Multiscale quasicontinuum methods for fibrous materials

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Aim of this presentation

Show that the quasicontinuum method is suitable for discrete models of fibrous materials

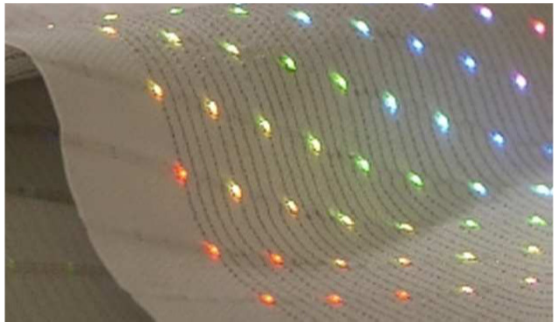
Outline

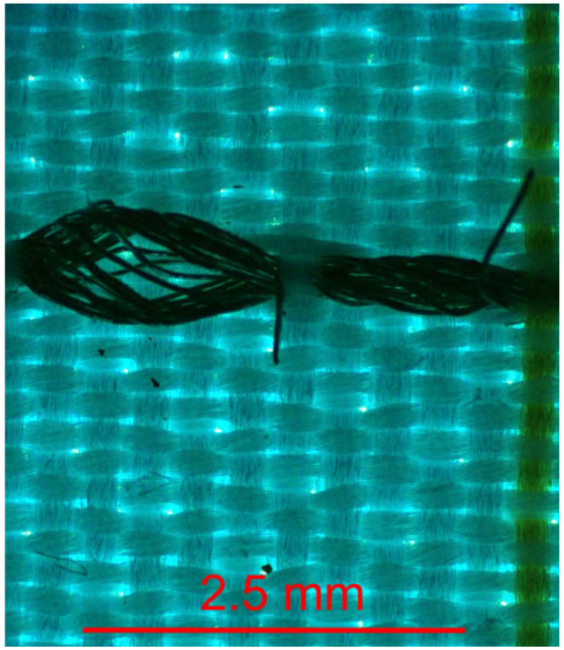
1. Discrete models for fibrous materials

