta_p}{\lambda} (e^\Theta - \mathbf{I})$	$\Upsilon = \frac{1}{\lambda(\dot{\gamma})} (e^{-\Theta} - \mathbf{I})$
Giesekus	<i>GiesekusLog</i>	$\tau = \frac{\eta_p}{\lambda} (e^\Theta - \mathbf{I})$	$\Upsilon = \frac{1}{\lambda} \left[(e^{-\Theta} - \mathbf{I}) - \alpha e^\Theta (e^{-\Theta} - \mathbf{I})^2 \right]$
⁴ PTT	<i>PTTLog</i>	$\tau = \frac{\eta_p}{\lambda(1-\zeta)} (e^\Theta - \mathbf{I})$	$\Upsilon = \frac{f}{\lambda} (e^{-\Theta} - \mathbf{I})$, where $f = 1 + \frac{\epsilon}{1-\zeta} [\text{tr}(e^\Theta) - 3]$ (linear), $f = e^{\frac{\epsilon}{1-\zeta} (\text{tr}(e^\Theta) - 3)}$ (exponential), or $f = \Gamma(\beta) E_{\alpha,\beta} \left[\frac{\epsilon}{1-\zeta} (\text{tr}(e^\Theta) - 3) \right]$ (generalized)
FENE-CR	<i>FENE-CRLog</i>	$\tau = \frac{\eta_p f}{\lambda} (e^\Theta - \mathbf{I})$	$\Upsilon = \frac{f}{\lambda} (e^{-\Theta} - \mathbf{I})$, where $f = \frac{L^2}{L^2 - \text{tr}(e^\Theta)}$
FENE-P	<i>FENE-PLog</i>	$\tau = \frac{\eta_p}{\lambda} (f e^\Theta - a \mathbf{I})$	$\Upsilon = \frac{1}{\lambda} (a e^{-\Theta} - f \mathbf{I})$, where $a = \frac{L^2}{L^2 - 3}$ and $f = \frac{L^2}{L^2 - \text{tr}(e^\Theta)}$
¹⁰ Rolie-Poly	<i>Rolie-PolyLog</i>	$\tau = \frac{\eta_p}{\lambda_D} k (e^\Theta - \mathbf{I})$	$\Upsilon = -\frac{1}{\lambda_D} e^{-\Theta} \left\{ (e^\Theta - \mathbf{I}) + 2k \frac{\lambda_D}{\lambda_R} \left(1 - \sqrt{3/\text{tr}(e^\Theta)} \right) \left[e^\Theta + \beta \left(\frac{\text{tr}(e^\Theta)}{3} \right)^\delta (e^\Theta - \mathbf{I}) \right] \right\}$
eXtended Pom-Pom	<i>XPomPomLog</i>	$\tau = \frac{\eta_p}{\lambda_B} (e^\Theta - \mathbf{I})$	$\Upsilon = -\frac{1}{\lambda_B} e^{-\Theta} [(f - 2\alpha) e^\Theta + \alpha e^\Theta e^\Theta + (\alpha - 1) \mathbf{I}]$ where $f = 2 \frac{\lambda_B}{\lambda_S} e^{\frac{2}{q}(\Lambda - 1)} \left(1 - \frac{1}{\Lambda^{n+1}} \right) + \frac{1}{\Lambda^2} [1 - \alpha - \frac{\alpha}{3} \text{tr}(e^\Theta (e^\Theta - 2\mathbf{I}))]$ and $\Lambda = \sqrt{\frac{\text{tr}(e^\Theta)}{3}}$



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RheoTool – Reduced Version



Solvers

- RheoInterFoam Solver (Two-phase flow)

Constitutive Models

- Giesekus
- Giesekus-Log
- PTT
- PTT-Log
- Newtonian
- Carreau-Yasuda



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P4 – Case 41



Extrudate Swell

- Carreau-Yasuda (CY)
- Giesekus-Log (GL)
- Giesekus-Log Multimode – illustrative (MGL)



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P4 – Case 41

1. Open Ubuntu terminal
2. of2206 //Load OpenFOAM variables
3. >> run
4. >> cd case41
5. >> code .
6. Study the CY and GL cases files namely file constant/constitutiveProperties and dictionaries fvSolution and fvSchemes.
7. Study the Allrun files for both cases
8. Run both cases
9. Post-process the data in paraview to compare the extrudate swell
10. Study the MGL case files namely file constant/constitutiveProperties, dictionaries fvSolution and fvSchemes and 0 folder to understand how to define the multimode model

