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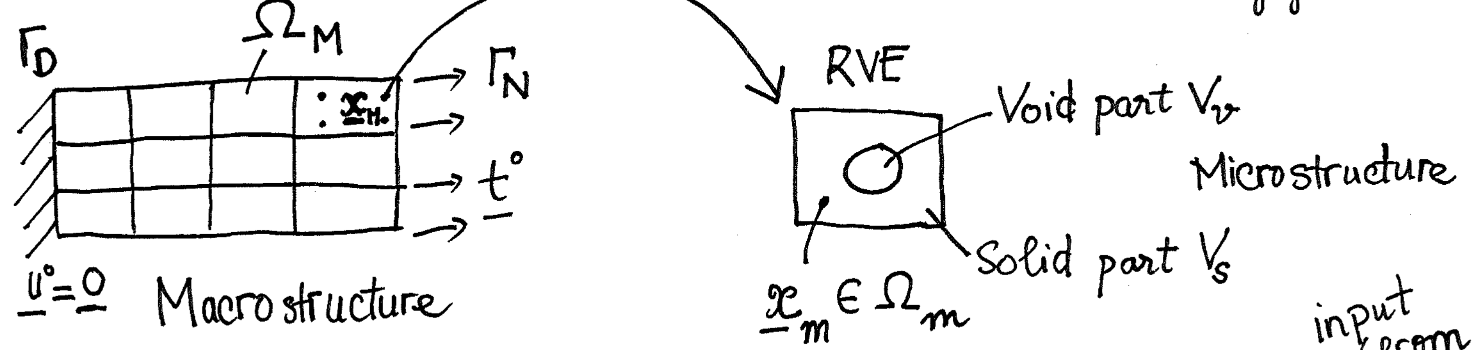

BVP in MACRO

$\nabla \cdot \overline{\sigma}_M + f = 0 \quad \forall x_M \in \Omega_M$

$\overline{u} = u^\circ$ on Γ_D (Dirichlet)

$\overline{\sigma}_M \cdot n = t^\circ$ on Γ_N (Neumann)

BVP in MICRO

$\nabla \cdot \sigma_m = 0 \quad \forall x_m \in \Omega_m$

input from Macro

$\sigma_m = \mathbb{C}(x) : [\tilde{\varepsilon}(u) + \boxed{\overline{\varepsilon}_M}]$

$\tilde{u}$ is periodic on Ω_m.

$\sigma \cdot n$ is antiperiodic on Ω_m.

Finally, solving micro BVP we can obtain $\sigma(x_m)$ & $\varepsilon(x_m)$.

We homogenize them by:

$$\langle \sigma \rangle = \frac{1}{|\Omega_m|} \int_{\Omega_m} \sigma(x_m)\, dx_m = \overline{\sigma}$$

$$\langle \varepsilon \rangle = \frac{1}{|\Omega_m|} \int_{\Omega_m} \varepsilon(x_m)\, dx_m = \overline{\varepsilon}$$

$$\Rightarrow \overline{\mathbb{C}} = \frac{\partial \overline{\sigma}}{\partial \overline{\varepsilon}}$$

4^{th}-order tensor or 36 component in matrix form.

upscaling

Algorithm:

Macro.py
Loop elm in Elements
- Loop ~~gauss~~ gp in Gauss
  - $\overline{\varepsilon}_M = B \cdot u$ at step n in Newton-Raphson.
  - ↳ call Micro $(\overline{\varepsilon}_M) \xrightarrow{\text{return}} \overline{\sigma}, \overline{\mathbb{C}}$
  - → calculate K_T, F_{int}, F_{ext} where $K_T = \frac{\partial K_{int}}{\partial u}$
  - ...