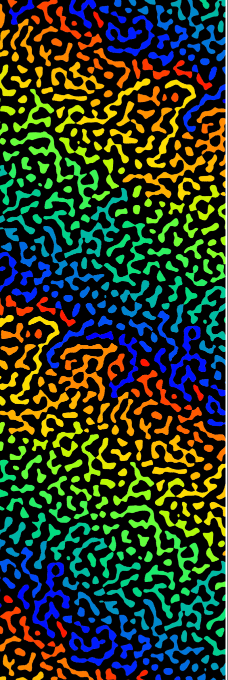


Physics and Mechanics of Contact Interfaces
... and beyond

Vladislav A. Yastrebov

MINES ParisTech, PSL University, CNRS
Centre des matériaux, Évry, France

HDR defense
Ecole des mines de Paris
Nov 12, 2021

Outline

Scientific research

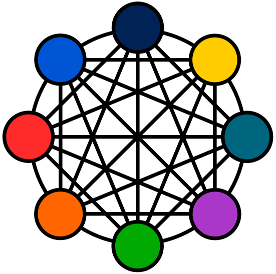
- Brief overview
- Major contributions
- Selected contributions

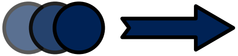
Community

- Collaborations
- Teaching
- Open Science
- Extra CV info

Future

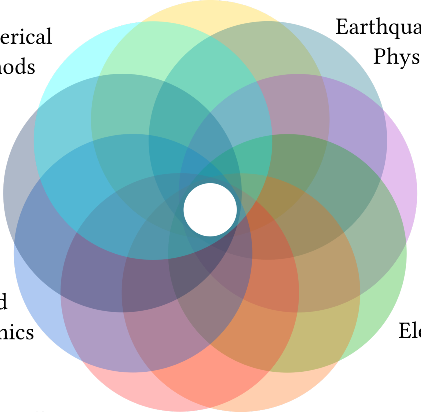
- Current work
- Prospective work





Scientific Research

Research domains & applications



Some problems & applications

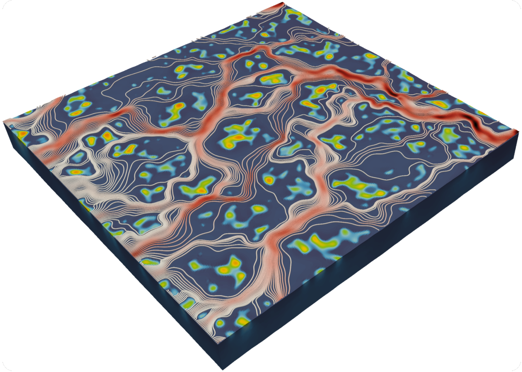
- Wear of drilling tools
- Fault slip
- Microstructure of cemented carbides
- Contact of rough surfaces
- MorteX method for wear
- Sealing of metal-to-metal contacts
- Iceberg-glacier-ocean interaction
- Electric-arcs in contacts
- Waves in asymmetric materials

Common divisors

Particularity of problems

- Simulation-based studies
- Presence of mechanical contact
- Multiphysical nature
- Mainly stationary problems
- Nonlinear materials
- Presence of complex geometries

Example

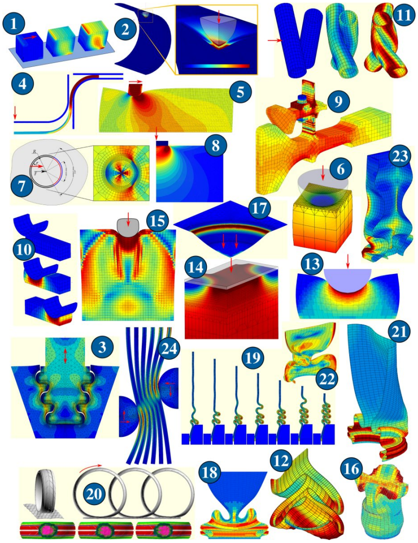


Strongly coupled simulations of stationary creeping fluid flow in contact interface between rough surfaces

[1] A.G. Shvarts. "Coupling mechanical frictional contact with interfacial fluid flow at small and large scales" PhD Thesis (2019)

Methods & code development

- **Finite Element Method**
  contact algorithms, friction laws, constitutive behavior of materials, fluid/solid interaction
- **Boundary Element Method**
  spectral solver, multi-asperity based solver
- **Dislocation Dynamics**
  Coupling Numodis with FEM, simple 2D code for teaching
- **Molecular Dynamics**
  Simple code for teaching
- **Miscellaneous**
  fluid-solid interaction, microstructure constructor, wave dynamics, roughness generator, arc-induced damage, etc



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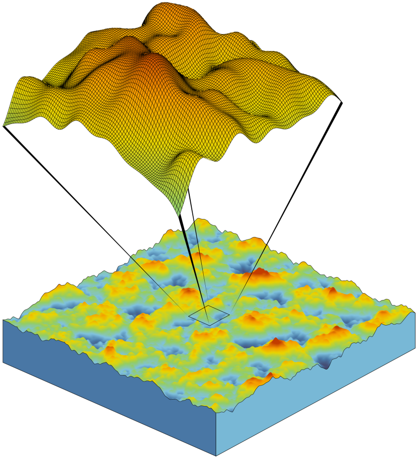

Model surface-roughness

Methods & code development

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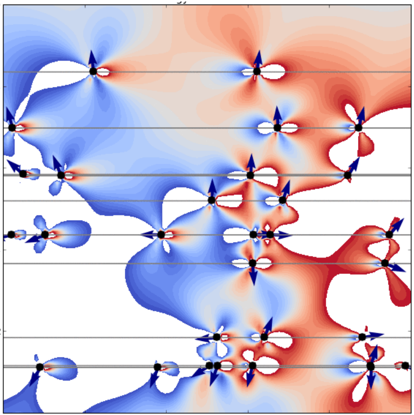

Shear stress field and Peach-Koehler forces on dislocation cores

Methods & code development

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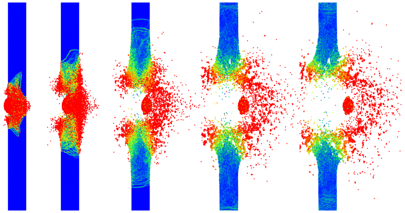
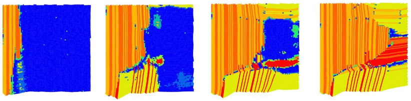


Perforation of a defectless thin single-crystal film



Martensitic transformation using Kastner bi-stable pair potential

Methods & code development

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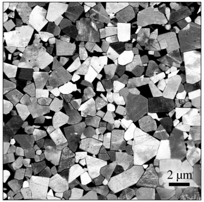
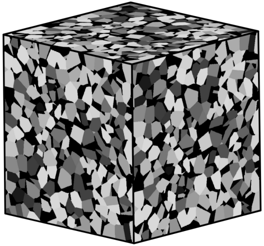


WC/Co microstructure (SEM)



WC/Co artificial microstructure

Methods & code development

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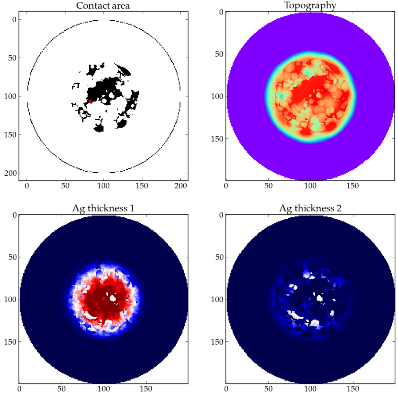


Contact area with electric arc's location, composite surface topography, demixed silver thickness on two contactors (after 500 arcs)

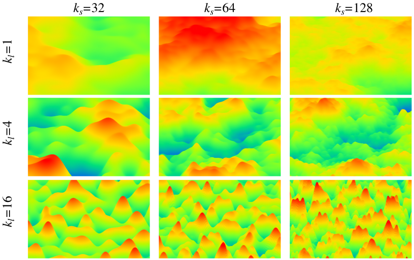
Major contribution I

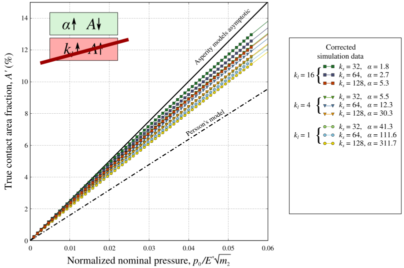
1. Understanding the role of surface-roughness parameters in elastic normal contact of rough surfaces[1–5] thanks to numerical simulations with a novel error correction technique[6]... and some insights on scale separation[7]

with G. Anciaux (EPFL), J.F. Molinari (EPFL), G. Cailletaud (MINES)

+ *A. Almqvist, F. Pérez-Ràfols, P. Beguin, S. Forest, V. Phalke, A. Fouque, F.S.M. Mballa, J. Durand*

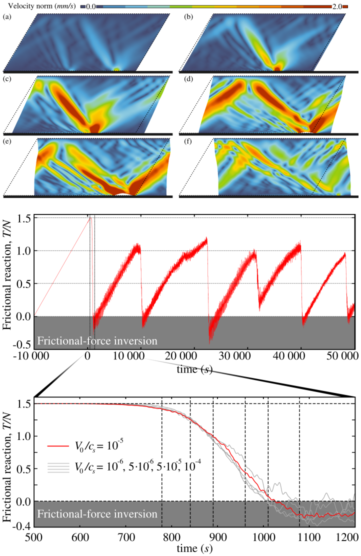
[1] VY, J. Durand, H. Proudhon, G. Cailletaud. *CR Mécanique* (2011).
[2] VY, G. Anciaux, J.F. Molinari. *Phys. Rev. E* (2012).
[3] VY, G. Anciaux, J.F. Molinari. *Tribol. Lett.* (2014).
[4] VY, G. Anciaux, J.F. Molinari. *Int. J. Solids Struct.* (2015).
[5] VY, G. Anciaux, J.F. Molinari. *J. Mech. Phys. Solids* (2017).
[6] VY, G. Anciaux, J.F. Molinari. *Tribol. Int.* (2017).
[7] VY. *J. Multiscale Model.* (2019)





2. Study of frictional dynamics at bi-material interfaces[1,2] and a discovery of opening waves[3]... and a search for supersonic slip fronts

with D.S. Kammer (ETHZ), J.F. Molinari (EPFL)



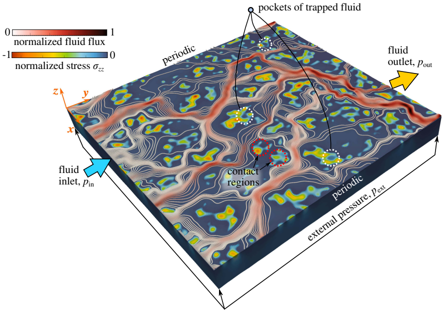
[1] D.S. Kammer, VY, P. Spijker, J.F. Molinari. *Tribol. Lett.* (2012).
[2] D.S. Kammer, VY, G. Anciaux, J.F. Molinari. *J. Mech. Phys. Solids* (2014).
[3] VY. *Tribol. Lett.* (2016).

Major contribution III

3. Construction of a monolithic finite element framework for thin creeping fluid flow in contact interfaces taking into account fluid entrapment in pockets surrounded by contact zones

with A. Shvarts (Univ. Glasgow), J. Vignollet (Safran tech)

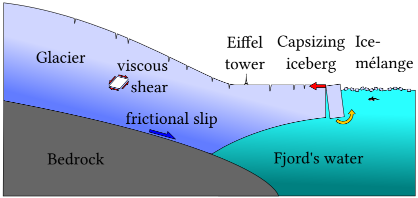

- Best PhD thesis CSMA award
- Best thesis in tribology, Prix Hirn of the AFM

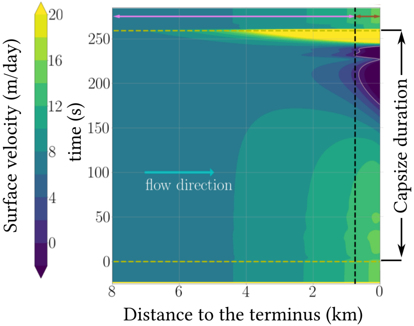


[1] A.G. Shvarts, VY. *Tribol. Int.* (2018).
[2] A.G. Shvarts, VY. *J. Mech. Phys. Solids* (2018).
[3] A.G. Shvarts. *PhD thesis* (2019).
[4] A.G. Shvarts, J. Vignollet, VY. *Comp. Meth. Appl. Mech. Eng.* (2021).

4.Understanding the processes underlying glacial earthquakes: interaction of the solid earth, glacier, iceberg, ocean and ice-mélange

with A. Sergeant, P. Bonnet, A. Mangeney, O. Castelnau, A. Leroyer, P. Queutey, E. Stutzmann, J.P. Montagner



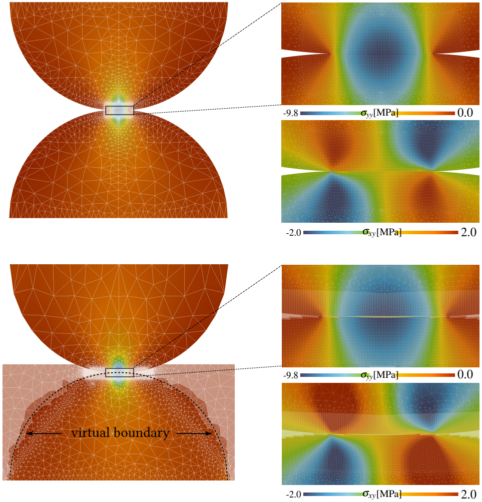


[1] A. Sergeant, VY, A. Mangeney, O. Castelnau, J.P. Montagner, E. Stutzmann. *J. Geophys. Res.* (2018)
[2] A. Sergeant, A. Mangeney, VY, F. Walter, J.-P. Montagner, O. Castelnau, E. Stutzmann, P. Bonnet, V.J.L. Ralaiarisoa, S. Bevan, A. Luckman. *Ann. Glaciol.* (2019)
[3] P. Bonnet, VY, P. Queutey, A. Leroyer, A. Mangeney, O. Castelnau, A. Sergeant, E. Stutzmann, J.-P. Montagner. *Geophys. J. Int.* (2020)
[4] A. Sergeant. *PhD Thesis* (2016)
[5] P. Bonnet. *PhD Thesis* (2021)

5. Construction of MorteX – a unifying and stable finite-element framework to deal with boundary unfitted tying, contact and wear (combination of the mortar method with the X-FEM)

with B.R. Akula (Transvalor) & J. Vignollet (Safran tech)

[1] B. Raju Akula, J. Vignollet, VY. Mortex for tying. *arXiv:1902.04003* (2019)
[2] B. Raju Akula, J. Vignollet, VY. MorteX for contact. *arXiv:1902.04000* (2019)
[3] B. Raju Akula, J. Vignollet, VY. MorteX for wear. *submitted* (2020)



Handling of frictional contact using the classical mortar method and the novel MorteX method using boundary unfitted contact surface.

Selected Contributions

Contact of Rough Surfaces

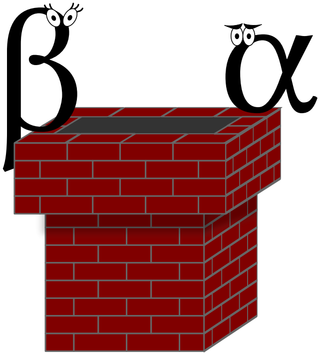
Parameter α and "magic" number β

- Nayak parameter[1]

$$\alpha = m_{00} m_{40} / m_{20}^2$$

with $m_{pq} = \iint\limits_{-\infty}^{\infty} k_x^p k_y^q \Phi(k_x, k_y)\, dk_x dk_y,$

Φ is the power spectral density of the roughness and k_x, k_y are wavenumbers



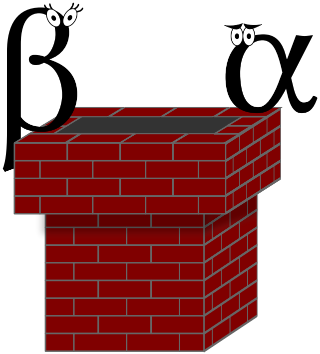
Nayak, P.R. 1971. Random process model of rough surfaces. J. Lubr. Technol. 93:398–407 .

Parameter α and "magic" number β

- Nayak parameter[1]

$$\alpha = \frac{4\langle z^2\rangle\langle(\nabla^2 z)^2\rangle}{\langle|\nabla z|^2\rangle^2}$$

i.e. for two surfaces with equivalent height $\langle z^2\rangle$ and gradient $\langle|\nabla z|^2\rangle$ variance, α is proportional to the variance of the surface curvature $\langle(\nabla^2 z)^2\rangle$.



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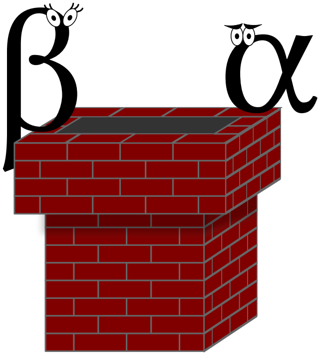
- Magic number

$$\beta = \frac{\pi - 1 + \ln 2}{6\pi} \approx 0.15038761899481015 1\ldots$$

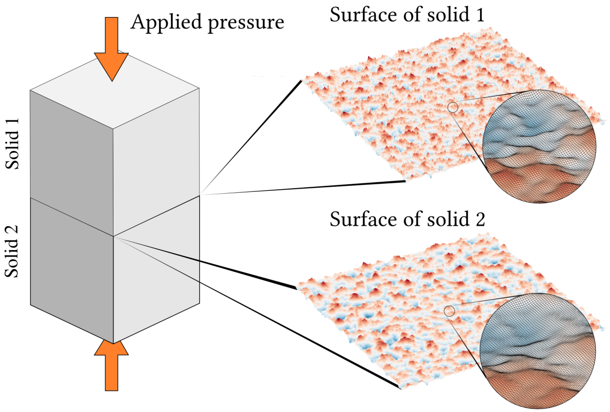


Nayak, P.R. 1971. Random process model of rough surfaces. J. Lubr. Technol. 93:398–407 .

