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**.

Update of $\boldsymbol{w}, \boldsymbol{F}_\psi, J_\psi, \boldsymbol{H}_\psi$
$\boldsymbol{F} = \boldsymbol{F}_\phi \boldsymbol{F}_\psi^{-1}$
$\boldsymbol{P} = \boldsymbol{P}(\boldsymbol{F})$
$\boldsymbol{v} = J_\psi^{-1} \boldsymbol{p}_{\boldsymbol{x}} / \rho$
$\hat{\boldsymbol{v}} = \boldsymbol{v} + \left[\left(\boldsymbol{F}_\phi \boldsymbol{F}_\psi^{-1} \right) \boldsymbol{w} \right]$
$\hat{\boldsymbol{P}} = \left[\boldsymbol{P} + \left((J_\psi^{-1} \boldsymbol{p}_{\boldsymbol{x}}) \otimes \boldsymbol{w} \right) \right] \boldsymbol{H}_\psi$
$\boldsymbol{vC}$, point to edge interpolation of $\hat{\boldsymbol{v}}$
$\Lambda^2_{\boldsymbol{H}_\phi} = \left(\boldsymbol{H}_\psi^{Ave} \boldsymbol{N}_{\boldsymbol{\chi}} \right) \cdot \left(\boldsymbol{H}_\psi^{Ave} \boldsymbol{N}_{\boldsymbol{\chi}} \right)$
$c^p_{\boldsymbol{x}} = J_\psi^{-1} \left[\Lambda_{\boldsymbol{H}_\phi} c_R^p - \boldsymbol{w} \cdot (\boldsymbol{H}_\psi \boldsymbol{N}_{\boldsymbol{\chi}}) \right]$
$c^s_{\boldsymbol{x}} = J_\psi^{-1} \left[\Lambda_{\boldsymbol{H}_\phi} c_R^s - \boldsymbol{w} \cdot (\boldsymbol{H}_\psi \boldsymbol{N}_{\boldsymbol{\chi}}) \right]$
$\boldsymbol{tC} = \hat{\boldsymbol{P}}^{Ave} \boldsymbol{N}_{\boldsymbol{x}} + \frac{1}{2} Smat(c^p_{\boldsymbol{x}}, c^s_{\boldsymbol{x}}) \left(\boldsymbol{p}^+_{\boldsymbol{x}} - \boldsymbol{p}^-_{\boldsymbol{x}} \right)$
$\boldsymbol{rhsLm} = \sum_{b \in \Lambda_a} \left(\boldsymbol{tC} \, ||C^{\boldsymbol{x}}_{ab}|| \right)$
$\boldsymbol{rhsF} = \sum_{b \in \Lambda_a} \left(\boldsymbol{vC} \otimes \boldsymbol{\mathcal{C}}^{\boldsymbol{x}}_{ab} \right)$

Algorithm 2: Use of Right Hand Sides.

Data: **rhsLm**, **rhsF**.
Result: $\boldsymbol{p}^n_{\boldsymbol{x}}, \boldsymbol{F}^n_\phi, \boldsymbol{u}^n, \boldsymbol{u}^n_{\boldsymbol{w}}$

$\boldsymbol{v} = J_\psi^{-1} \boldsymbol{p}_{\boldsymbol{x}} / \rho$
$\hat{\boldsymbol{v}} = \boldsymbol{v} + \left[\left(\boldsymbol{F}_\phi \boldsymbol{F}_\psi^{-1} \right) \cdot \boldsymbol{w} \right]$
$\boldsymbol{x} \mathrel{+}= \Delta t \, \hat{\boldsymbol{v}}$
$\boldsymbol{x}_{\boldsymbol{w}} \mathrel{+}= \Delta t \, \boldsymbol{w}$
$\boldsymbol{p}_{\boldsymbol{x}} \mathrel{+}= \Delta t \, \boldsymbol{rhsLm}$
$\boldsymbol{F} \mathrel{+}= \Delta t \, \boldsymbol{rhsF}$
$\boldsymbol{p}^n_{\boldsymbol{x}} = \frac{1}{2} \left(\boldsymbol{p}^{n-1}_{\boldsymbol{x}} + \boldsymbol{p}^n_{\boldsymbol{x}} \right)$
$\boldsymbol{F}^n_\phi = \frac{1}{2} \left(\boldsymbol{F}^{n-1}_\phi + \boldsymbol{F}^n_\phi \right)$
$\boldsymbol{x}^n = \frac{1}{2} \left(\boldsymbol{x}^{n-1} + \boldsymbol{x}^n \right)$
$\boldsymbol{x}^n_{\boldsymbol{w}} = \frac{1}{2} \left(\boldsymbol{x}^{n-1}_{\boldsymbol{w}} + \boldsymbol{x}^n_{\boldsymbol{w}} \right)$
$\boldsymbol{u}^n = \boldsymbol{x}^n - \boldsymbol{X}$
$\boldsymbol{u}^n_{\boldsymbol{w}} = \boldsymbol{x}^n_{\boldsymbol{w}} - \boldsymbol{X}$