2. Quasicontinuum method

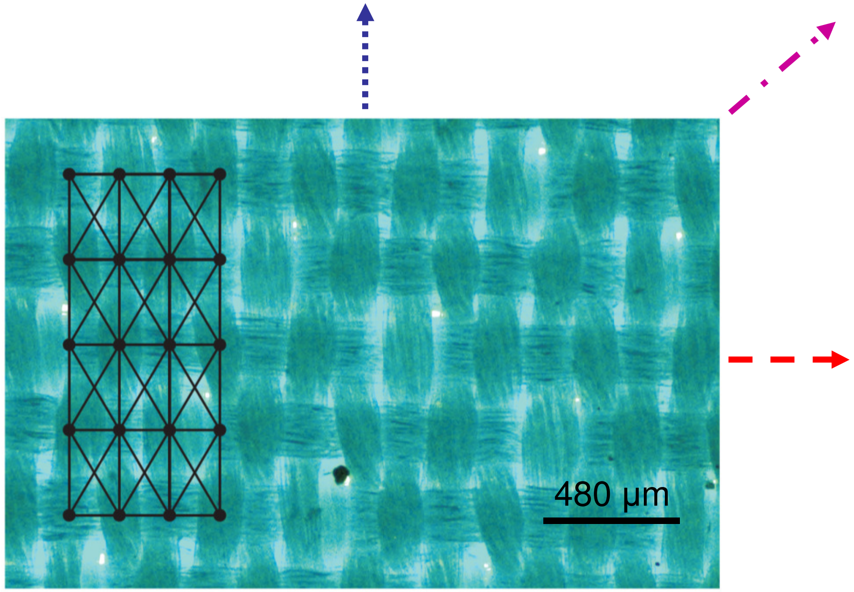
3. Results

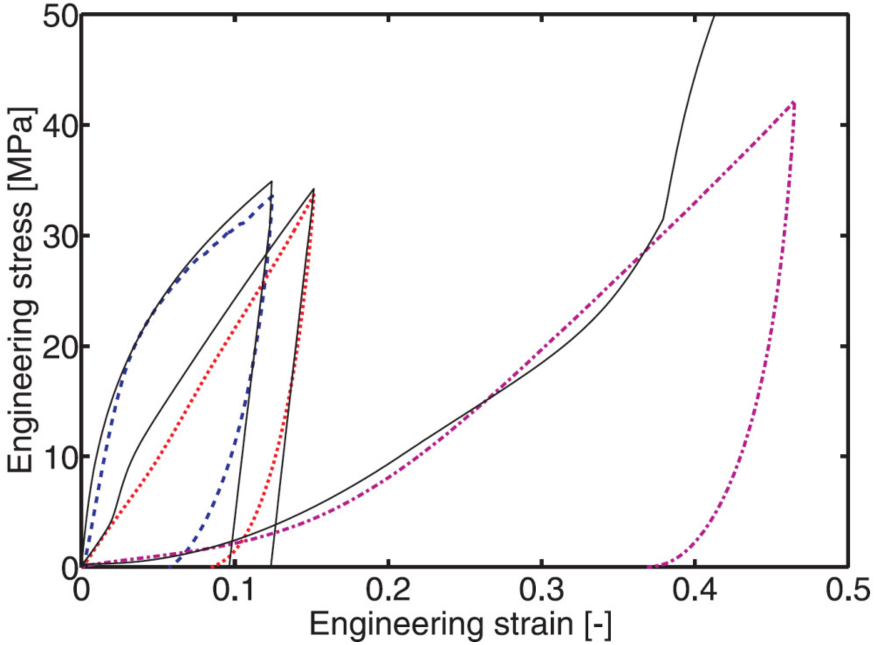
Fibrous material 1: electronic textile



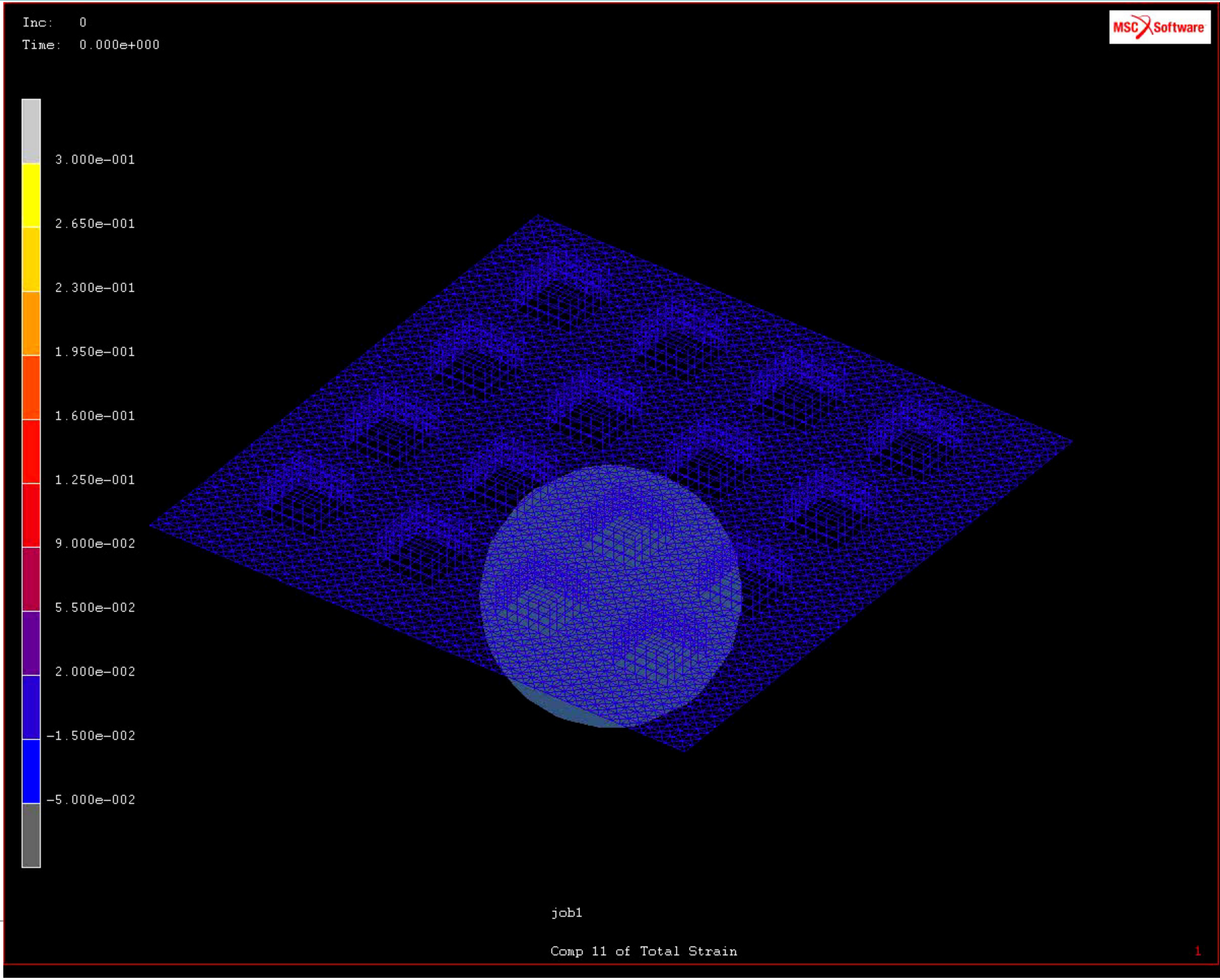


Fibrous material 1: electronic textile

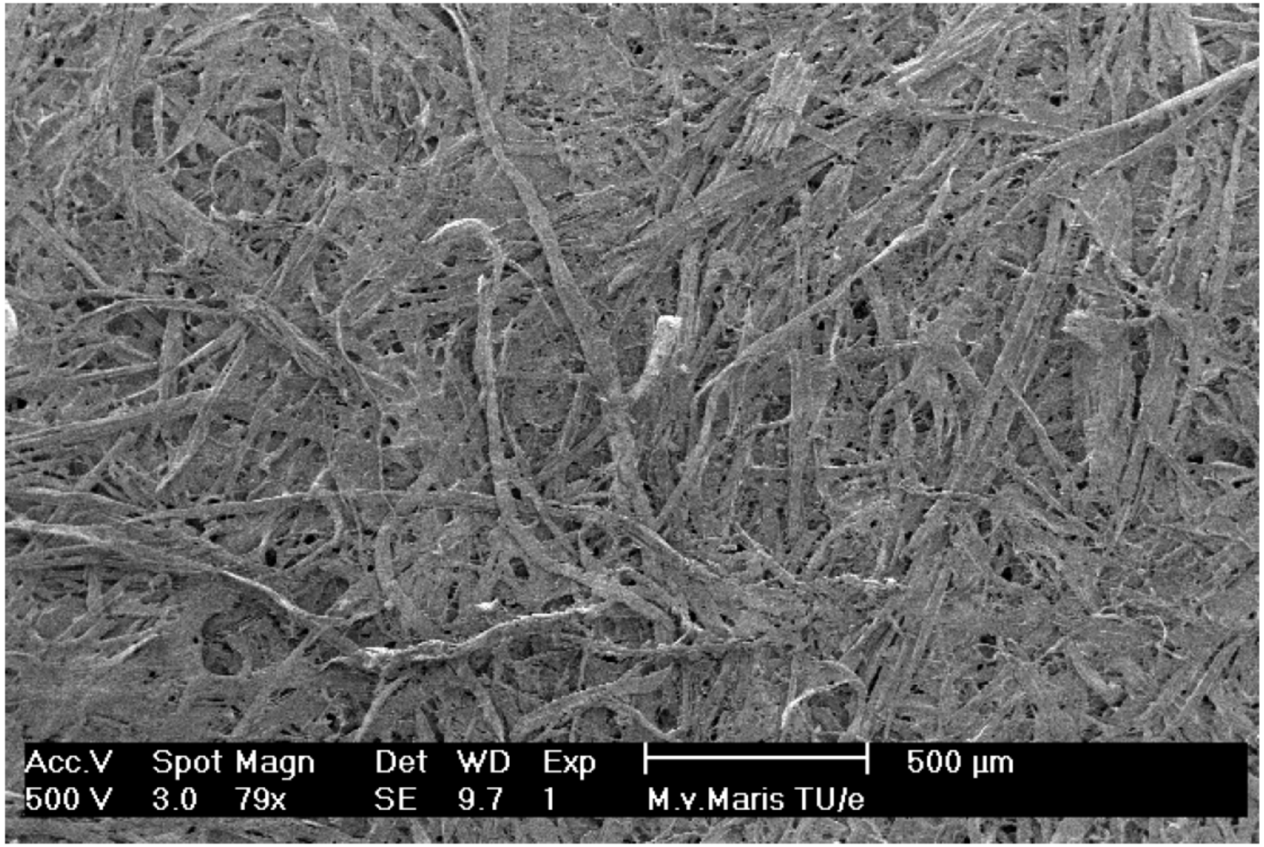




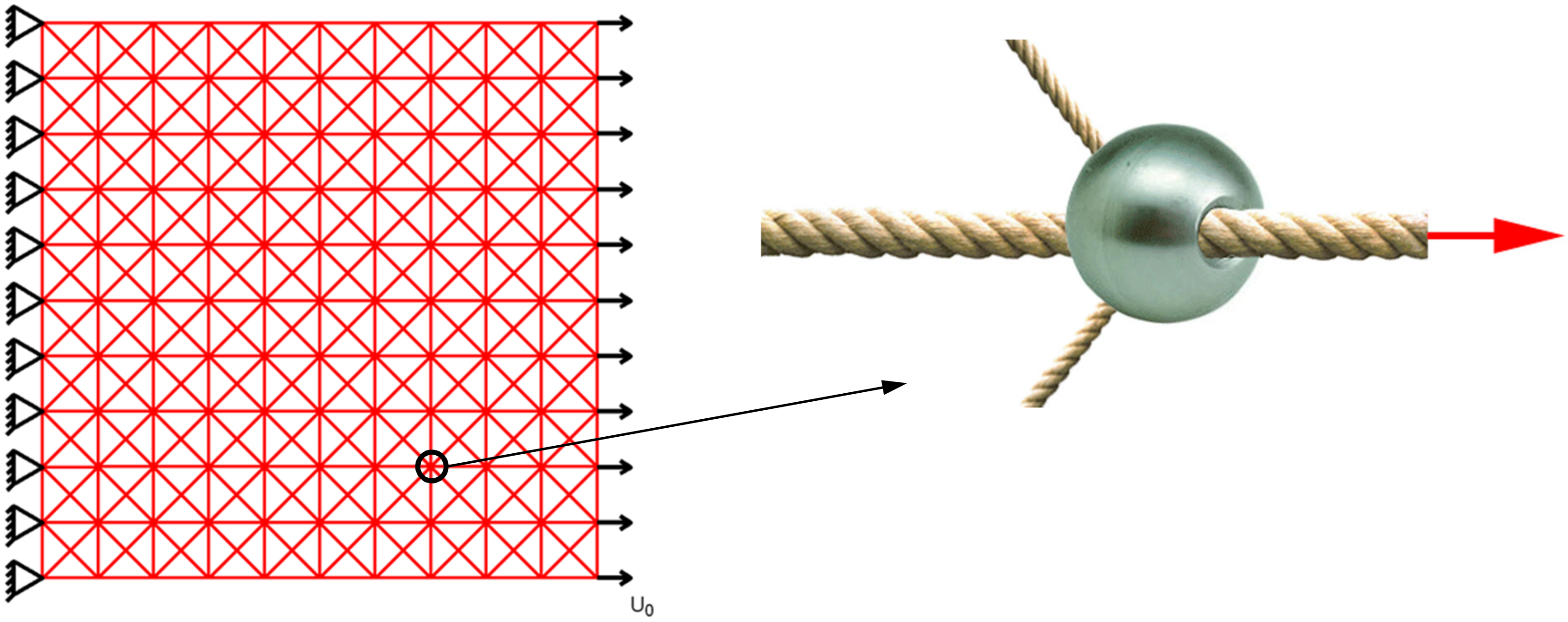
Fibrous material 1: electronic textile



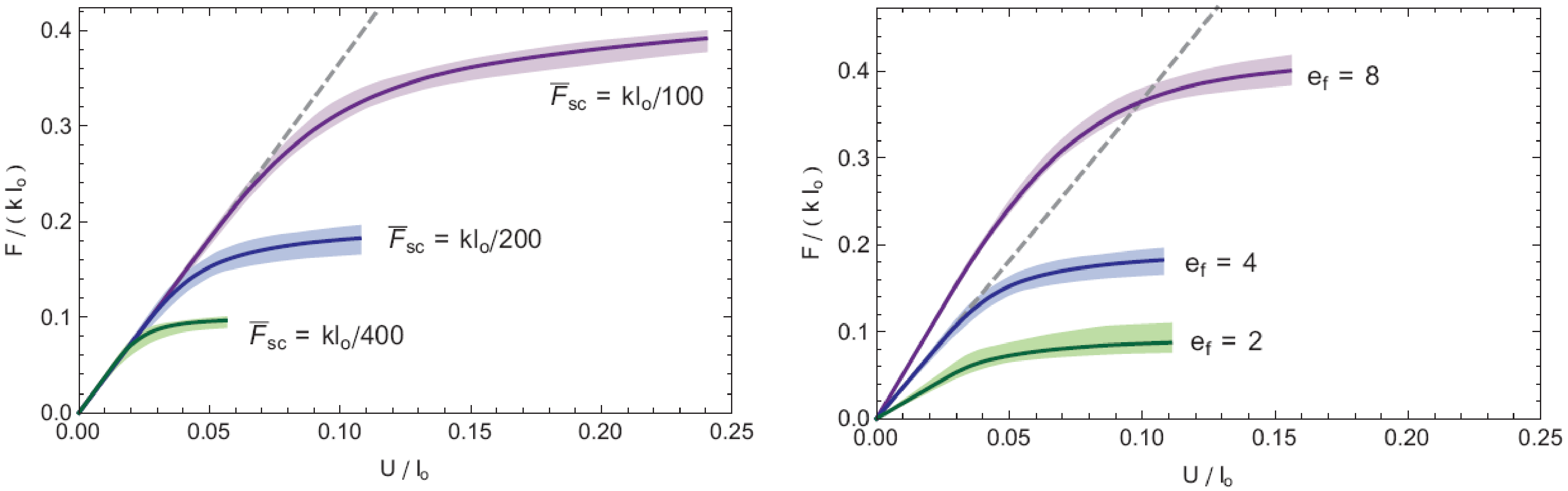
Fibrous material 2: paper materials



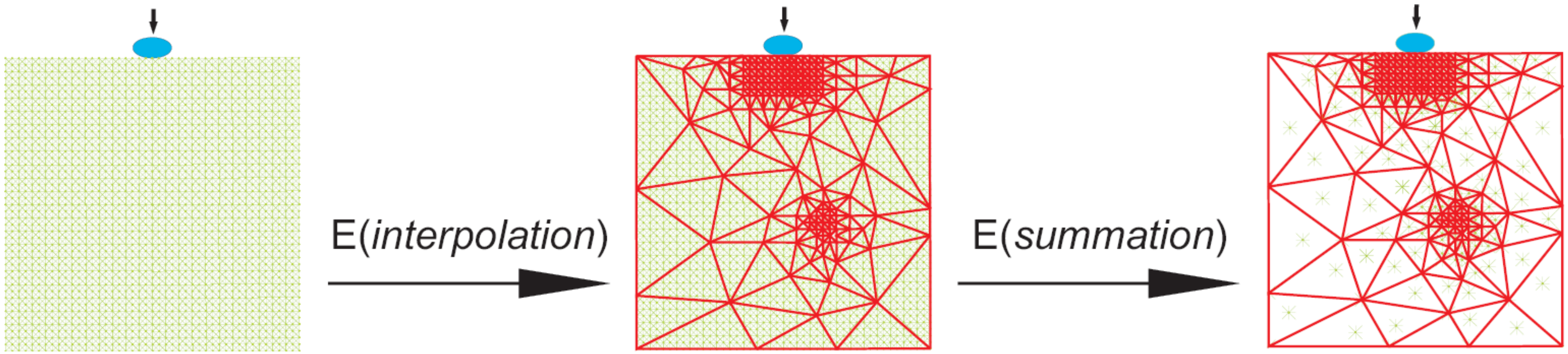
Fibrous material 2: paper materials