Contact of rough surfaces

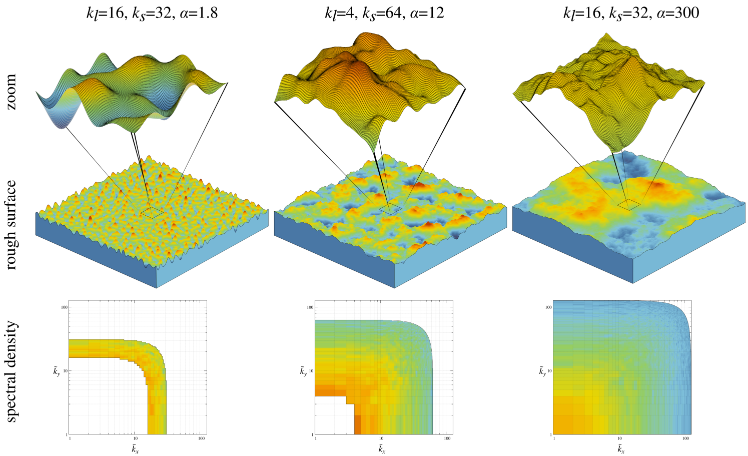
- All surfaces are rough
- When they are squeezed together they contact over a true contact area which is smaller than the nominal one
- The evolution of the true contact area controls the interface physics

Long history of research: Archard, Bowden, Tabor, Greenwood, Johnson... later Robbins, Molinari, Persson, Müser, Pastewka, Paggi, Ciavarella, and many others

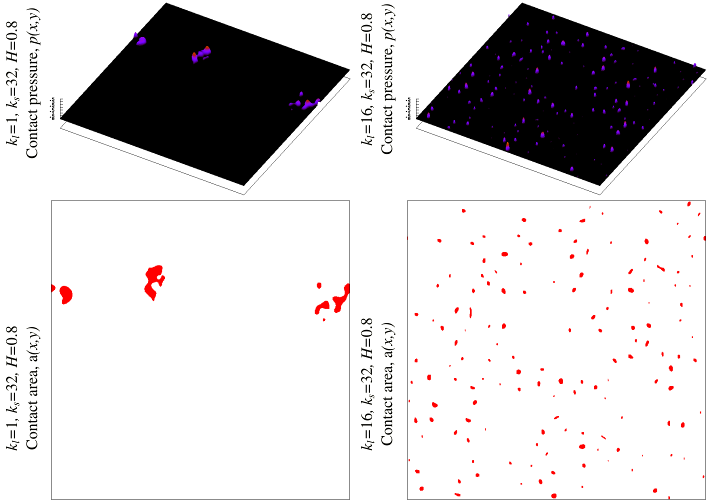


Statistically meaningful simulations

- Cut-off wavelengths in surface roughness: $\lambda_l/L = \{1, 4, 16\}$, $\lambda_s/L = \{32, 64, 128\}$
- Hurst exponent (sim. fractal dimension) $H = \{0.4, 0.8\}$
- Surface realizations $N = 50$
- Discretization $L \times L = 1024 \times 1024$



Contact area and contact pressure evolution



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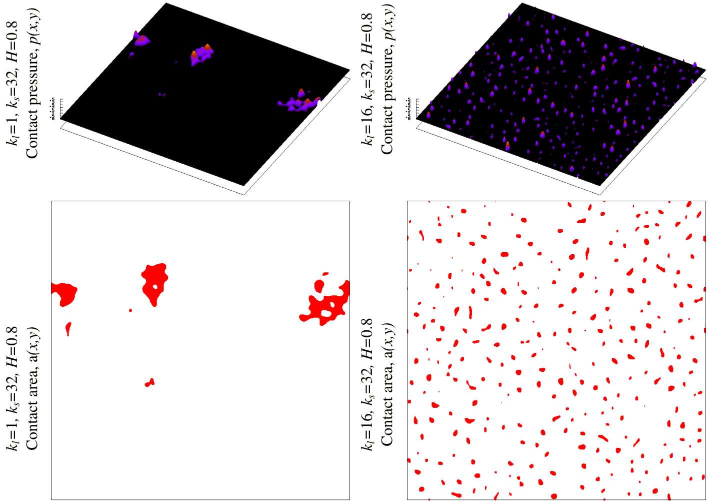

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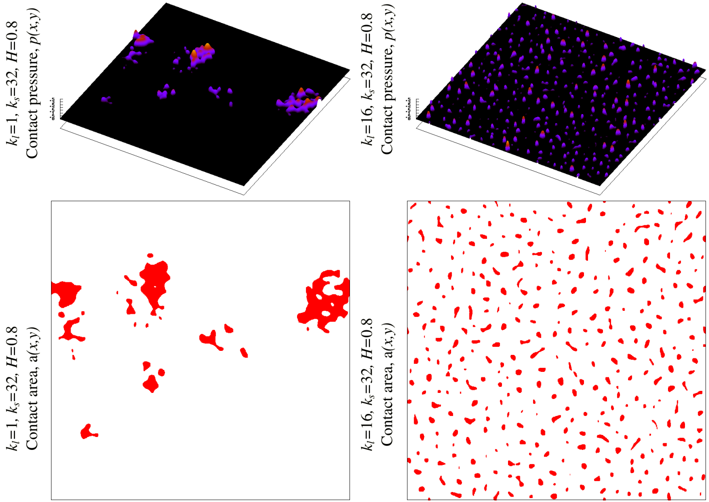

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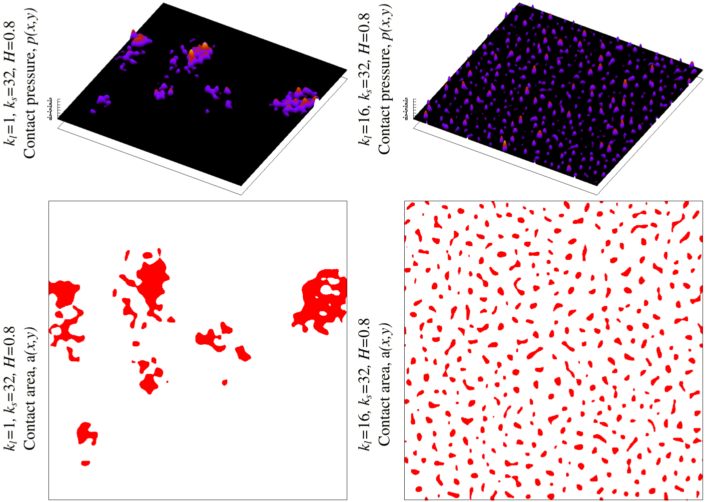

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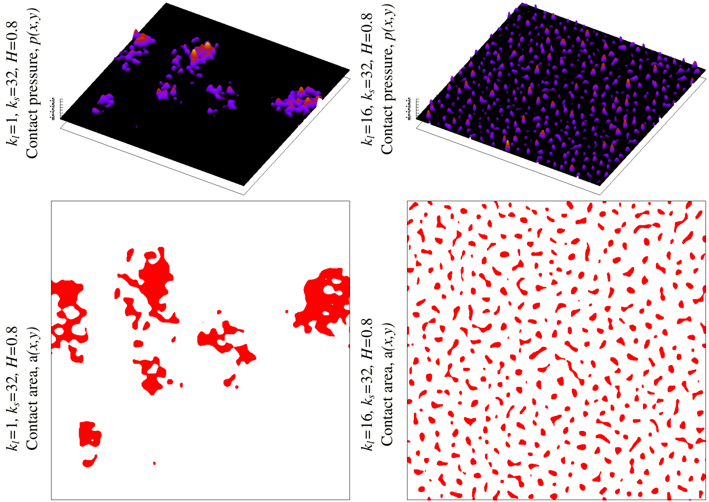

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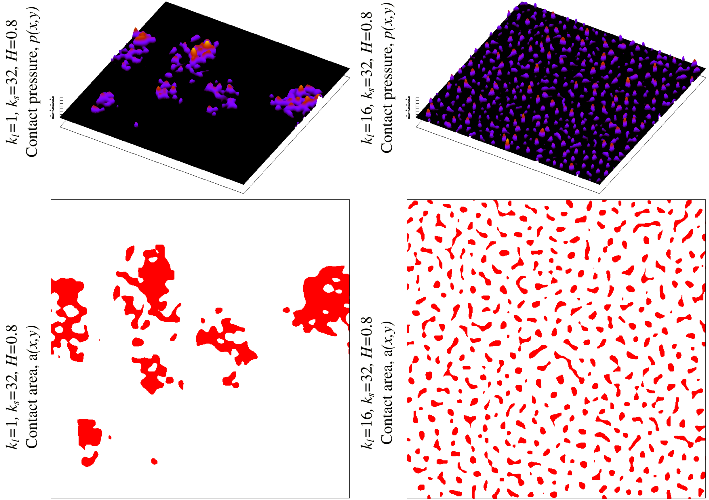

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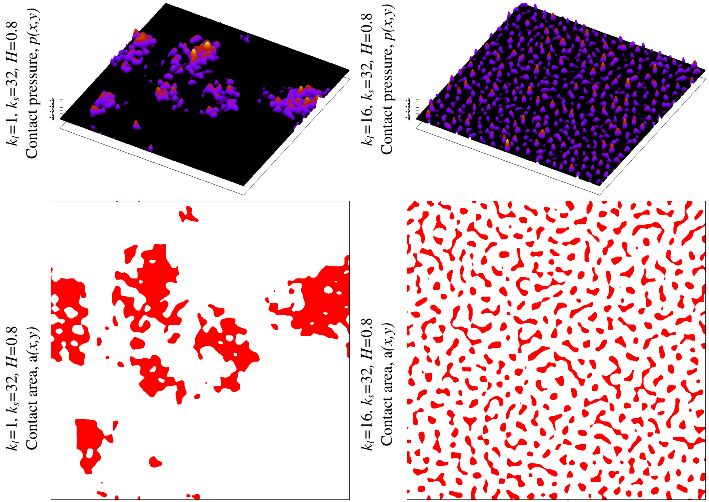

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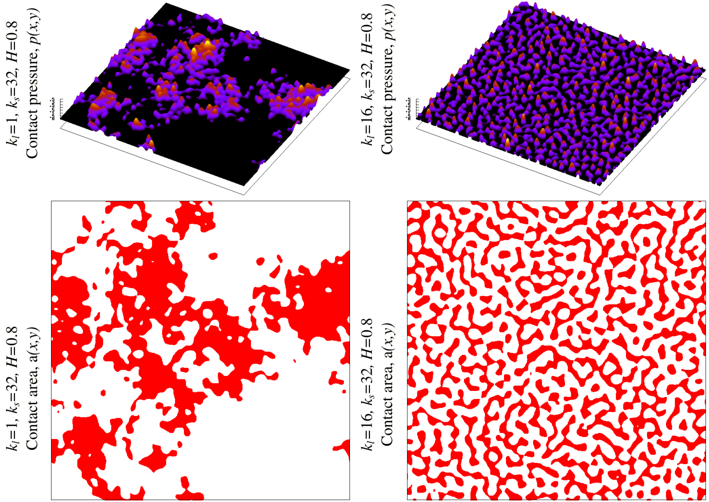

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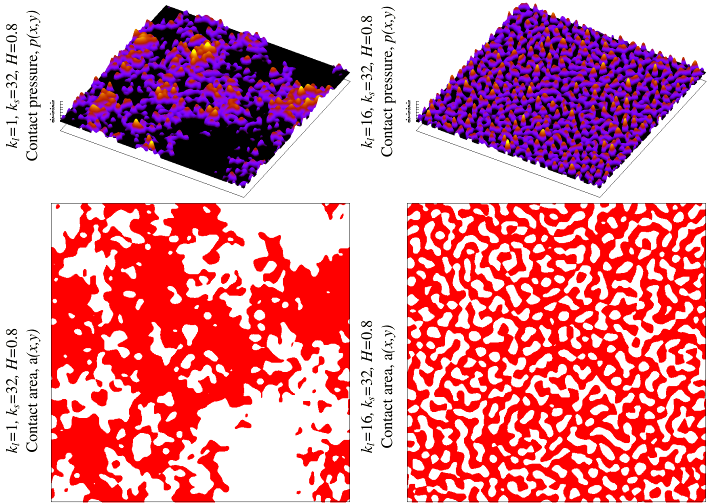
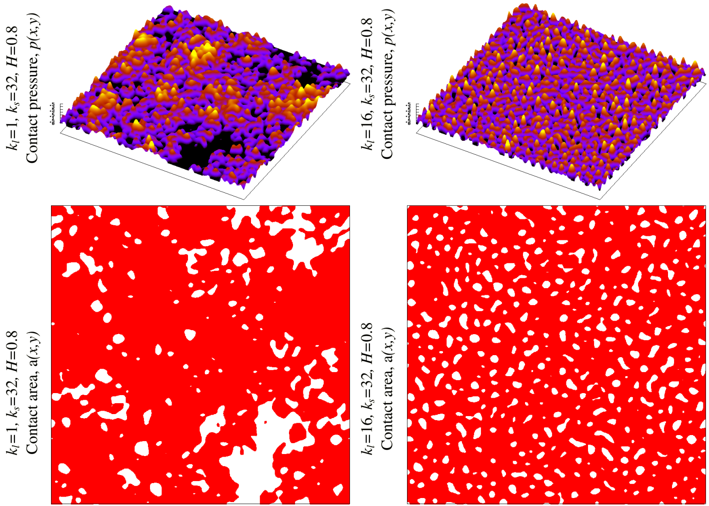
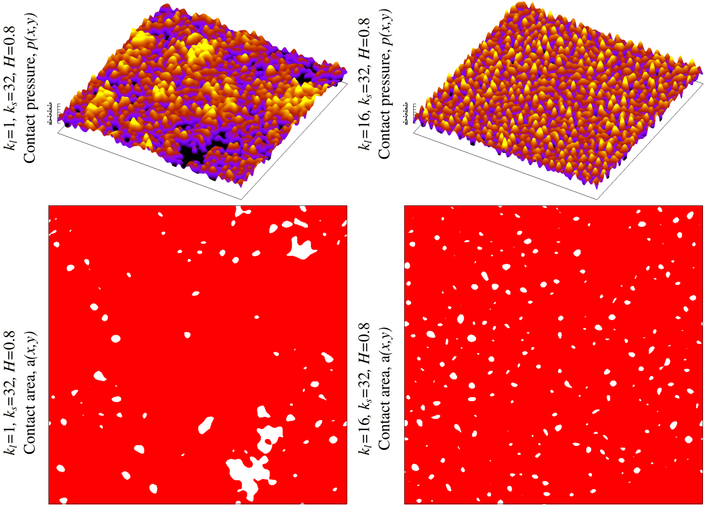
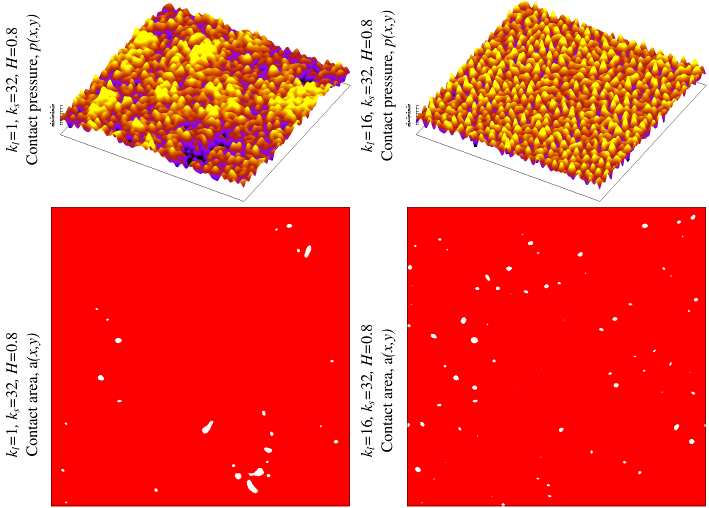




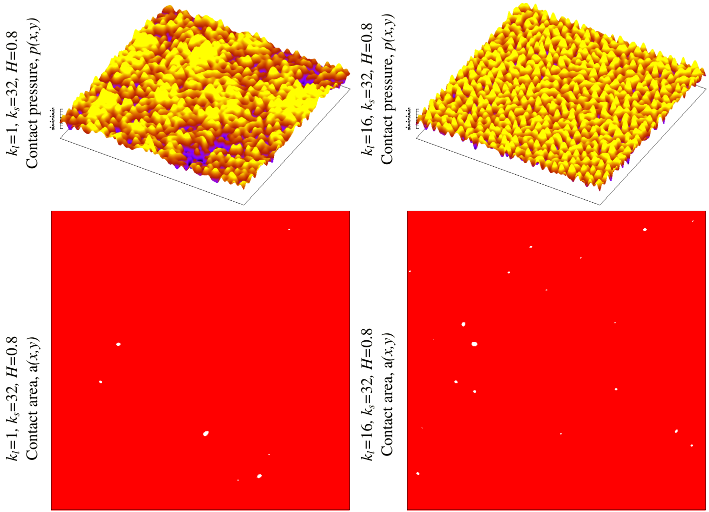
k_l=1, k_s=32, H=0.8
Contact pressure, $p(x,y)$
k_l=16, k_s=32, H=0.8
Contact pressure, $p(x,y)$
k_l=1, k_s=32, H=0.8
Contact area, $a(x,y)$
k_l=16, k_s=32, H=0.8
Contact area, $a(x,y)$

