Material Motion:

$$\psi = \psi_{\beta}(\boldsymbol{\chi}, t) = \begin{pmatrix} \chi_1 + \beta \sin(2\pi\chi_1)\sin(\pi\chi_2/3)\sin(\pi t/T) \\ \chi_2 + 5\beta \sin(2\pi\chi_1)\sin(\pi\chi_2/3)\sin(2\pi t/T) \\ \chi_3 \end{pmatrix}, \tag{1}$$

with T=2 and β an amplitude parameter defined for each simulation.

Algorithm 1: Computation of Right Hand Sides.

Data: c_R^p, c_R^s .

Result: rhsLm, rhsF.

1 Update of $\boldsymbol{w}, \boldsymbol{F}_{\psi}, J_{\psi}, \boldsymbol{H}_{\psi}$

2
$$oldsymbol{F} = oldsymbol{F}_{\phi} oldsymbol{F}_{\psi}^{-1}$$

з
$$P = P(F)$$

4
$$v = J_{y}^{-1} p_x / \rho$$

5
$$\hat{oldsymbol{v}} = oldsymbol{v} + \left[\left(oldsymbol{F}_{\phi} oldsymbol{F}_{\psi}^{-1}
ight) oldsymbol{w}
ight]$$

6
$$\hat{m{P}} = \left[m{P} + \left((J_{vv}^{-1}m{p_x})\otimesm{w}
ight)
ight]m{H}_{\psi}$$

7 vC, point to edge interpolation of \hat{v}

s
$$\Lambda^2_{m{H}_\phi} = \left(m{H}_\psi^{Ave}m{N}_{m{\chi}}
ight)\cdot\left(m{H}_\psi^{Ave}m{N}_{m{\chi}}
ight)$$

9
$$c_{m{x}}^p = J_{\psi}^{-1} \left[\Lambda_{m{H}_{\phi}} c_R^p - m{w} \cdot (m{H}_{\psi} m{N}_{\chi})
ight]$$

10
$$c_{m{x}}^s = J_{\psi}^{-1} \left[\Lambda_{m{H}_{\phi}} c_R^s - m{w} \cdot (m{H}_{\psi} m{N}_{m{\chi}})
ight]$$

11
$$tC = \hat{P}^{Ave}N_x + \frac{1}{2}Smat(c_x^p, c_x^s)(p_x^+ - p_x^-)$$
12 $rhsLm = \sum_{b \in \Lambda_a} (tC ||C_{ab}^x||)$

12
$$rhsLm = \sum_{b \in \Lambda_a} (tC ||C_{ab}^x||)$$

13
$$m{rhsF} = \sum_{b \in \Lambda_a}^{b \in \Lambda_a} (m{vC} \otimes m{\mathcal{C}_{ab}^x})$$

Algorithm 2: Use of Right Hand Sides.

Data: rhsLm, rhsF.

Result: $p_x^n, F_\phi^n, u^n, u_w^n$

1
$$\boldsymbol{v} = J_{\psi}^{-1} \boldsymbol{p_x} / \rho$$

2
$$\hat{m{v}} = m{v} + \left[\left(m{F}_{\phi} m{F}_{\psi}^{-1}
ight) \cdot m{w}
ight]$$

з
$$\boldsymbol{x} += \Delta t \; \hat{\boldsymbol{v}}$$

4
$$\boldsymbol{x_w} += \Delta t \boldsymbol{w}$$

5
$$p_x += \Delta t \ rhsLm$$

6
$$\boldsymbol{F} += \Delta t \ \boldsymbol{rhsF}$$

$$\mathbf{7} \ \mathbf{p}_{-}^{n} = \frac{1}{2} \left(\mathbf{p}_{-}^{n-1} + \mathbf{p}_{-}^{n} \right)$$

7
$$m{p}_{m{x}}^n=rac{1}{2}\left(m{p}_{m{x}}^{n-1}+m{p}_{m{x}}^n
ight)$$
8 $m{F}_{\phi}^n=rac{1}{2}\left(m{F}_{\phi}^{n-1}+m{F}_{\phi}^n
ight)$

9
$$x^n = \frac{1}{2}(x^{n-1} + x^n)$$

10
$$m{x}_{m{w}}^n = \frac{1}{2} \left(m{x}_{m{w}}^{n-1} + m{x}_{m{w}}^n
ight)$$

11
$$oldsymbol{u}^n = oldsymbol{ar{x}}^n - oldsymbol{X}$$

12
$$oldsymbol{u}_{oldsymbol{w}}^n = oldsymbol{x}_{oldsymbol{w}}^n - oldsymbol{X}$$