Fibrous material 2: paper materials



Quasicontinuum method (Tadmor et al, 1996)



- Ideal for local events in large-scale lattice computations
- Underlying lattice fully resolved where needed
- No continuum/constitutive assumptions

Virtual-power-based QC framework

Dissipative lattice model based on a Coleman-Noll procedure

Kinematic variables $\boldsymbol{u}$ & history variables $\boldsymbol{z}$

Internal energy $E = \sum_{i=1}^{n} E_i$

Virtual-power $\dot{\boldsymbol{u}}^T \boldsymbol{f}_{int} = \dot{\boldsymbol{u}}^T \boldsymbol{f}_{ext} \quad \forall \dot{\boldsymbol{u}}$

Internal power $P_{int} = \dot{E} + \dot{D}$

Energy rate $\dot{E} = \dot{\boldsymbol{u}}^T \frac{\partial E}{\partial \boldsymbol{u}} + \dot{\boldsymbol{z}}^T \frac{\partial E}{\partial \boldsymbol{z}}$

Dissipation rate $\dot{D} = \dot{\boldsymbol{u}}^T \left(\boldsymbol{f}_{int} - \frac{\partial E}{\partial \boldsymbol{u}} \right) - \dot{\boldsymbol{z}}^T \frac{\partial E}{\partial \boldsymbol{z}} \geq 0$

Virtual-power-based QC framework