Contact area and contact pressure evolution

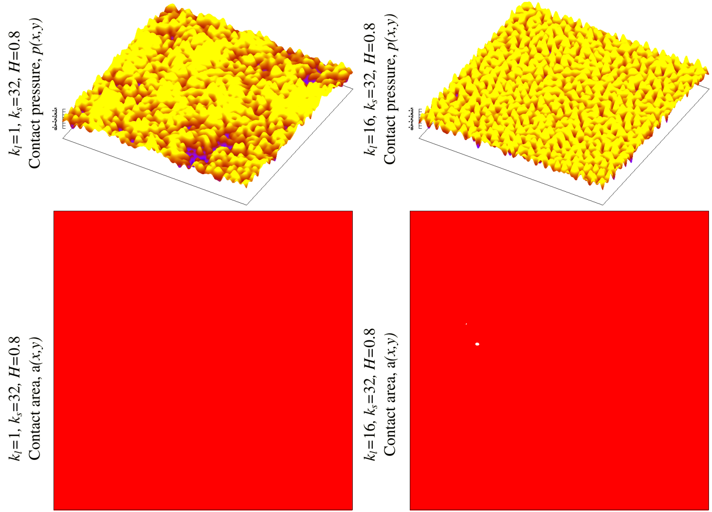



k_l=1, k_s=32, H=0.8
Contact pressure, $p(x,y)$
k_l=16, k_s=32, H=0.8
Contact pressure, $p(x,y)$
k_l=1, k_s=32, H=0.8
Contact area, a(x,y)
k_l=16, k_s=32, H=0.8
Contact area, a(x,y)

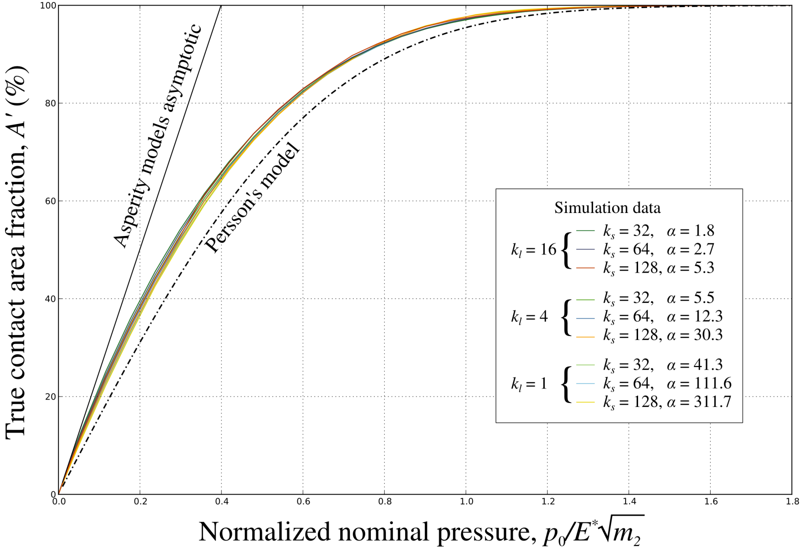
Contact area and contact pressure evolution



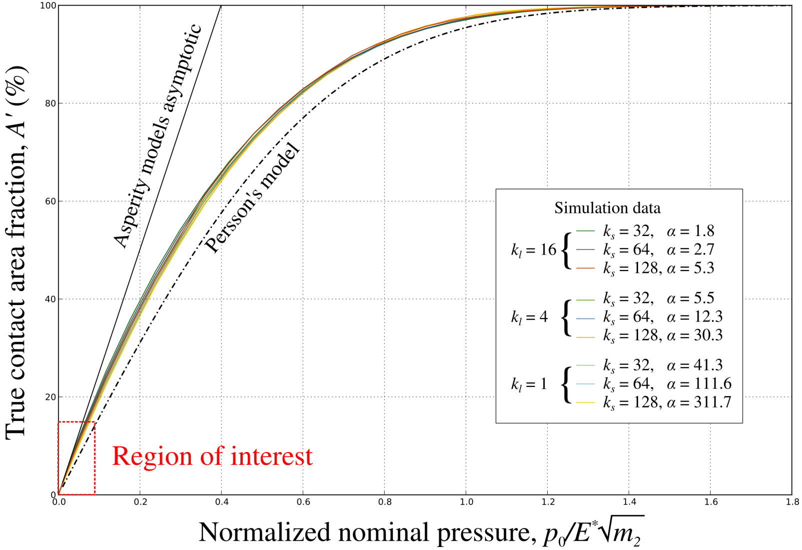
Contact area and contact pressure evolution



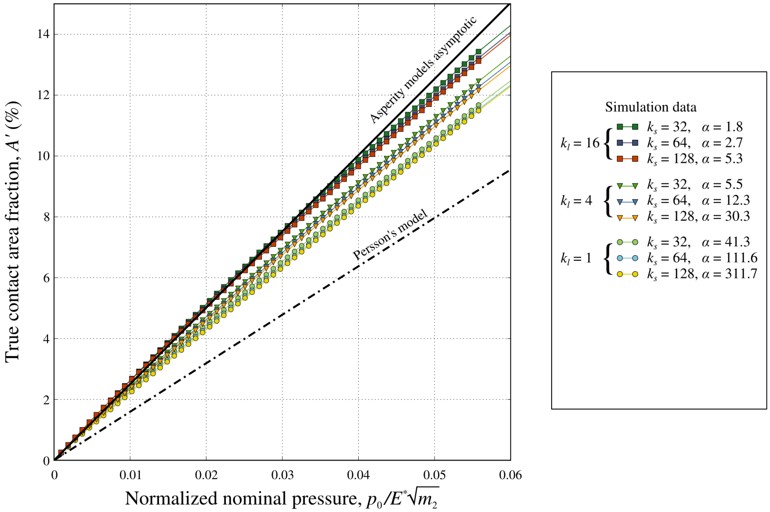
Real contact area evolution



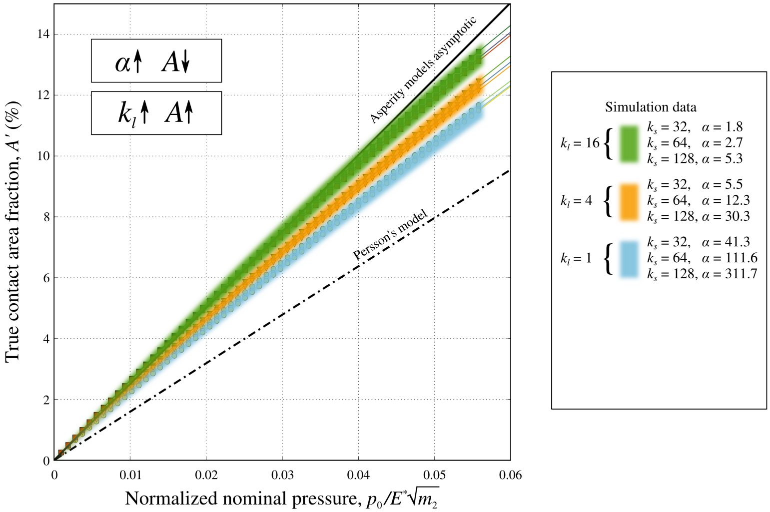
Real contact area evolution



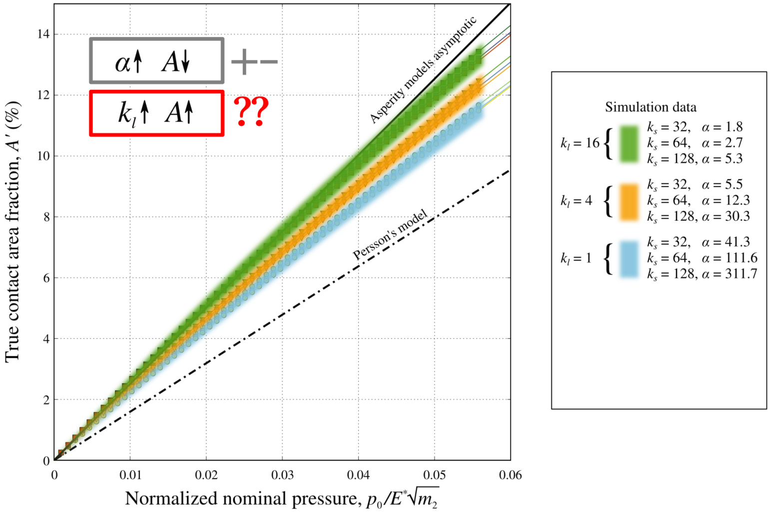
Real contact area evolution



Real contact area evolution

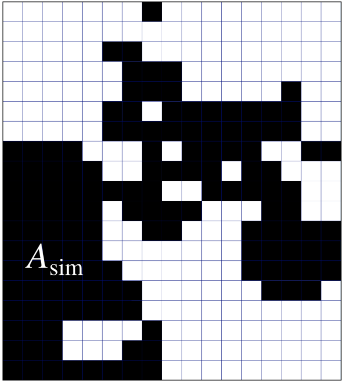


Real contact area evolution



- Contact area is overestimated in simulations:

  $A_{\text{sim}} > A_*$



Numerical error correction

- Contact area is overestimated in simulations:

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- The overestimation is localized at boundary nodes:

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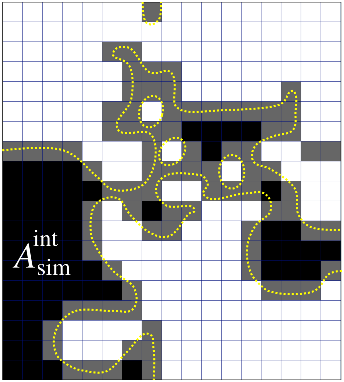

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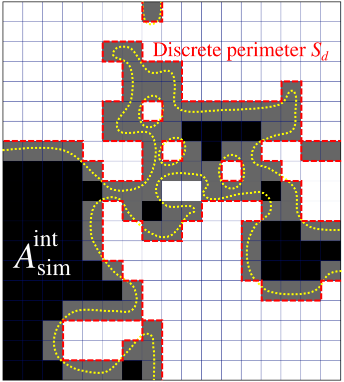

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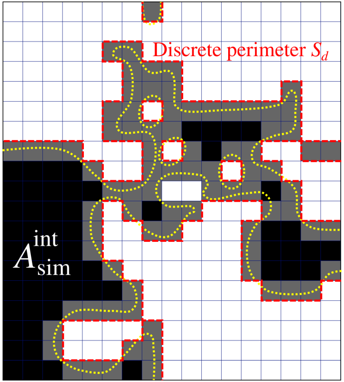

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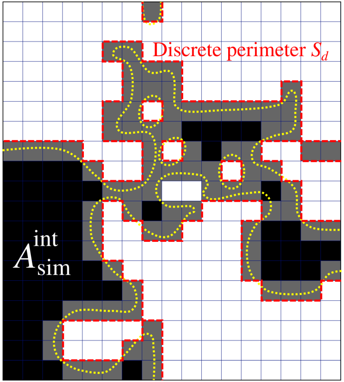
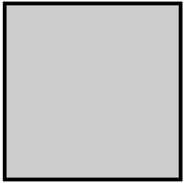
$$\boxed{A_* \approx A_{\text{sim}} - \beta \frac{\pi}{4} S_d \Delta x}$$



Numerical error correction: corrective factor



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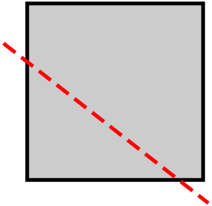

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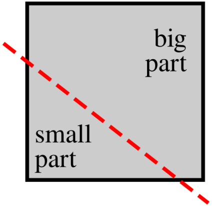

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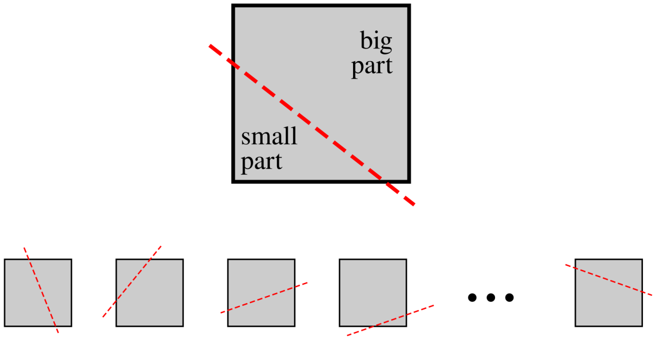

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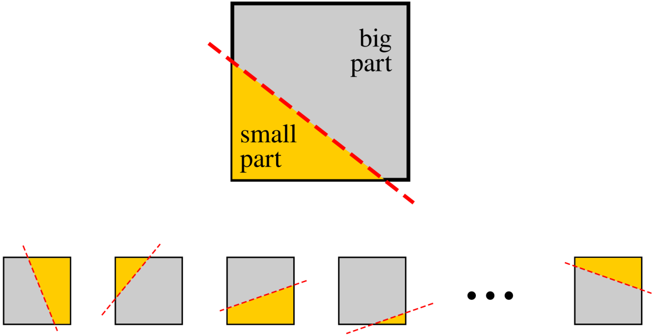

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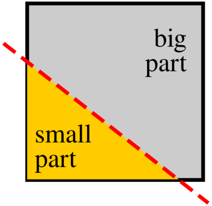
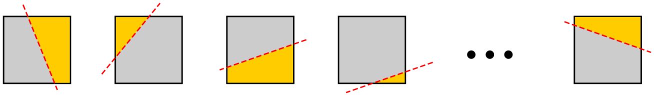
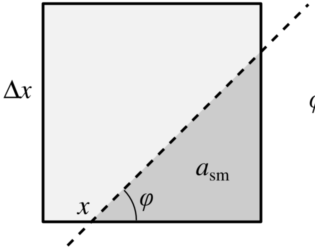
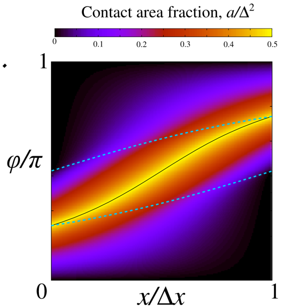




$$\left\langle \frac{\text{area of the small part}}{\text{area of the square}} \right\rangle = \frac{\pi - 1 + \ln 2}{6\pi}$$

Numerical error correction: corrective factor



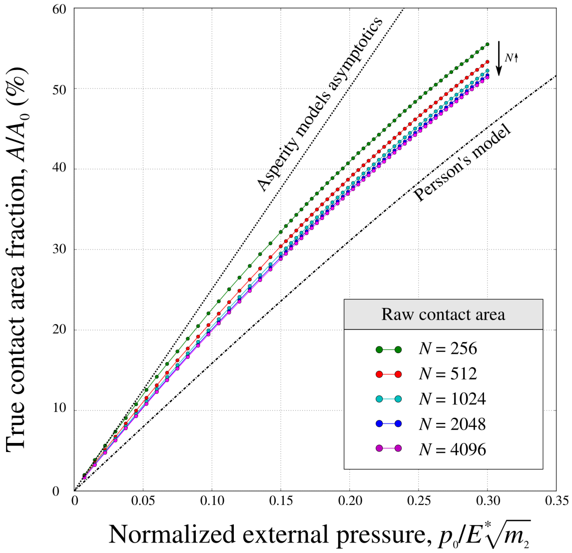


Corrective factor $\beta = \dfrac{\langle a_{\rm sm}\rangle}{\Delta x^2} = \dfrac{1}{\Delta x^2}\displaystyle\int\limits_0^h\int\limits_0^\pi a_{\rm sm} P(x,\varphi)\,dx d\varphi = \dfrac{\pi - 1 + \ln 2}{6\pi}$

$\beta = 0.150387618994810151606955\ldots$

True area estimation: $\boxed{A_* \approx A_{\rm sim} - \dfrac{\pi - 1 + \ln 2}{24} S_d \Delta x}$

Numerical error correction: convergence study



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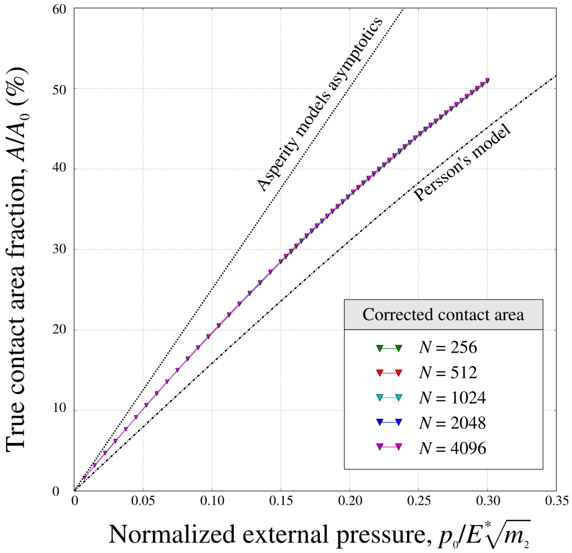
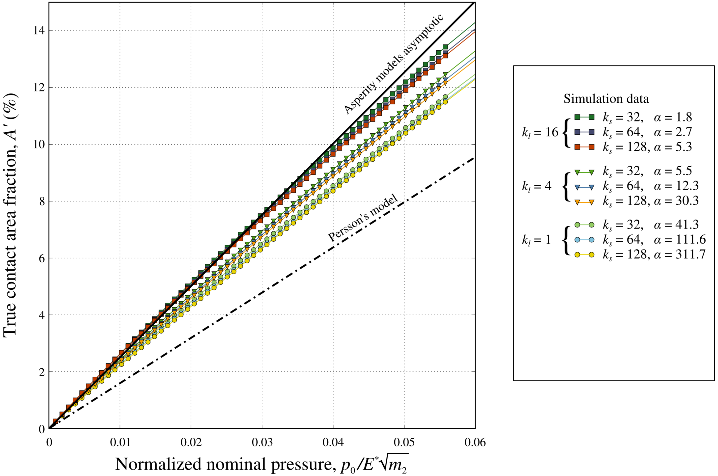


Real contact area: accurately computed



Raw data

VY, G. Anciaux, J.F. Molinari. IJSS (2015).

