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ABSTRACT

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2.2. Surface operations and projections

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E W

$$E = \frac{1}{2}(\nabla u + (\nabla u)^T), \quad W = \frac{1}{2}(\nabla u - (\nabla u)^T), \qquad (12)$$

T

3.1.3. Relationship between macroscopic and microscopic interface strains

$\tilde{\chi}$ $\partial\tilde{u}/\partial\xi$ $\tilde{u}$ $\xi_n, \xi_s, \xi_t)$

$\tilde{\chi}$ $\xi_n, \xi_s, \xi_t)$

n,

$$\tilde{\chi}\ \xi_n, \xi_t, \xi_s) \quad \langle\tilde{\chi}\rangle\ \xi_t, \xi_s) \quad \langle\langle\tilde{\chi}\rangle\rangle\ \xi_t, \xi_s)\, \xi_n \quad \xi_n^2 \qquad 22)$$

$\langle\tilde{\chi}\rangle$ $\langle\langle\tilde{\chi}\rangle\rangle$

μ Γ

$\zeta_s^{\perp}$] μ /h. 3)

, 1/h .

, $\upsilon_s^{\perp}$ (1),

] μ .

$$\tilde{q}\ \xi_n,\xi_t,\xi_s) \quad q_s^{\|} \quad q_s^{\perp} n \quad \xi_t,\xi_s) \quad q_m\ \xi_t,\xi_s)\frac{\xi_n}{h} \quad \xi_n^2 , \qquad 4\ )$$

( ) ( )

4. Mass conservation

$$\rho^f \quad \phi\rho_t^f \qquad \rho^s \quad 1] \quad \phi)\rho_t^s, \qquad 4\ )$$

t

. W

$\bar{\rho}^\alpha$ $\bar{\bar{\rho}}^\alpha$

α (α s,f)

$$\bar{\rho}^\alpha \quad h\langle\tilde{\rho}^\alpha\rangle, \quad \bar{\bar{\rho}}^\alpha \quad h^2\langle\langle\tilde{\rho}^\alpha\rangle\rangle \qquad 4\ )$$

$$\tilde{\rho}^f \quad \tilde{\phi}\tilde{\rho}_t^f \qquad \tilde{\rho}^s \quad 1] \quad \tilde{\phi})\tilde{\rho}_t^s$$

$\tilde{\rho}_t^\alpha$

α.

h

Upc5 0 Tcombin.1(s)-27F7 46.7(o)0(n)-2ar

(.)

$$\tilde{\rho}^\alpha\ \xi_n,\xi_t,\xi_s) \quad \langle\tilde{\rho}^\alpha\rangle\ \xi_t,\xi_s) \quad \langle\langle\tilde{\rho}^\alpha\rangle\rangle\ \xi_t,\xi\upsilon$$

$\cdot\,\tilde{\mathbf{v}} = \dot{\bar{e}}^{v}$

(2) (1) ,

$$\frac{D\bar{\rho}^{s}}{Dt} + \bar{\rho}^{s}\dot{e}_{s}^{v} + \bar{\bar{\rho}}^{s} I \dot{e}_{m}^{v} = 0 \qquad)$$

$$\frac{D\bar{\bar{\rho}}^{s}}{Dt} + \bar{\bar{\rho}}^{s}\dot{e}_{s}^{v} + \bar{\rho}^{s}\dot{e}_{m}^{v} = 0, \qquad)$$

I -

$$I = \frac{1}{h^{3}}\int_{-h/2}^{h/2} \xi_{n}^{2}\, d\xi^{n} = \frac{1}{12}.$$

( ) $\bar{\rho}^{s}$

∂

. T

$$\delta E_{int} = \int_{\Omega} \mathrm{div}\,T \cdot \delta u\, dV + \int_{\Gamma} t_s \cdot \delta u - \mathrm{div}^{\parallel} T_s \cdot \delta\{u\}$$
$$- \mathrm{div}^{\parallel} T_m \cdot \delta u \, dS - \int_{\Gamma} T \cdot n \cdot \delta u\, dS + \int_{\partial\Omega} T \cdot \bar{n} \cdot \delta u\, dS$$
$$+ \int_{\ell_i} T_s \cdot m \cdot \delta u\, d\ell + \int_{\ell_e} T_s \cdot m \cdot \delta\{u\} + T_m \cdot m \cdot \delta u \, d\ell \quad 4)$$

$\bar{n}$ $\partial\Omega$ m

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($\partial\Omega$). ,

u 0 $\{u\}$ u ℓ_i. ,

,

$$T \cdot n \cdot \delta u = T \cdot n \cdot \{\delta u\} + \{T \cdot n\} \cdot \delta u \quad)$$

$$\int_{\ell_i} T_s \cdot m \cdot \delta u\, d\ell = \int_{\Omega} T_s \cdot m\, \delta(x - x_{\ell_i}) \cdot \delta u\, dV \quad)$$

$\delta(x - x_{\ell_i})$, δE_{int}

$$\delta E_{int} = \int_{\Omega} -\mathrm{div}\,T + T_s \cdot m\, \delta(x - x_{\ell_i}) \cdot \delta u\, dV$$
$$+ \int_{\Gamma} t_s - \mathrm{div}^{\parallel} T_m - \{T \cdot n\} \cdot \delta u + - \mathrm{div}^{\parallel} T_s$$
$$- T \cdot n \cdot \delta\{u\} dS + \int_{\partial\Omega} T \cdot n \cdot \delta u\, dS$$
$$+ \int_{\ell_e} T_s \cdot m \cdot \delta\langle u\rangle + T_m \cdot m \cdot \delta u \, d\ell. \quad)$$

( ) (3) (2)

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δu, $\{\delta u\}$ δu

$\delta u = 0$ $\partial\Omega^u$, $\delta u = 0$ ℓ_e^u $\delta\{u\} = 0$ ℓ_e^u,

$\mathrm{div}\,T + b - T_s \cdot m\, \delta\, x$

n. ,