Apply 2 QC reduction steps to

Dissipative lattice model based on a Coleman-Noll procedure

Kinematic variables $\boldsymbol{u} = \Psi \overline{\boldsymbol{u}}$ & history variables $\boldsymbol{z}$

Internal energy $E = \sum_{i \in S} E_i$

Virtual-power $\dot{\overline{\boldsymbol{u}}}^T \Psi^T \boldsymbol{f}_{int} = \dot{\overline{\boldsymbol{u}}}^T \Psi^T \boldsymbol{f}_{ext} \quad \forall \dot{\overline{\boldsymbol{u}}}$

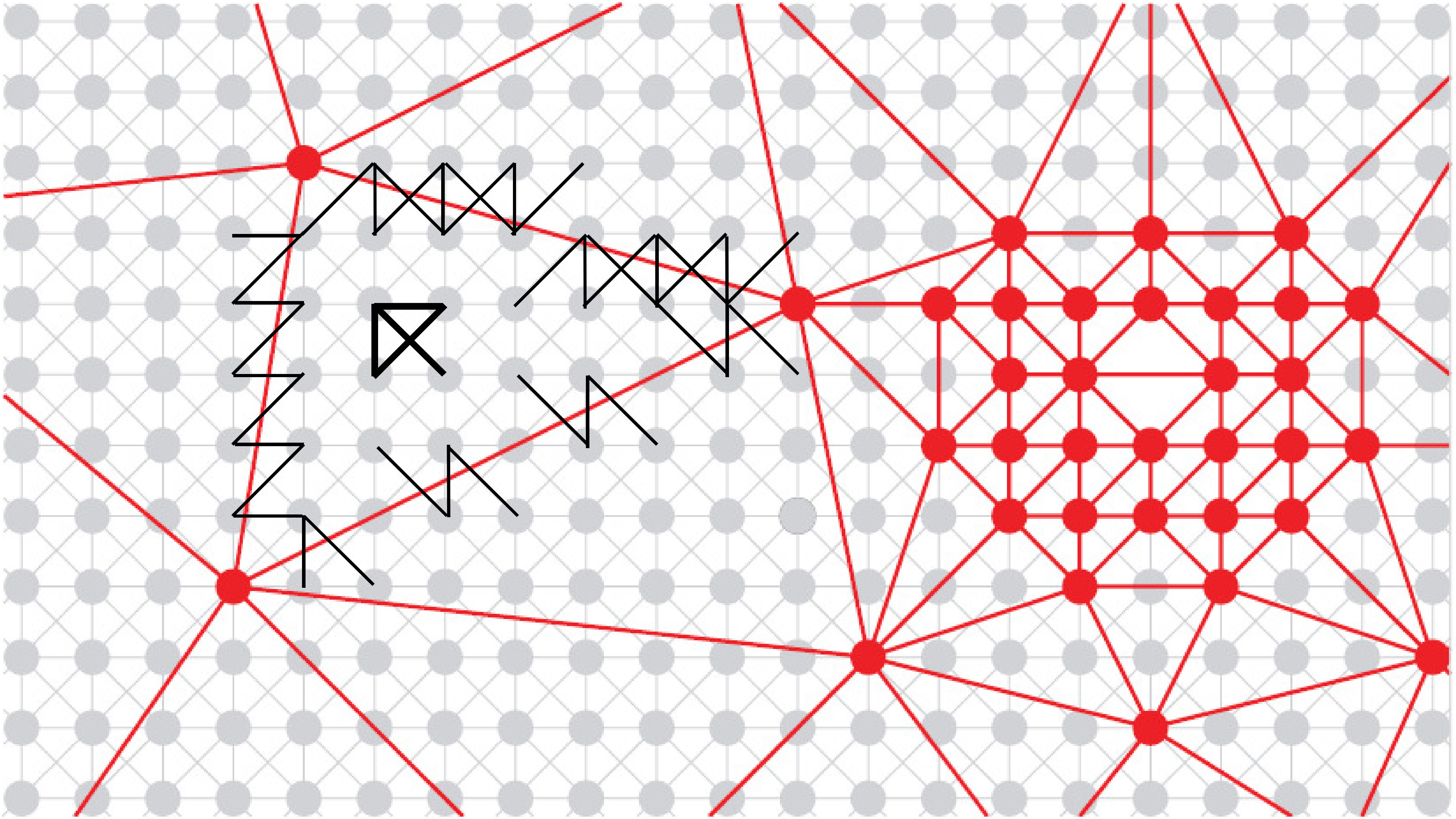
Internal power $P_{int} = \dot{E} + \dot{D}$