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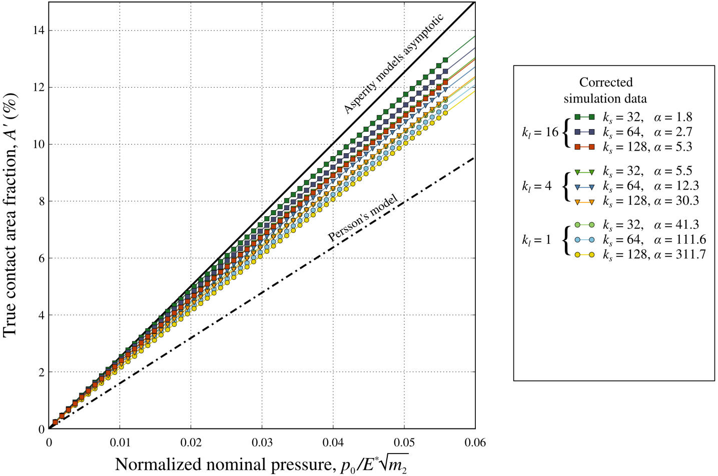

Corrected data

VY, G. Anciaux, J.F. Molinari. JMPS (2017).

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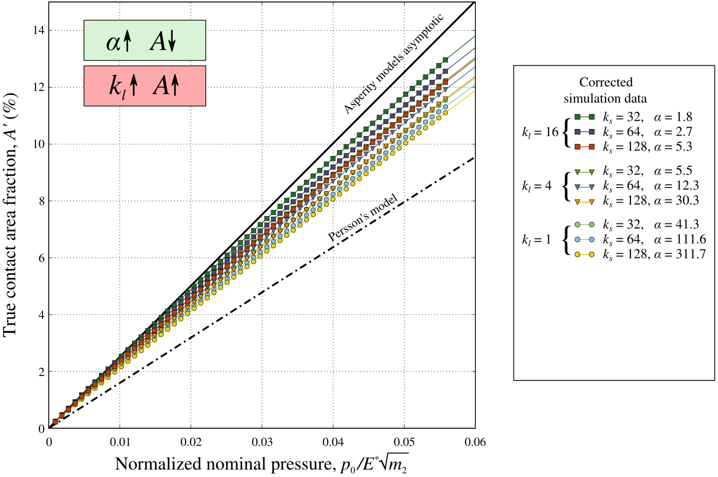

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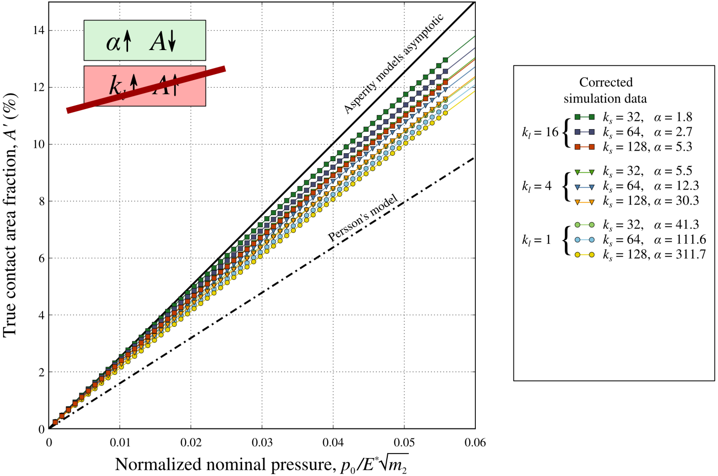

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Hurst or Nayak? H or α?

Contact area fraction $A'(p')$ growth with the normalized nominal pressure p' as a function of the Hurst exponent H and the Nayak parameter α:

$$A' = A'(p', H, \alpha)$$

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Subtility: $\alpha = \alpha(\zeta, H)$

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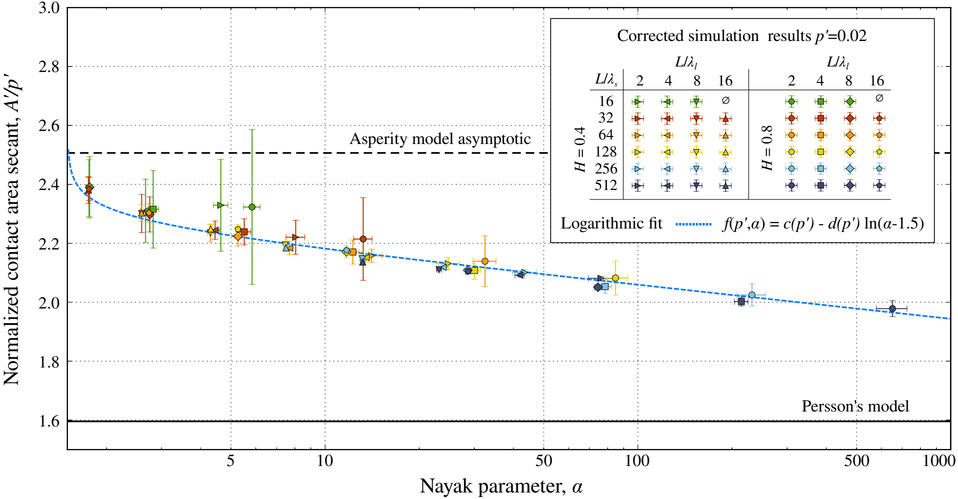

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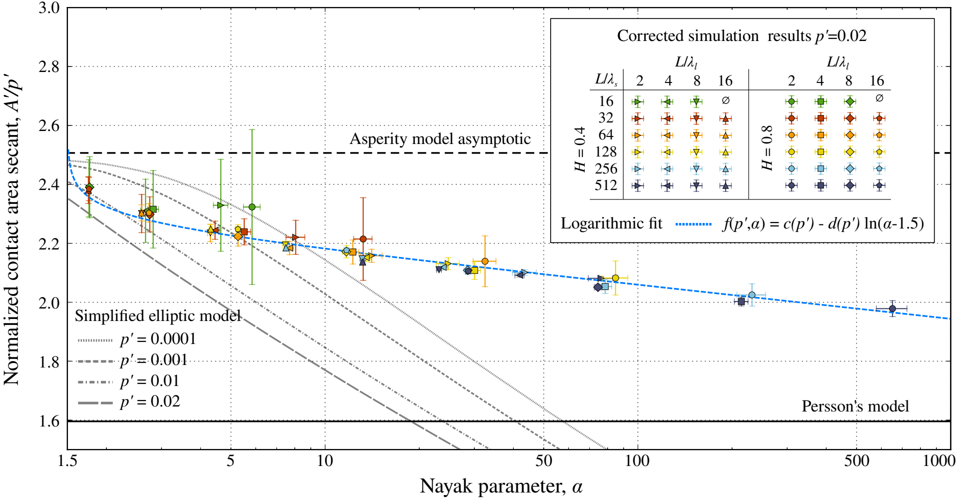

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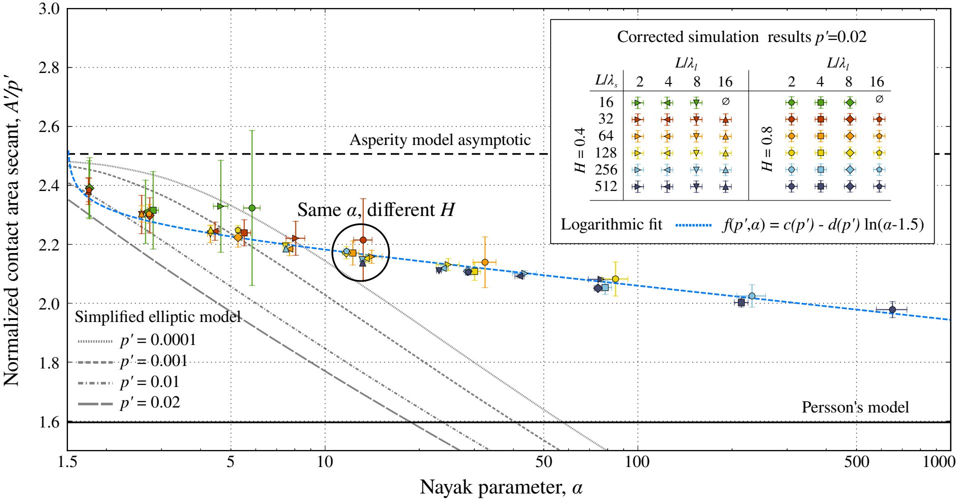

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Hurst or Nayak? H or α?

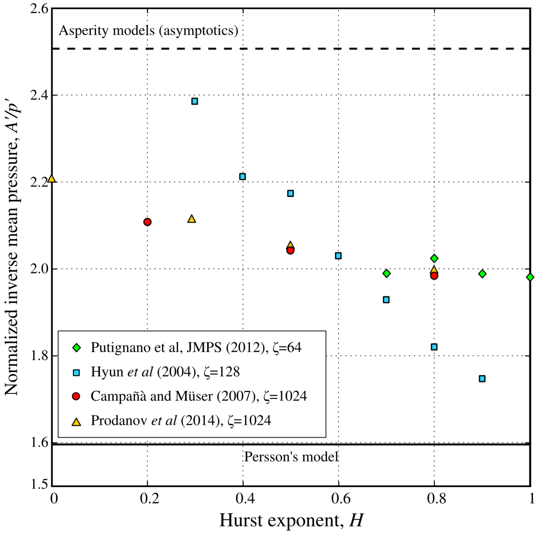
- In many study the focus was set on the Hurst exponent's effect

$$A' = A'(H)$$

- Nayak parameter α was completely forgotten
- Relation between α and H:

$$\alpha(H,\zeta) = \frac{3}{2}\frac{(1-H)^2}{H(H-2)}\frac{(\zeta^{-2H}-1)(\zeta^{4-2H}-1)}{(\zeta^{2-2H}-1)^2},$$

with $\zeta = \lambda_l/\lambda_s$ is magnification.



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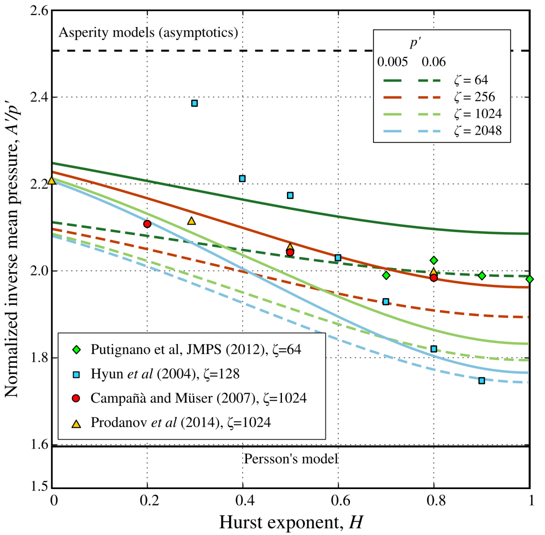
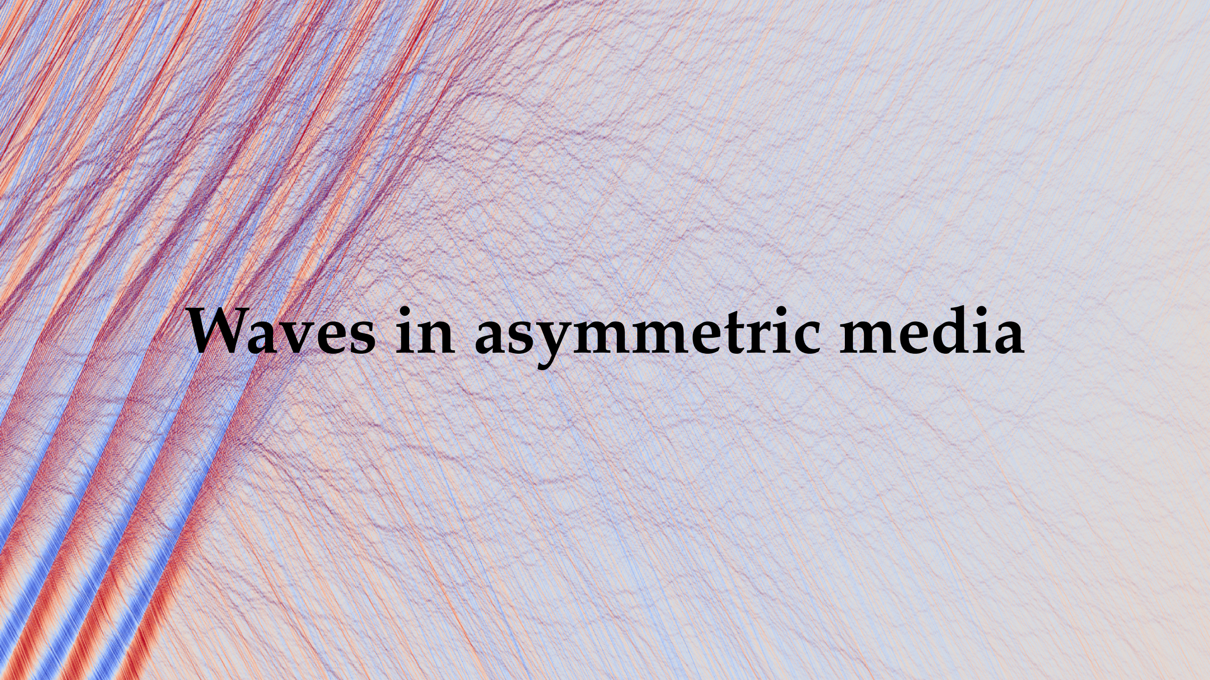


Conclusion

Contact area evolution does not depend on the Hurst exponent H but on the Nayak parameter α

Unfortunately, the Nayak parameter is a resolution-dependent characteristics of the roughness, contrary to the Hurst exponent which is resolution-independent one...



Waves in asymmetric media

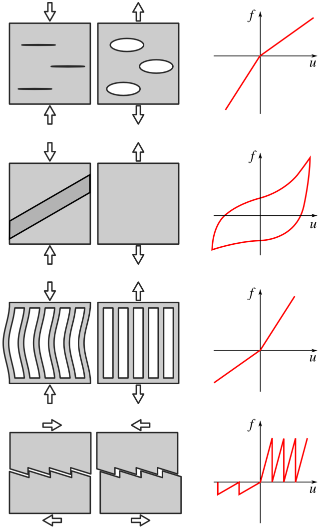
Asymmetry in materials

Sources of asymmetry[A,B]**:**

- Micro-fractures
  concrete/rocks
- Local buckling/wrinkling
  fiber networks, ropes, membranes
- Phase transformations/twinning
  Mg alloys, Ti alloys
- Pressure dependent plasticity
  concrete/rocks/soils
- Sliding asymmetry
  patterned surfaces
- ★ Contacts
  granular matter, granular crystals

[A] Ambartsumyan (1965), Izv Academ Nauk USSR Mech

[B] Gibson, Ashby (1987), Cellular Solids, Cambridge UP



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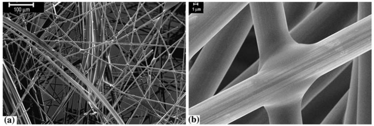

Fig. Carbon fiber network

[1] Mezeix, Bouvet, Huez, Poquillon (2009). J Mater Sci 44

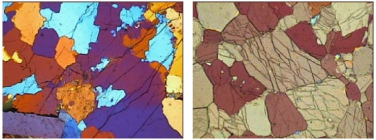

Fig. Microcracks in rocks (dolomite, granite)

[2] Obara (2007). Comput & Geosci 33
[3] Obara, Kozusnikova (2007). Computat Geosci 11

Fig. Torsional instability in multi-strand wires (ropes)

[4] www.industrialrope.com

Contact-based architectured material

- Contact as a functional element

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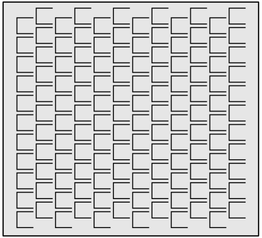
- Contact as a functional element
- Stiff in compression / soft in tension



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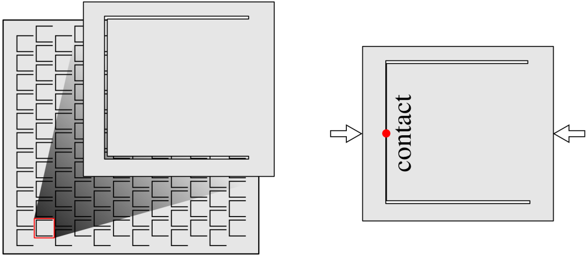

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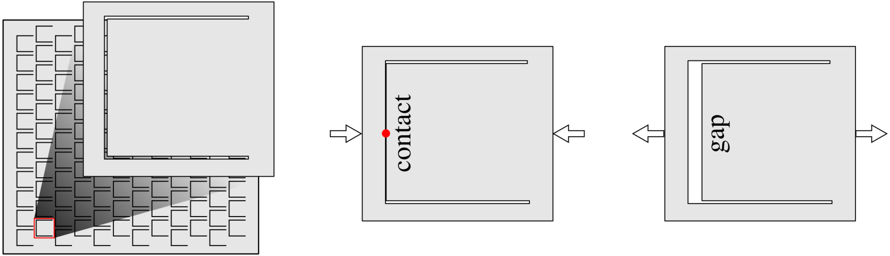

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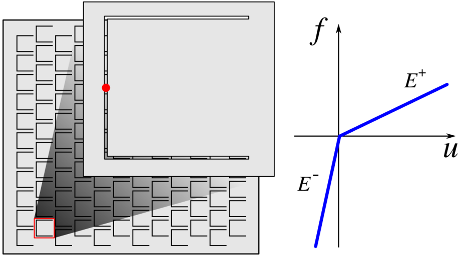

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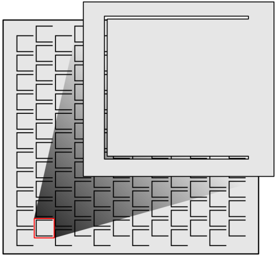

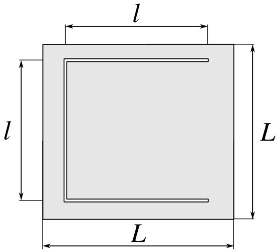

$$E^{+}/E^{-} \approx 1 - l/L$$

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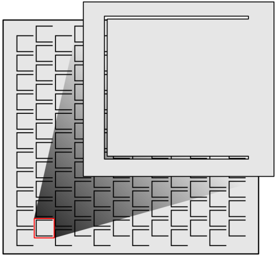
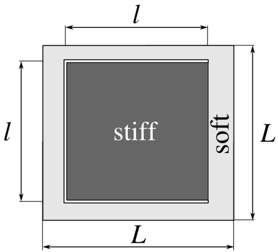
- Use different materials





$$E^+/E^- \approx (1 - l/L)\, E^{\text{soft}}/E^{\text{stiff}}$$

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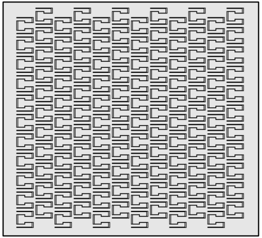
- Soft in compression/stiff in tension



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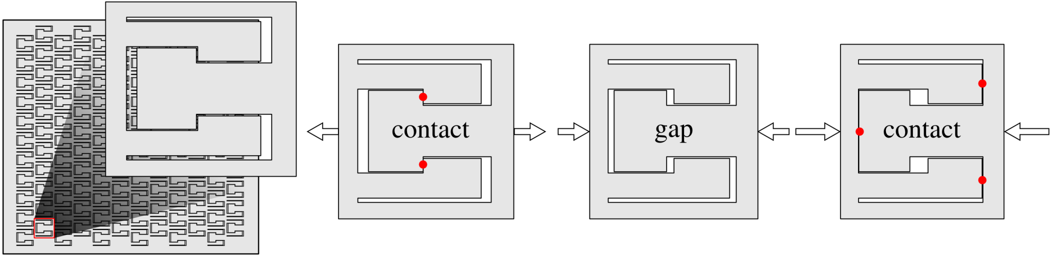

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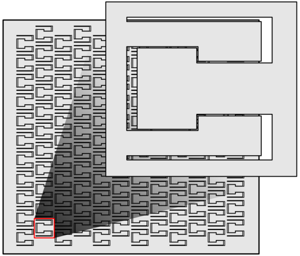

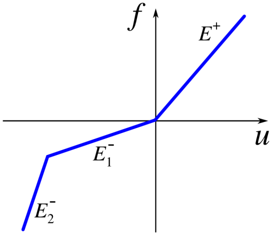

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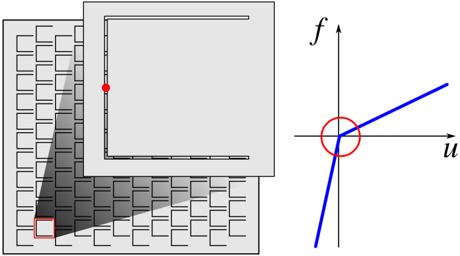

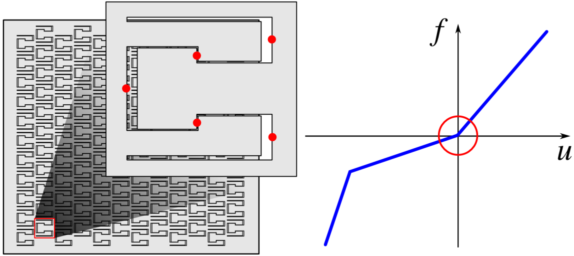

Contact-based architectured material

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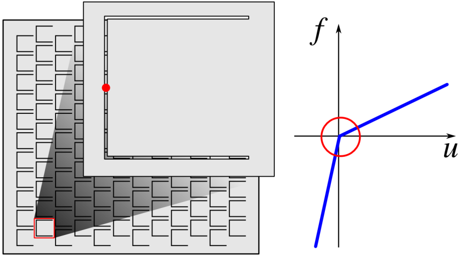
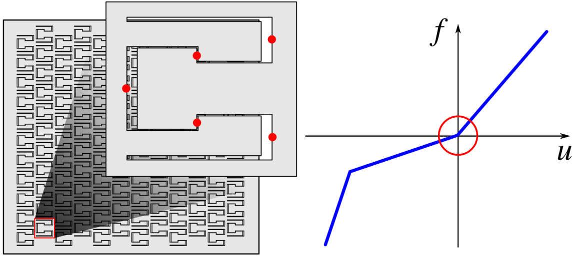
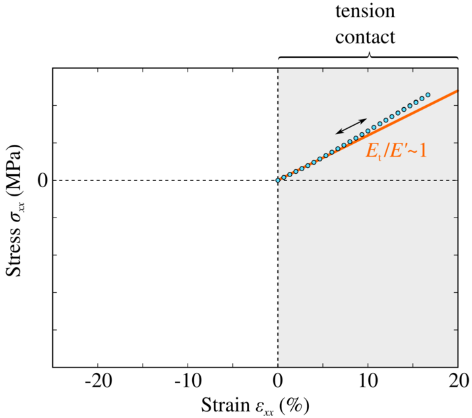
- Soft in compression/stiff in tension
- Extendable to 3D

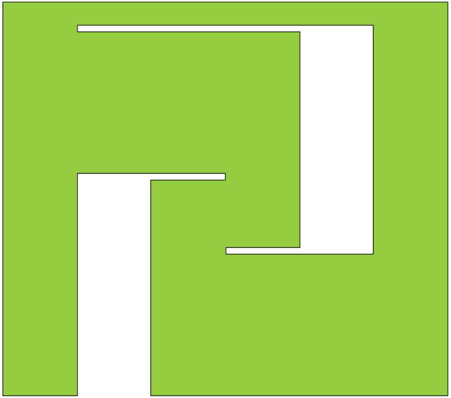




Stiff-in-tension / soft-in-compression: example

- Tension/compression test (FE simulation)





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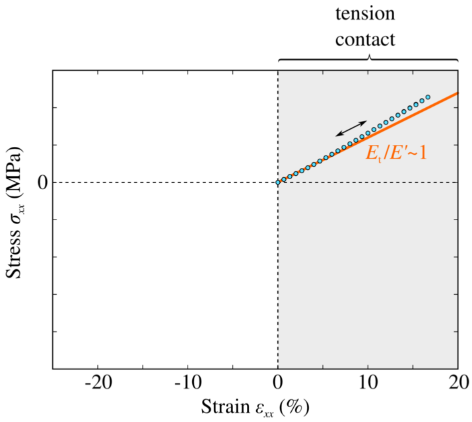

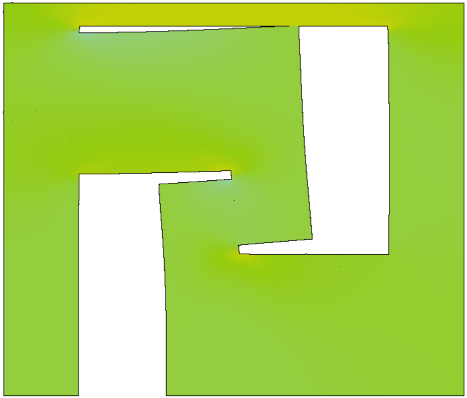

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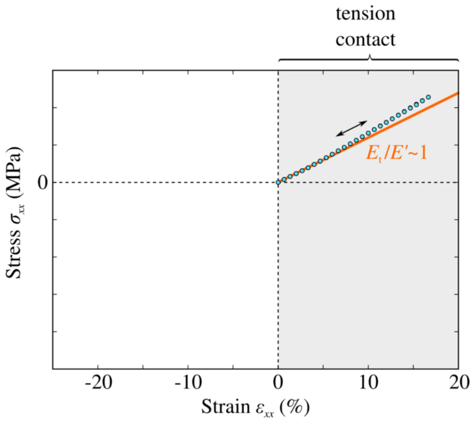

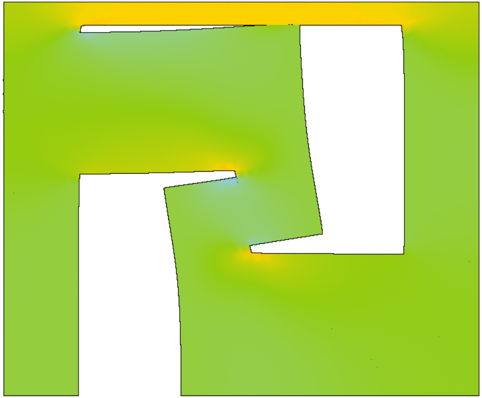

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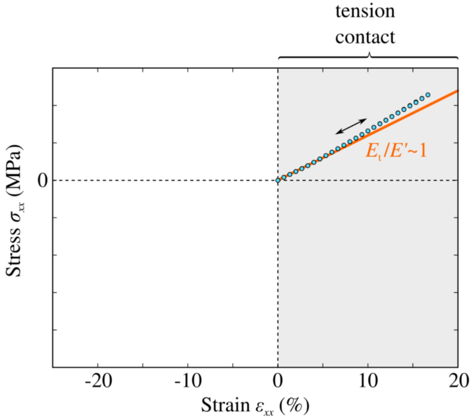

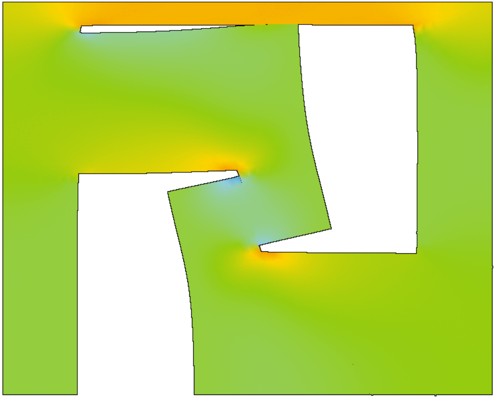

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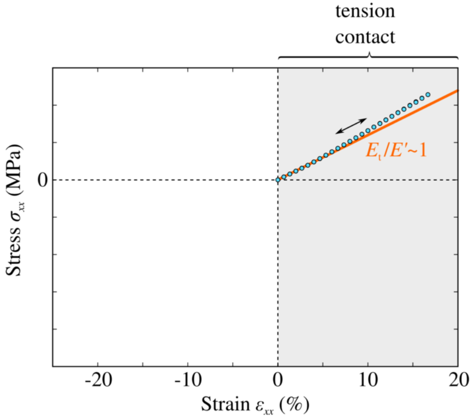

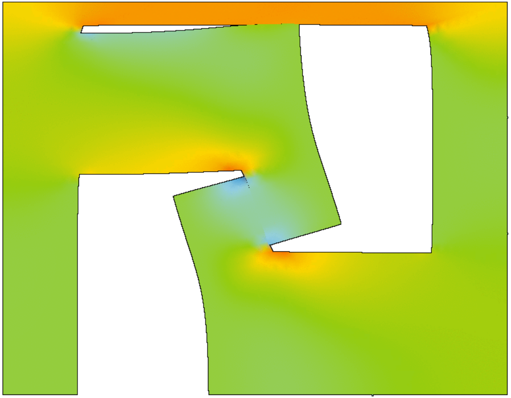

Stiff-in-tension / soft-in-compression: example

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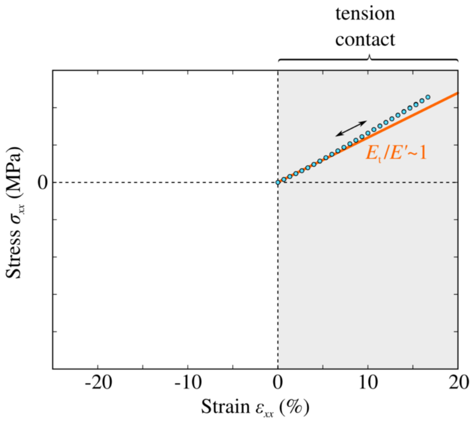

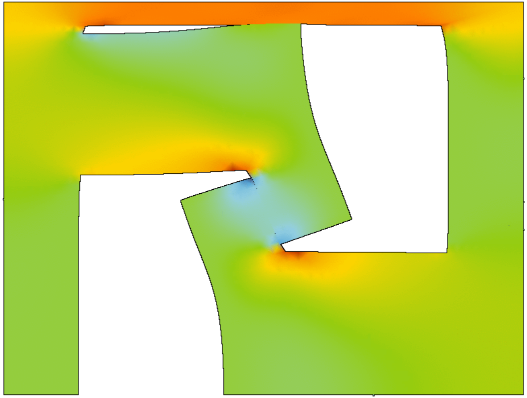

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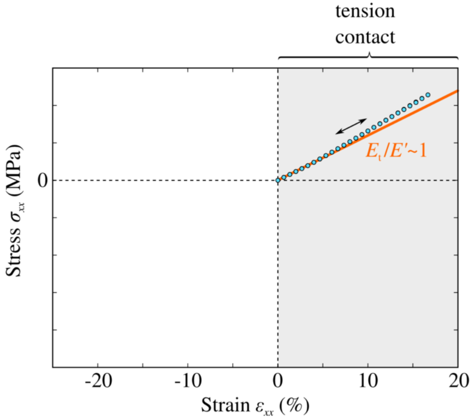

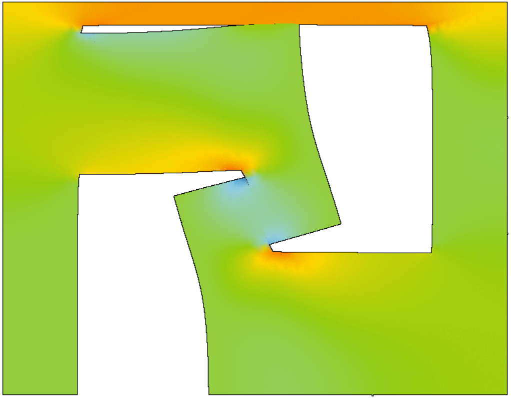

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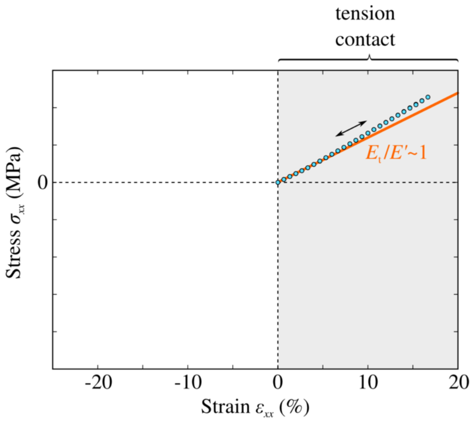

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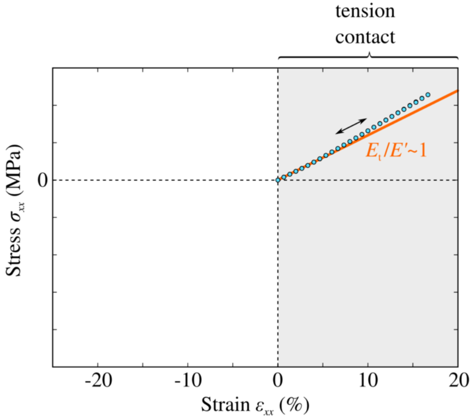

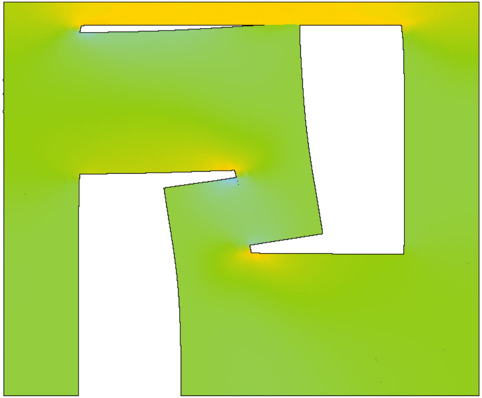

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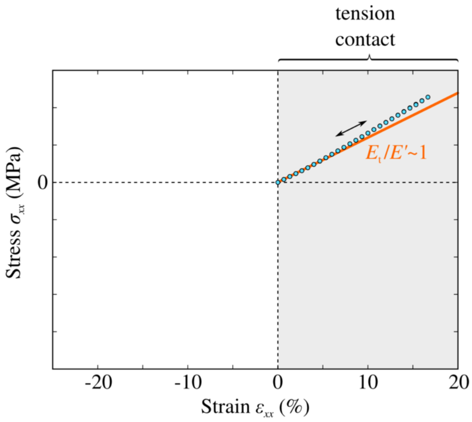