Energy rate $\dot{E} = \dot{\overline{\boldsymbol{u}}}^T \Psi^T \frac{\partial E}{\partial \boldsymbol{u}} + \dot{\boldsymbol{z}}^T \frac{\partial E}{\partial \boldsymbol{z}}$

Dissipation rate $\dot{D} = \dot{\overline{\boldsymbol{u}}}^T \left(\boldsymbol{f}_{int} - \Psi^T \frac{\partial E}{\partial \boldsymbol{u}} \right) - \dot{\boldsymbol{z}}^T \frac{\partial E}{\partial \boldsymbol{z}} \geq 0$

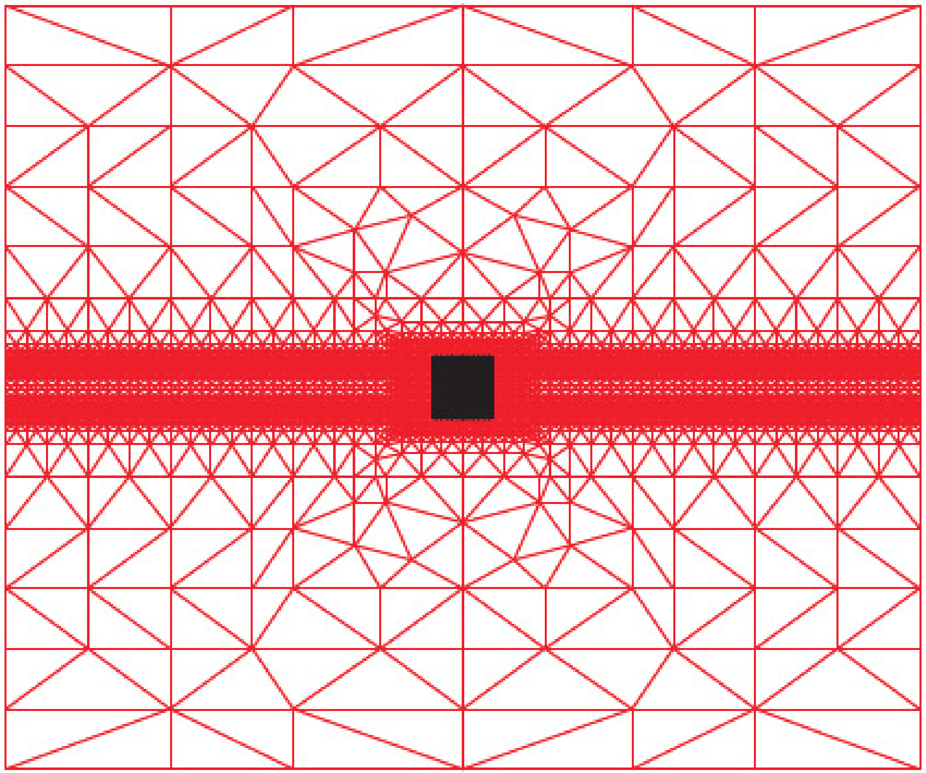
Virtual-power-based QC framework

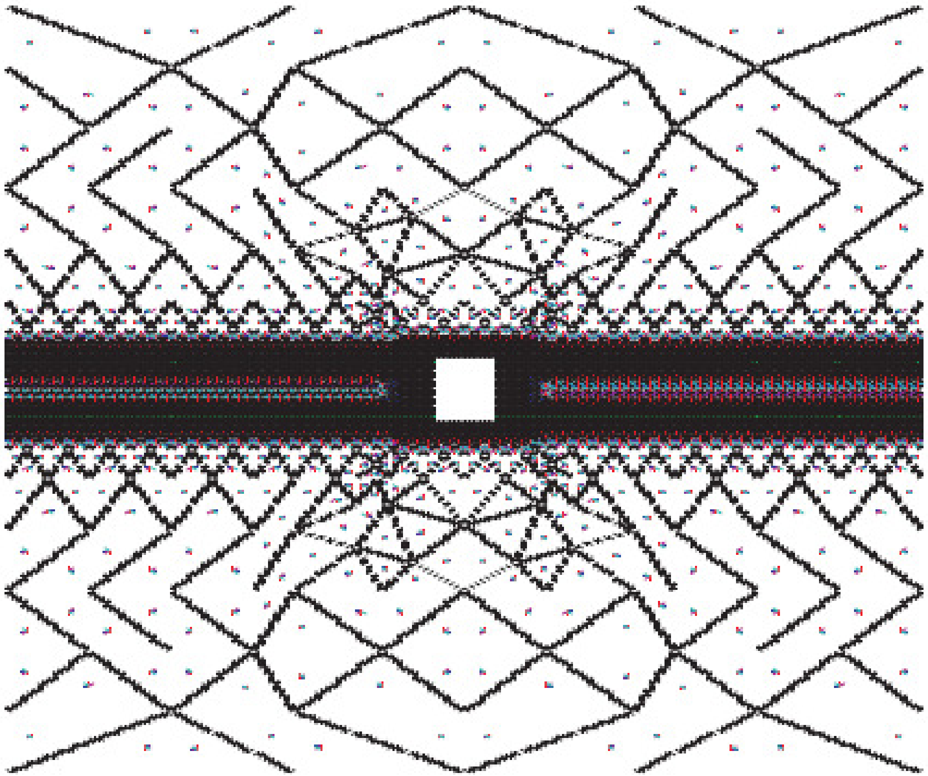