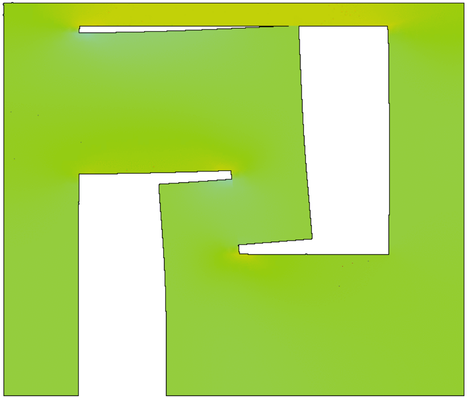

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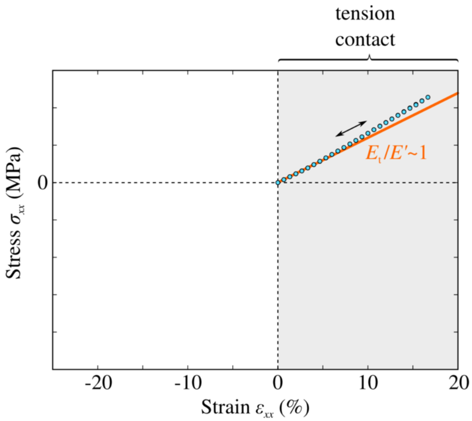

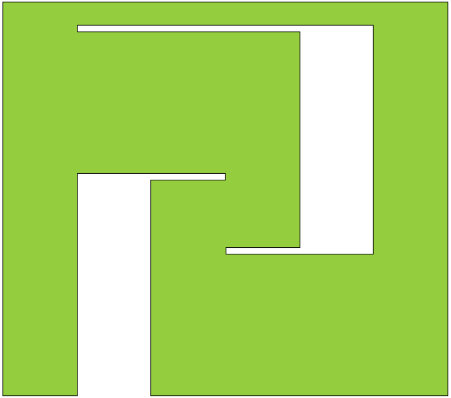

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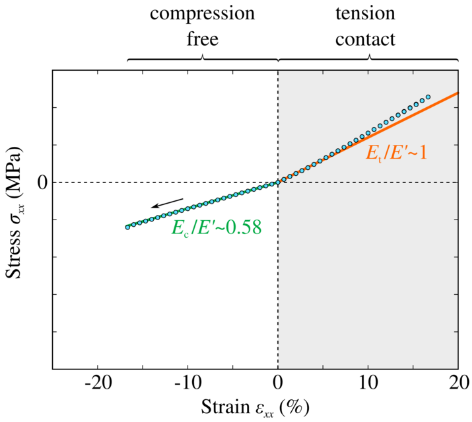

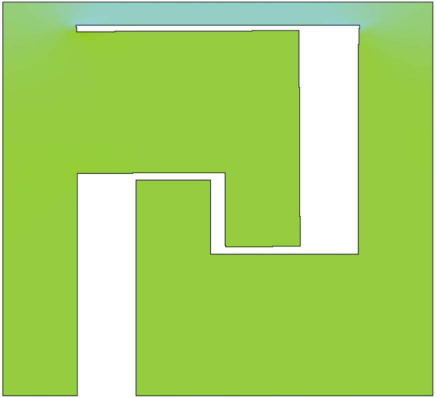

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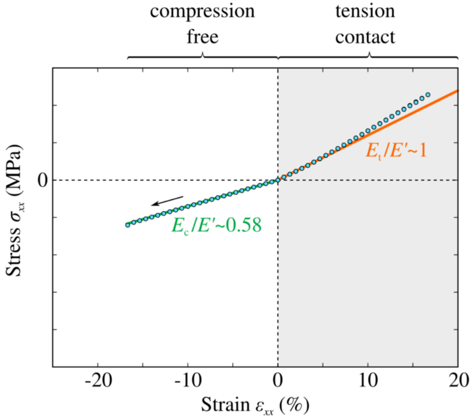

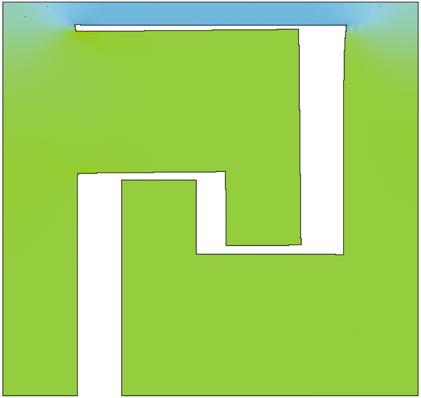

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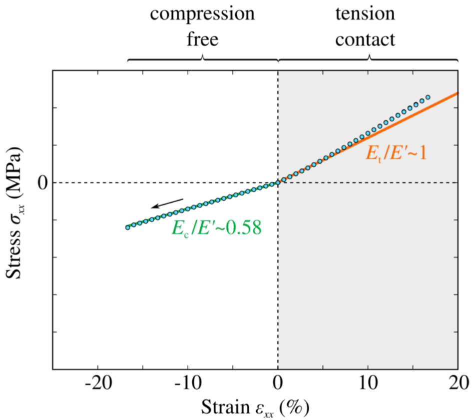

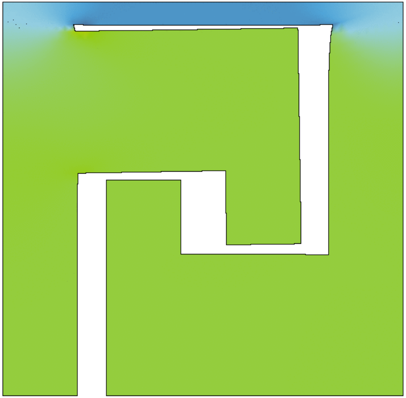

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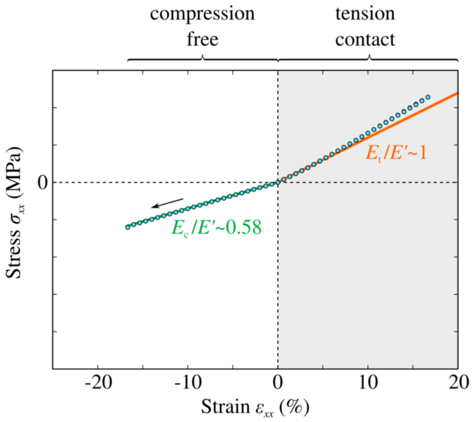

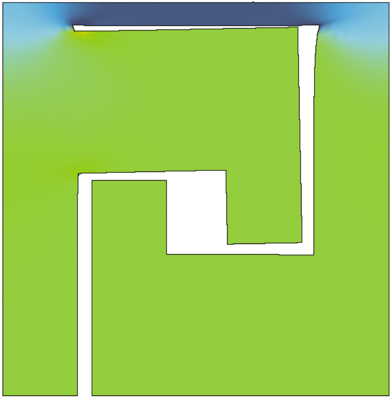

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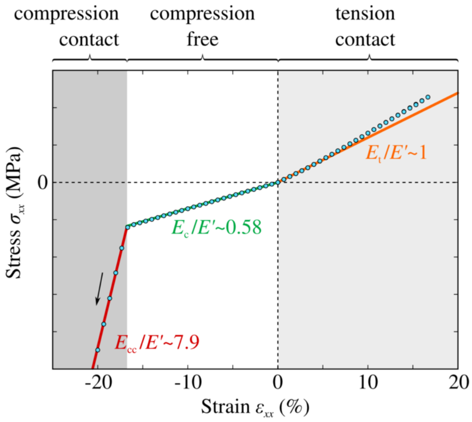

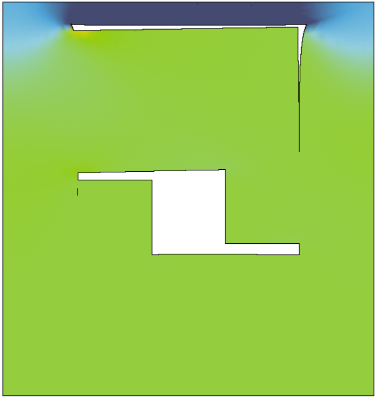

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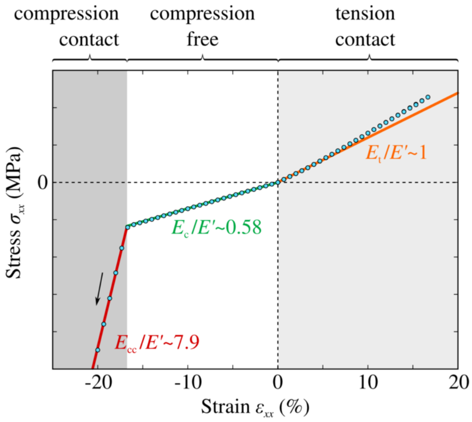

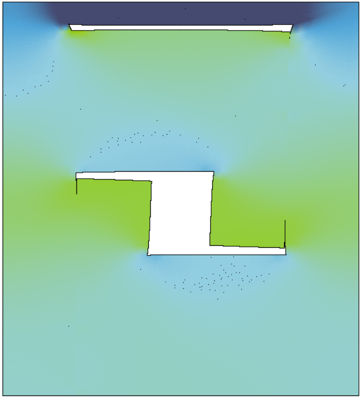

Stiff-in-tension / soft-in-compression: example

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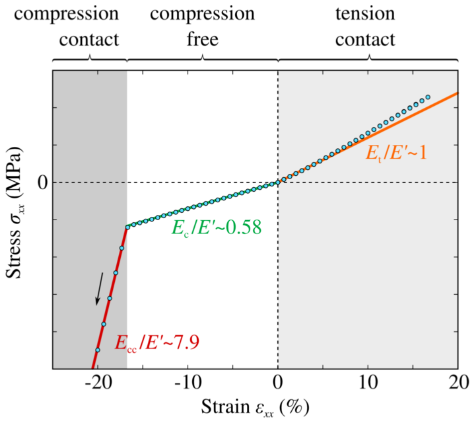

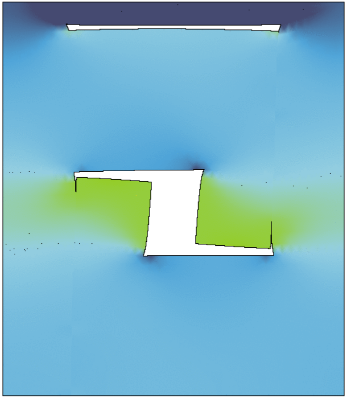

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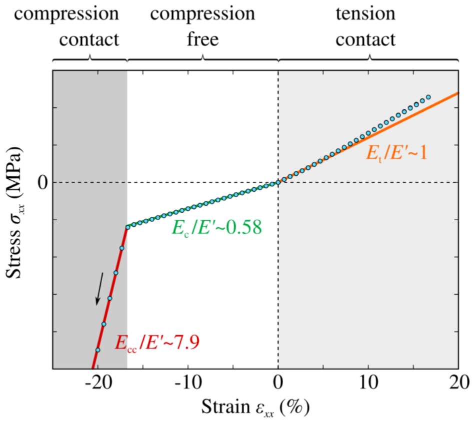

Governing equation for asymmetric materials

- Quastistatic 1D behavior:

$$\sigma = E(\nabla u + \alpha|\nabla u|) = \begin{cases} (1+\alpha)E\nabla u, & \text{if } \nabla u > 0, \text{ tension} \\ (1-\alpha)E\nabla u, & \text{if } \nabla u \le 0, \text{ compres.} \end{cases}, \quad -1 < \alpha < 1$$

- Elastic contrast γ:

$$\frac{E^+}{E^-} = \frac{1+\alpha}{1-\alpha} = \gamma$$

- Elastodynamic equation in 1D (the simplest approximation):

$$\rho\ddot u = E\nabla\left(\nabla u + \alpha|\nabla u|\right) + \underbrace{\mu\Delta\dot u}_{\text{damping}}$$

- Wave speed c:

$$c = \begin{cases} \sqrt{(1+\alpha)E/\rho}, & \text{if } \nabla u > 0, \text{ tension} \\ \sqrt{(1-\alpha)E/\rho}, & \text{if } \nabla u \le 0, \text{ compres.} \end{cases}, \quad \frac{c^+}{c^-} = \sqrt{\frac{1+\alpha}{1-\alpha}} = \sqrt{\gamma}$$

System set-up

- One dimensional wave propagation
- Single oscillation: $F \approx \sin(\omega_0 t) = \sin(2\pi c_0 t/\lambda_0)$
- Scale separation $\lambda_0 \gg l$, where l is the characteristic element size

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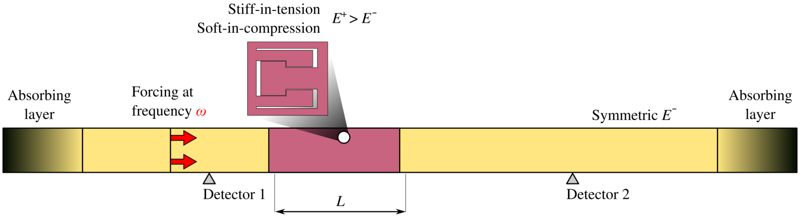

Configuration 1

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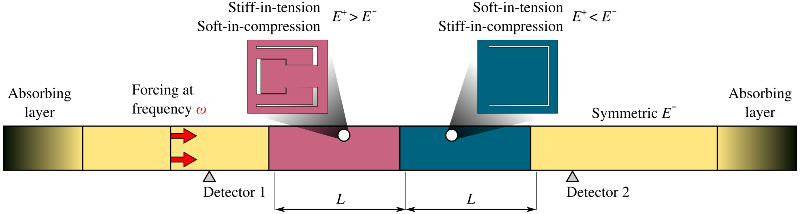

Configuration 2

System set-up

- One dimensional wave propagation
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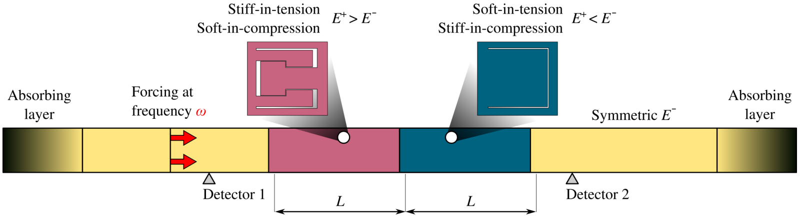
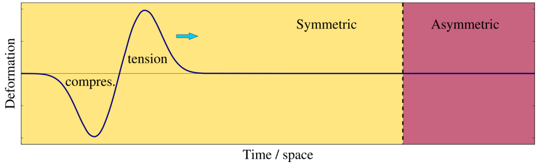
- Scale separation $\lambda_0 \gg l$, where l is the characteristic element size



Configuration 2



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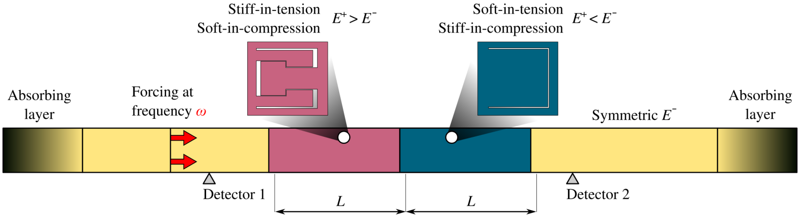
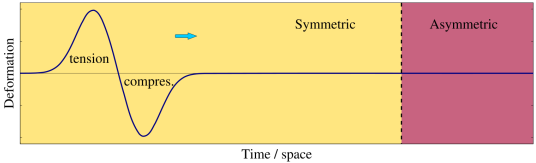


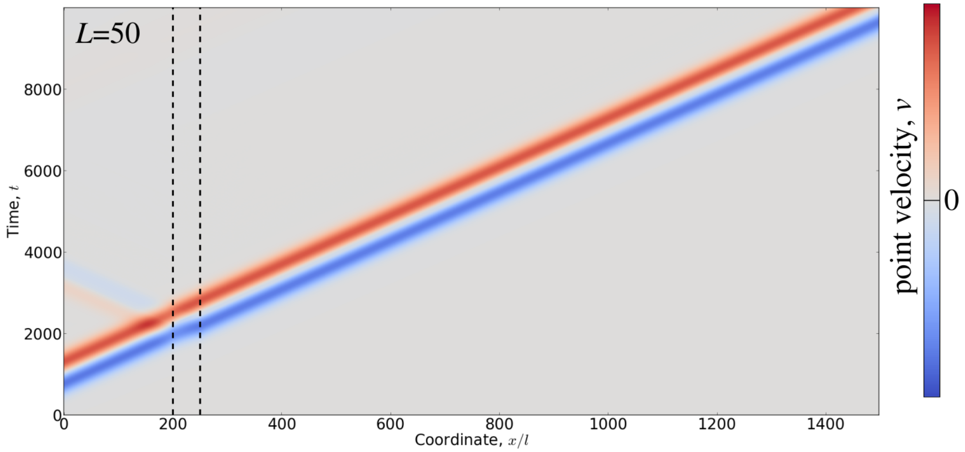
Configuration 2



Effect of the length of the asymmetric section

Separation of wave-components

tensile (faster) part preceeds compressive one



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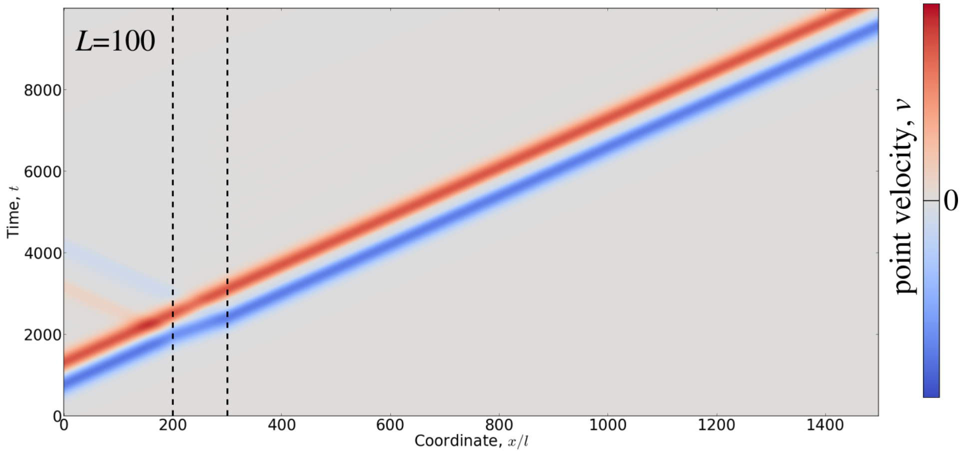