Summation



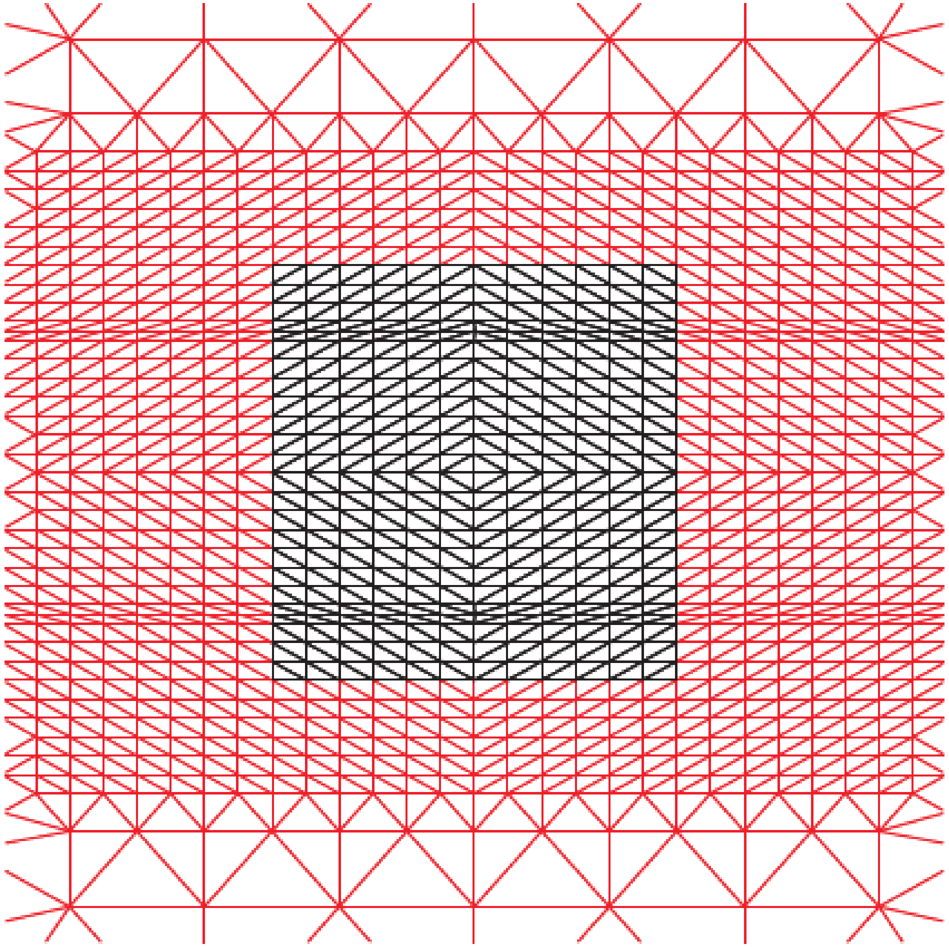
Virtual-power-based QC framework

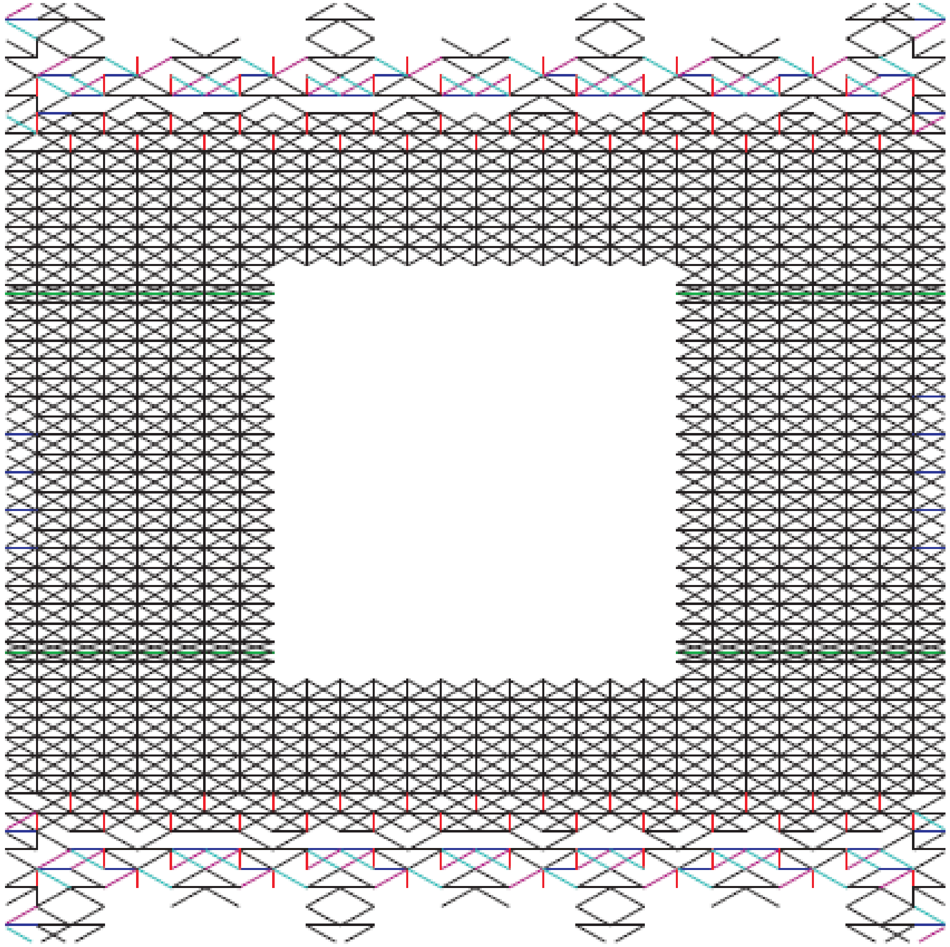
Electronic textile



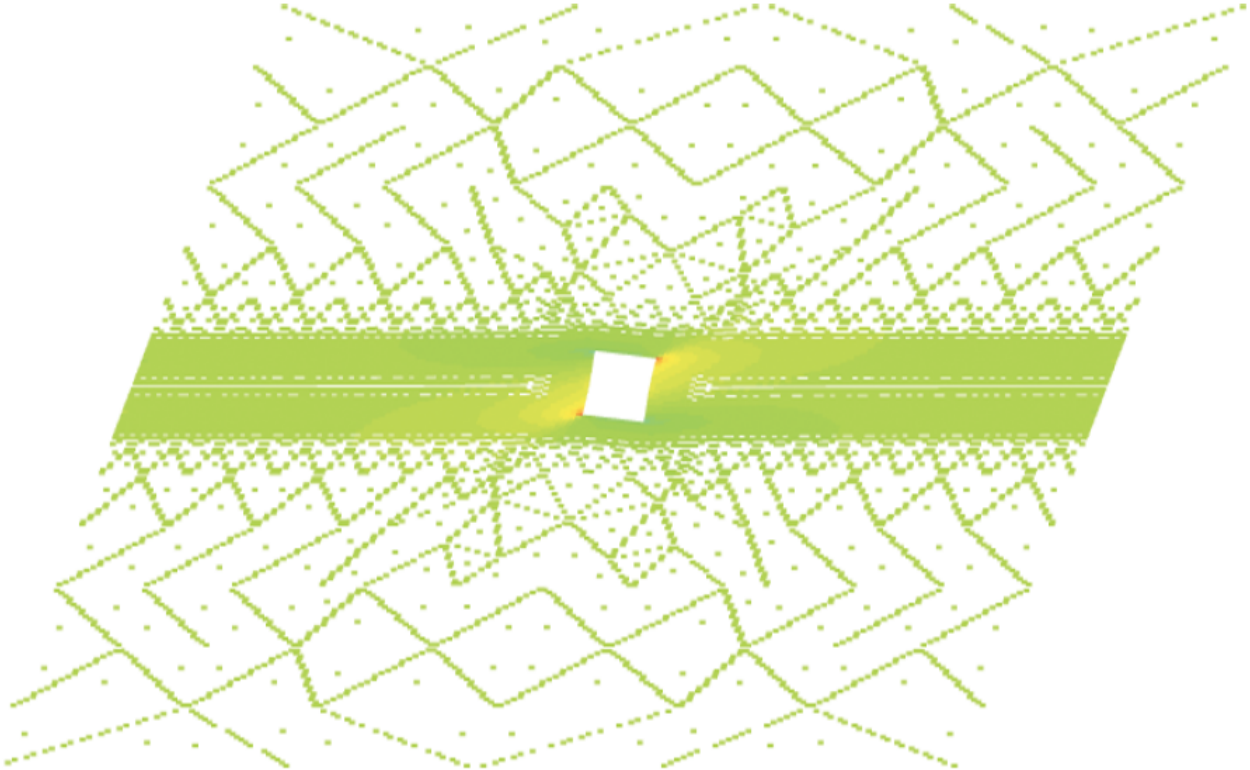


Electronic textile

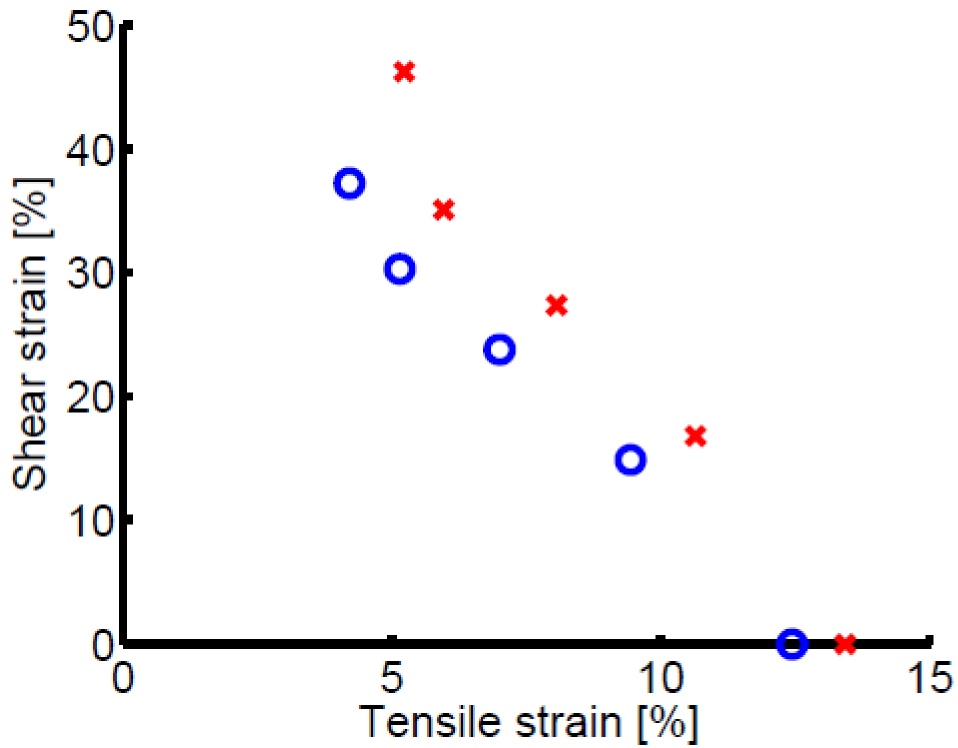




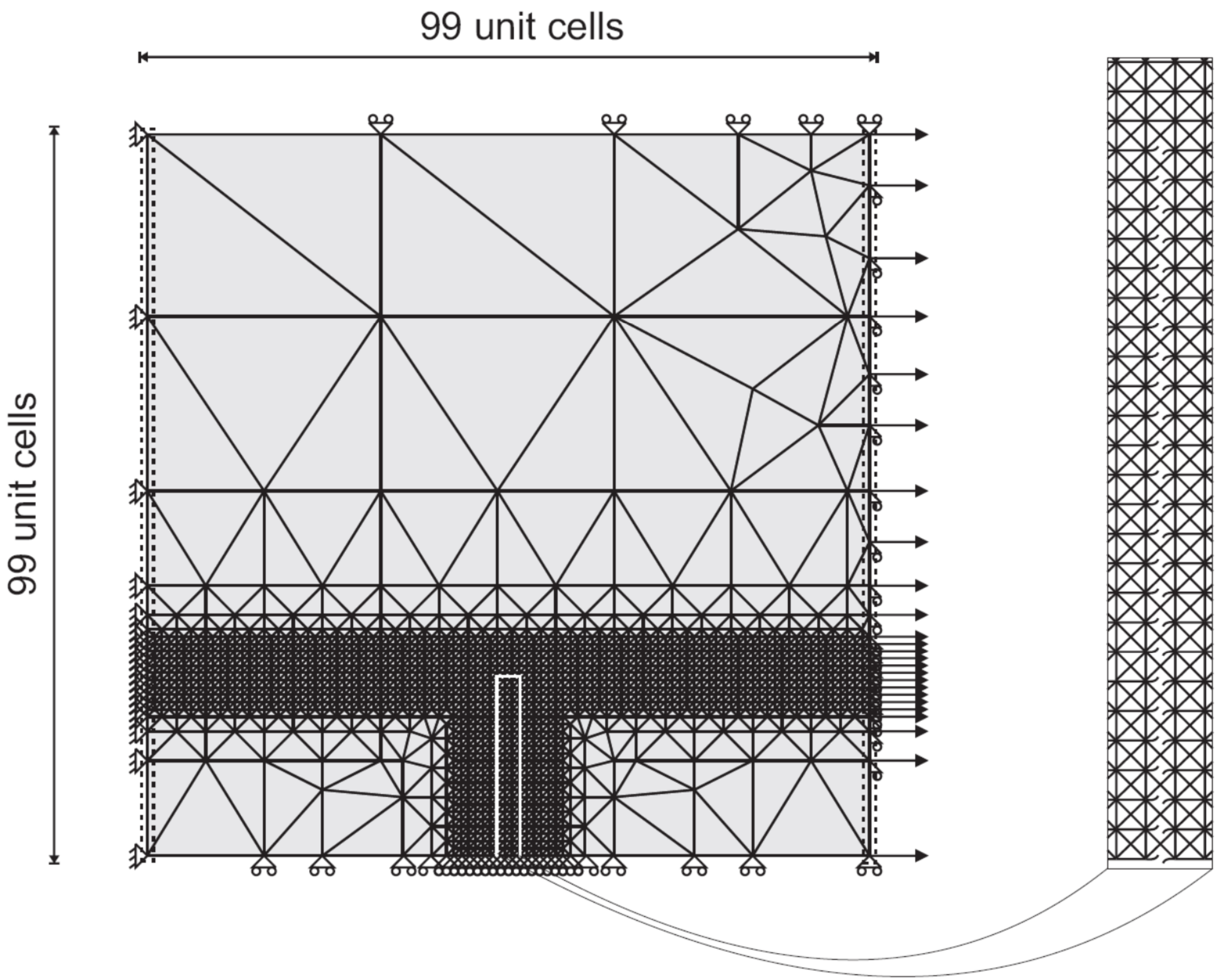
Results: electronic textile



Failure surfaces

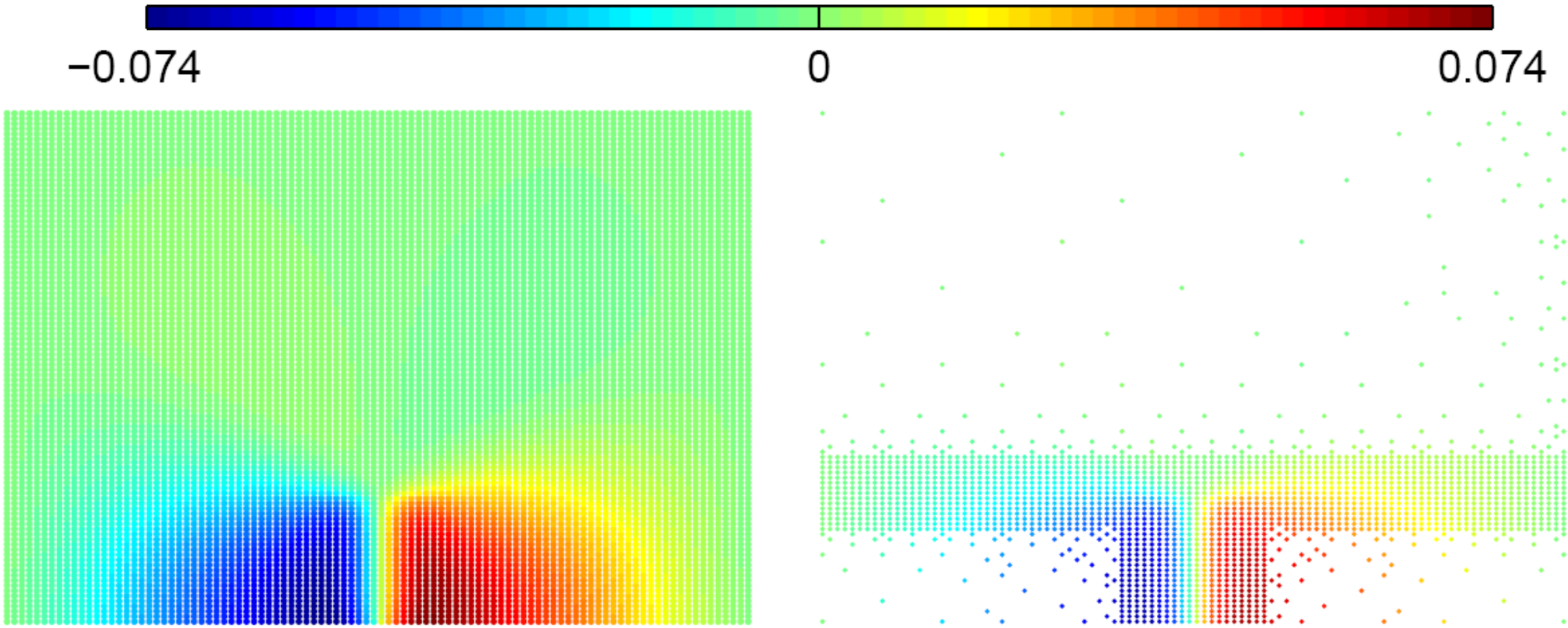


Results: fiber sliding in paper materials



Results: fiber sliding in paper materials

Horizontal displacement, relative to the uniform displacement



Summary

Virtual-power-based QC methodology

Summation: 1. exact rule

2. central rule

Dissipative effects included in QC via internal variables

- for elastoplasticity at sampling spring level
- for nodal sliding interpolated due to nonlocality

Future research

- Beams
- Irregularity
- Adaptivity
- Applications:
  1. Collagen networks
  2. Networks with matrix material
  3. CNT sheets/graphene sheets
  4. Nanofibers by electrospinning
  5. ……