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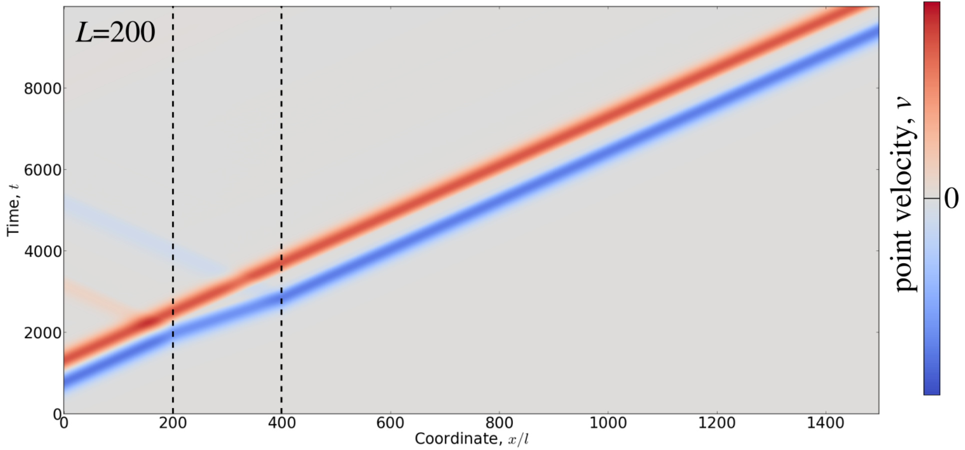

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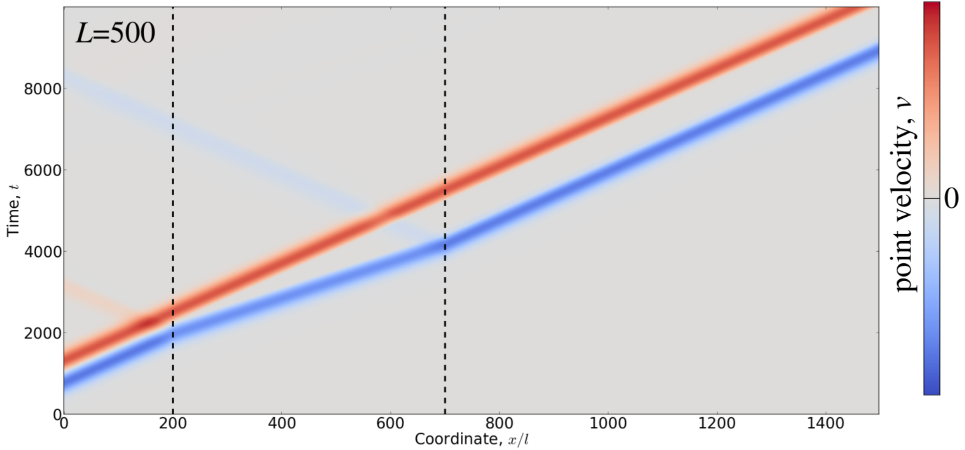

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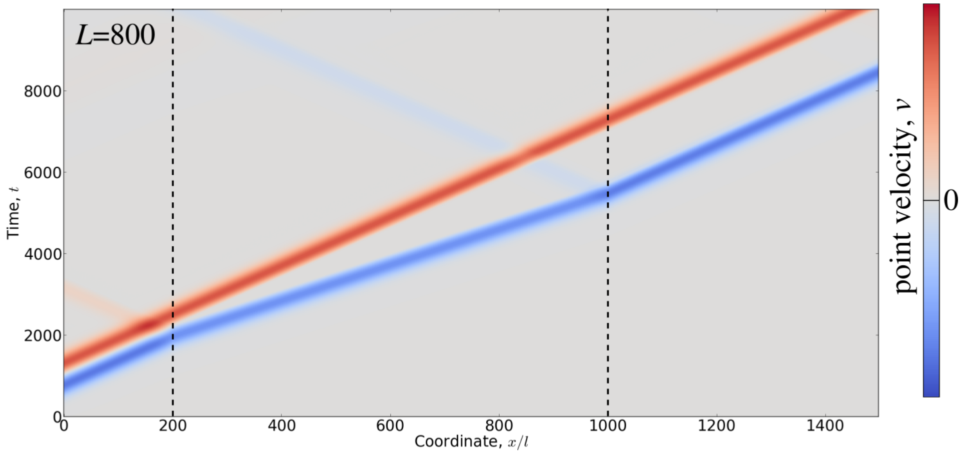

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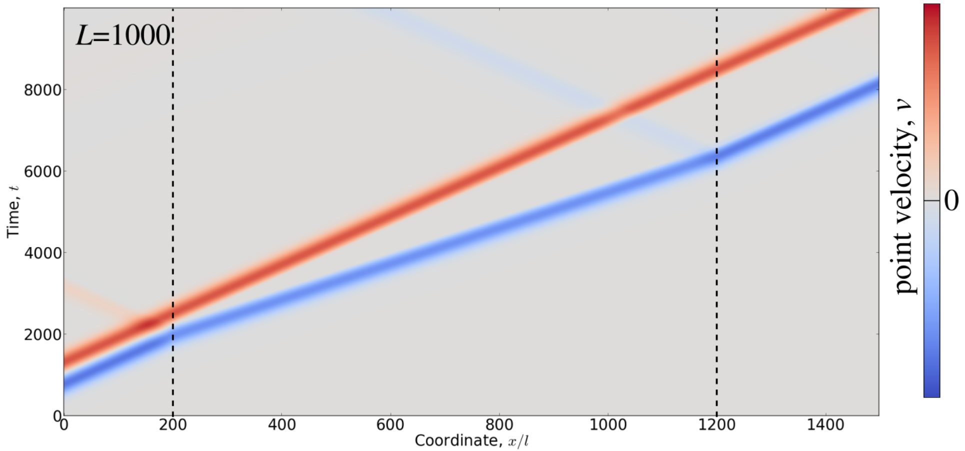

Overlap of wave-components

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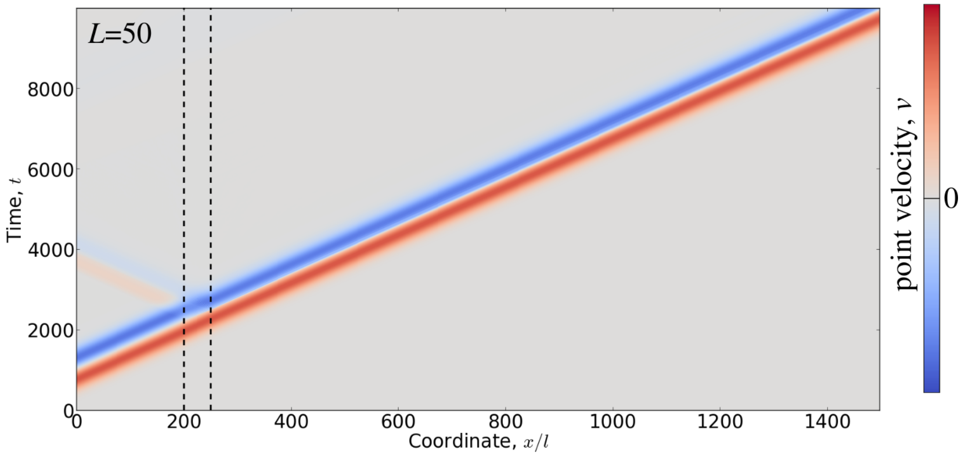

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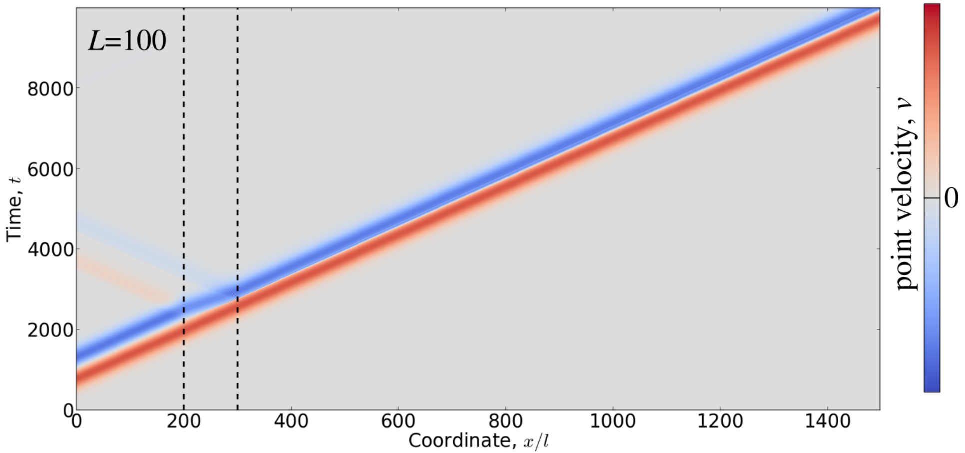

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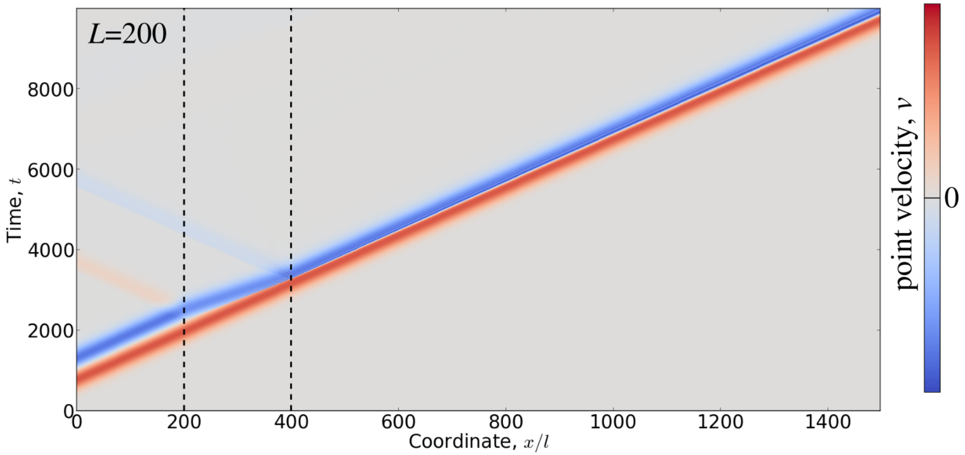

Overlap of wave-components
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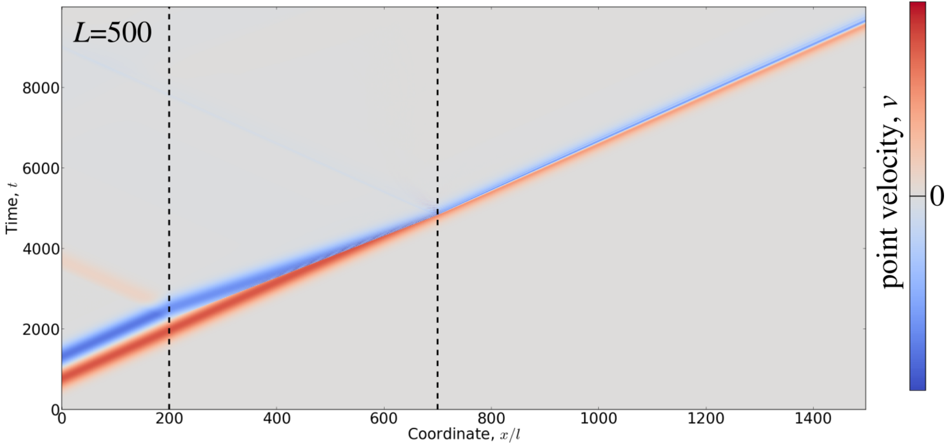

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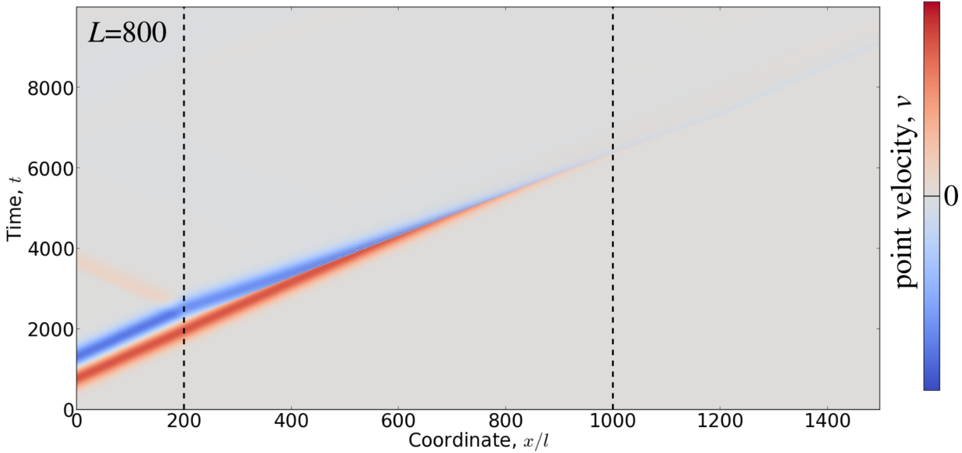

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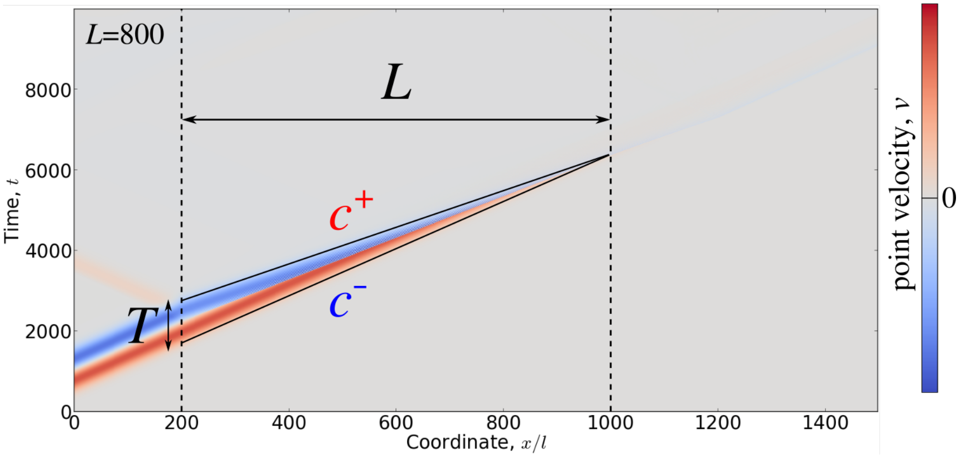


Overlap of wave-components

- To let + and - waves fully overlap

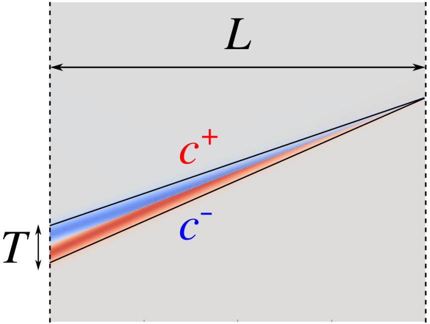
$$T \le \frac{L}{c_l^-} - \frac{L}{c_l^+}$$

- Since $T = 2\pi/\omega_0$, $c^+ = \sqrt{(1+\alpha)E/\rho}$
- Then the full overlap occurs at length L_o

$$L_o \ge \frac{2\pi c^+}{\omega_0\left[\frac{c^+}{c^-} - 1\right]} \Rightarrow \boxed{L_o \ge \frac{2\pi c^+}{\omega_0\left(\sqrt{\gamma} - 1\right)}}$$

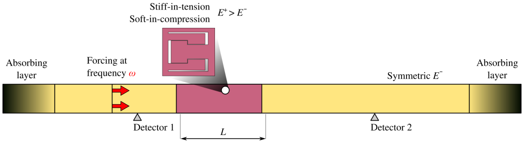
- In terms of wavelength:

$$\boxed{L_o \ge \frac{\lambda_0}{\sqrt{\gamma}-1}} \text{ if } c^0 = c^+ \quad \text{or} \quad \boxed{L_o \ge \lambda_0 + \frac{\lambda_0}{\sqrt{\gamma}-1}} \text{ if } c^0 = c^-$$

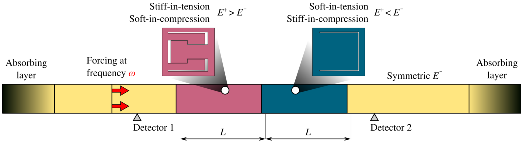


Energy transmission for single harmonics

- Energy injected $W_{in} = \frac{1}{2}\int\limits_0^T F(t)u_{,t}dt$
- Energy transmitted $W_{out} = A\int\limits_0^{T_{sim}}\left[\rho\left(\frac{\partial u}{\partial t}\right)^2 + E\left(\frac{\partial u}{\partial x}\right)^2\right]c_0 dt$
- Energy transmission factor: $\mathcal{F} = \log_{10}(\text{Energy out}/\text{Energy in})$

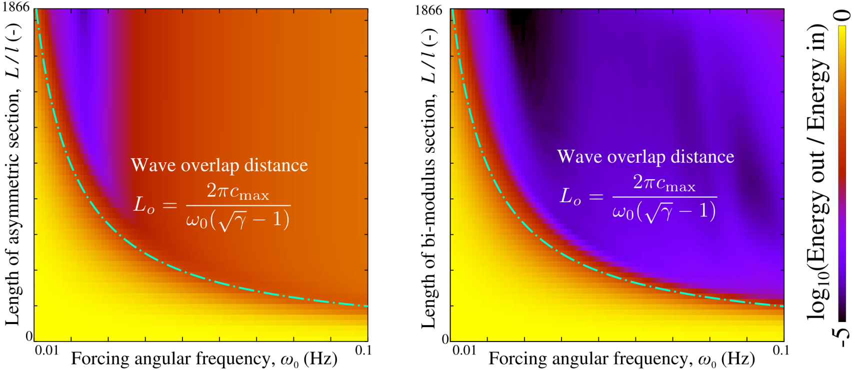


Configuration 1



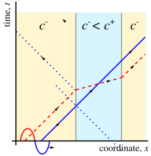
Configuration 2

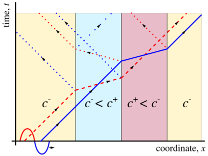
Energy transmission for single harmonics



Configuration 1: single overlap

Configuration 2: double overlap





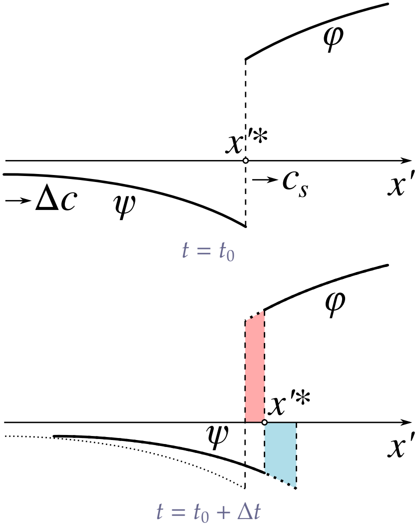
Seeming simplicity

- Need to track particular points:[1]
  α shock waves, β signotons, γ semi-signotons and δ simple discontinuities
- Energy loss around α shock wave[2]:

$$W_{\text{loss}}(t) = \frac{A(E^+ + E^-)}{2}\Delta c \int_0^t \sum_{x'^*(t')} \left(\frac{\varphi(x'^*)\psi(x'^*)}{\varphi(x'^*) + |\psi(x'^*)|} \right)^2 dt'.$$

  with φ tensile and ψ compressive parts, x'^* is α shock wave's position and $\Delta c = c_0(\sqrt{(1-\alpha)/(1+\alpha)} - 1)$
- For simple harmonic signal of different amplitude, the α shock wave moves accordingly to[2]

$$\dot{x}'^* = \Delta c \frac{a^- \sin\left(k\left(\Delta c t - x'^*\right)\right)}{a^- \sin\left(k\left(\Delta c t - x'^*\right)\right) + a^+ \sin\left(k x'^*\right)}$$



[1] V.P. Maslov, P.P. Mosolov, PMM USSR (1985)
[1] VY, arXiv:1712.06294 (2017,2021)

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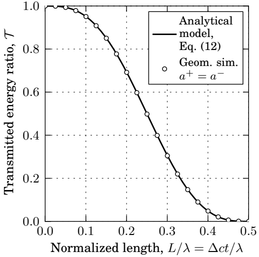
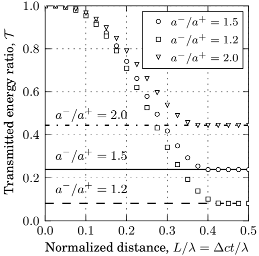
$$\dot{x}'^* = \Delta c \frac{a^- \sin\left(k\left(\Delta ct - x'^*\right)\right)}{a^- \sin\left(k\left(\Delta ct - x'^*\right)\right) + a^+ \sin\left(kx'^*\right)}$$

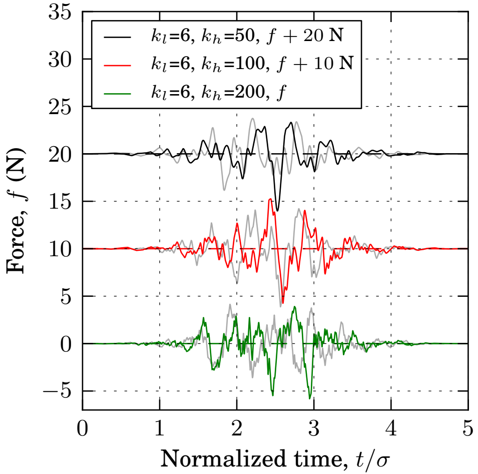


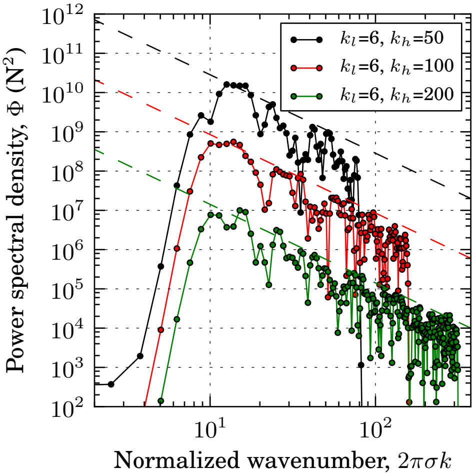


[1] V.P. Maslov, P.P. Mosolov, PMM USSR (1985)
[1] VY, arXiv:1712.06294 (2017,2021)

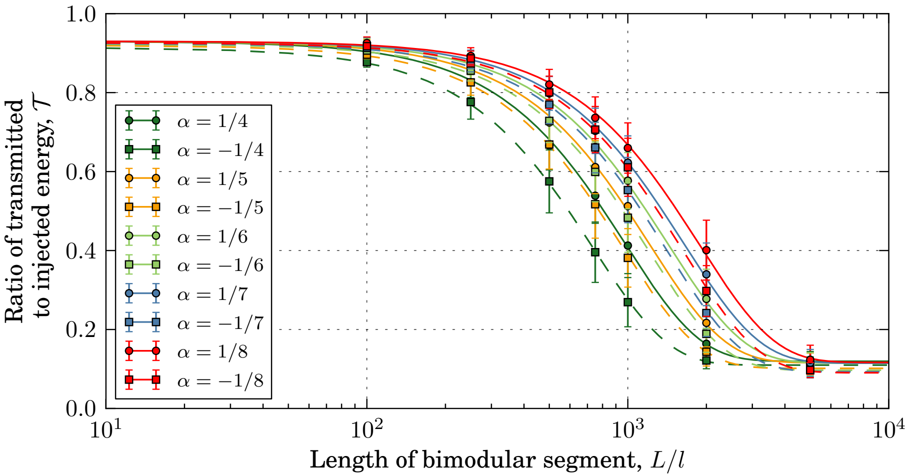
Energy transmission for wave packet

Self-affine wave packets with different spectral content





Energy transmission for wave packet



Energy transmission for wave packet

- Normalization for the asymmetric segment:

$$L' = \begin{cases} \dfrac{L}{l}\dfrac{2}{1-\sqrt{(1-\alpha)/(1+\alpha)}}, & \text{if } \alpha > 0,\\ \dfrac{L}{l}\dfrac{2}{\sqrt{(1+\alpha)/(1-\alpha)}-1}, & \text{if } \alpha < 0, \end{cases}$$

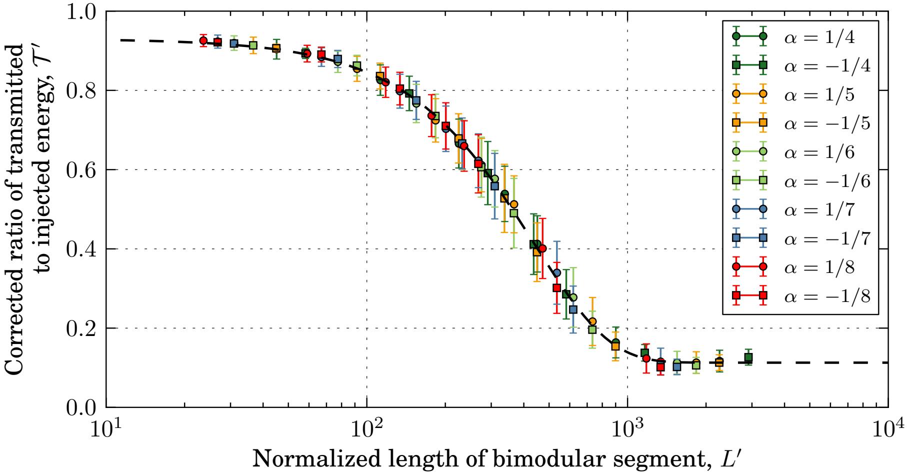
- Account for reflected portion:

$$\frac{W_{\text{refl}}}{W_{\text{in}}} \approx \left(1 - \frac{2}{1+\sqrt{(1-\alpha)/(1+\alpha)}}\right)^2$$

- Transmitted energy fraction:

$$\mathcal{T}'(L') = \frac{W_{\text{out}} + W_{\text{refl}}}{W_{\text{in}}} = \mathcal{T}'_{\text{min}} + (\mathcal{T}'_{\text{max}} - \mathcal{T}'_{\text{min}}) \exp\left(-(L'/L'_*)^{3/2}\right) + \frac{W_{\text{refl}}}{W_{\text{in}}}$$

Energy transmission for wave packet

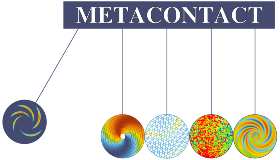


Conclusion

- Contact-based architectures have a great potential to broaden functionality of architected materials
- Enriched thermo-electro-mechanical coupling
- The strong contact nonlinearity is fully operation in small deformation regimes $\Rightarrow$ available for hard materials and demanding engineering applications
- Wave damping and polarisation property is only one of many examples of emerging properties

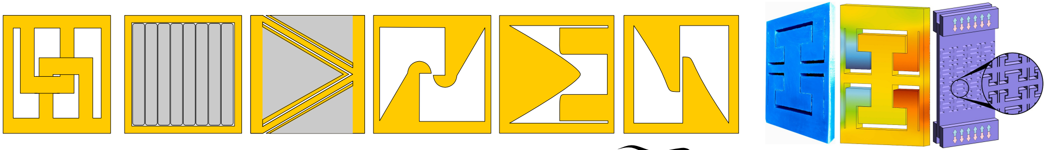
Contact-in project

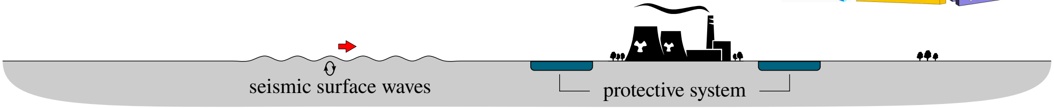
ERC StG 2015
Phase I: B



ERC StG 2018
Phase II: A

ERC StG 2019
Phase II: B





Community

Main collaborations

Academia

- **Centre des matériaux**
  G. Cailletaud, S. Forest, H. Proudhon, C. Ovalle-Rodas, D. Missoum-Benziane, S. Basseville, P. Arnaud
- **Institut de Physique du Globe de Paris**
  A. Mangeney, J.P. Montagner, E. Stutzmann
- **Arts et Métiers**
  O. Castelnau
- **EPFL (Switzerland)**
  J.F. Molinari, G. Anciaux
- **ETHZ (Switzerland)**
  D. Kammer
- **Centrale Supélec**
  F. Houzé, S. Noël, Ph. Testé
- **NTNU (Norway)**
  Ch. C. Li

Industry

- Safran tech (2 PhD theses, internship)
- DGA (2 PhD theses)
- EDF (PhD thesis)
- Mercedes (direct project)
- Schneider Electric (PhD thesis, internship)
- CEA Leti (PhD thesis)
- SINTEF (PhD thesis)
- CETIM (direct project)

Supervision

Internship students:

- **Olga Trubienko** (MINES, 2008), Computational Contact Mechanics (master)
- **Olga Zinovieva** (MINES, 2012), Plasticity induced Roughness (master)
- **Fadoua Majid** (MINES & Schneider, 2015-2016), Electric contactors (master)
- **Amine Saidi** (MINES & Safran Tech, 2018-2019), Simulation of fretting wear (master)
- **Yirun Zou** (MINES, 2019), Machine learning for non-linear dynamics (undegraduate)
- **Paul Beguin** (MINES, 2020), Iceberg-glacier dynamics (master).

Co-supervision of postdoctoral fellows:

- **Ming Liu** (MINES, 2012-2013), Indentation analysis
- **Ayaovi Dzifa Kudawoo** (MINES, 2012-2013), Computational contact
- **Frederick S. Mballa Mballa** (LaSIPS: MINES & SUPELEC, 2013-2015), Electric contact
- **Dmitry Tkalich** (MINES, 2016-2017), Microstructural mechancis of cemented tungsten carbides

Co-supervision of graduate students:

- ★ **Dmitry Tkalich** (MINES & NTNU, Norway, 2012-2016), Wear of drilling tools
- ★ **Amandine Sergeant-Boy** (IPGP, Paris, 2013-2016), Glacial earthquakes
- ★ **Andrei Shvarts** (MINES, 2015-2019), Fully coupled FE framework for fluid/contact interface
- ★ **Basava R. Akula** (MINES & Safran, 2015-2019), Parallel mortar-based contact algorithms
- ★ **Pauline Bonnet** (IPGP & ENSAM & MINES, 2017-2021), Glacial earthquakes
- ★ **Paul Beguin** (MINES, 2020-2023), Thermomechanical contact
- **Julian Durand** (MINES, 2009-2010), Elasto-plastic rough contact
- **Matti Lindroos** (TUT & TWC, Finland, 2014), Thermo-mechano-metallurgical wear model
- **Robin Lethiecq** (MINES & CEA-Leti, 2015-2018), Textile embedded chip on wire
- **Takahiro Sakimoto** (MINES, 2015-2017), Modeling DWTT for high-strength steels
- **Paolo Cinat** (IMT Lucca, Italy, 3 months stay, 2016), Sealing problems
- **Aurélien Fouque** (MINES & SUPELEC & Schneider Electric, 2016-2020), Electric arcs
- **Vikram Phalke** (MINES, 2018-2021), Size effect in single crystal indentation

Institutional responsibilities

- 2021: Member of the CSMA PhD award committee
- 2021: Member of the Assistant Professor selection procedure (INSA Lyon)
- 2020: Swedish Research Council, member of the review panel Mechanical Engineering
- Since 2017: Member of the committee CSMA Juniors, The French Association for Computational Mechanics, junior section (under 40)
- 2013-2018: Organizer of a bimonthly meeting of lab's computer-cluster users
- Since 2013: In scientific committees of 4 conferences, 8 master/PhD theses committees

Organization of conferences, symposia, seminars

- 5th CSMA Workshop for young researchers, Porquerolles, France, May 2022
- CSMA-GAMM Junior Workshop, World Congress on Computational Mechanics 2020, Jan 2021
- 3rd CSMA Workshop for young researchers, Porquerolles, France, May 2019
- 2nd CSMA Workshop for young researchers, Gif-sur-Yvette, France, March 2018
- 1st CSMA Workshop for young researchers, Giens, France, May 2017
- Micro/Nanoscale Modelling for Tribology, Lorentz Workshop, Leiden, Netherlands, Feb 2017
- Alan Needleman 70s Symposium, Ecole des Mines, Paris, France, August 2014

Teaching

Currently taught at MINES ParisTech

- **Contact Mechanics and Elements of Tribology**, author's master course, since 2016 (24-30h)
  In 2021 the course attracted 97 participants in hybrid mode from all over the world!
- **Multiscale Simulations of Materials and Structures**, since 2016 (8h).
- **Continuum Solid Mechanics**, 1st year students at MINES ParisTech, tutor, since 2015 (16h).
- **Nonlinear Computational Mechanics**, since 2014 (2-3h).

Taught in the past at MINES ParisTech

- Finite Element Method
- Short Course on Contact Mechanics and Tribology
- Mechanics of Solid Materials
- Computational Approach to Micromechanical Contacts

Selected invited presentations

- **"Weakly and strongly coupled simulations of interfacial fluid flow at roughness scale"**
  "Predictive approach of sealing", Maestral lab 50th anniversary, Pont du Garde, Oct 2-3 2019.
- **"Contact Mechanics at the Roughness Scale"**
  VI International Conference on Computational Contact Mechanics, Leibnizhaus Hannover, Germany, July 3-5 2019 (keynote lecture).
- **"The role of surface roughness in contact and transport phenomena"**
  School of Civil & Environmental Engineering, Cornell University, Ithaca, USA, October 4, 2018.
- **"Contact along virtual interfaces: coupling the X-FEM with the mortar discretization"**
  7th GACM Colloquium on Computational Mechanics, Stuttgart, Germany, October 12, 2017 (invited lecture).
- **"Contact and sealing between solids with rough surfaces: numerical approach"**
  Institute of Mechanics, Lomonosov State University, Moscow, Russia, November 21, 2016.
- **"Quelques exemples de dynamique non-linéaire dans la mécanique du contact / frottement"**
  Manifestation du GDR DYNLIN, ENSTA, Palaiseau, France, Oct 11, 2016 (opening lecture).
- **"Contact between rough surfaces: mechanical and transport phenomena at small scales"**
  ICTAM 2016: 24th International Congress of Theoretical and Applied Mechanics, Montreal, Canada, August 26, 2016 (panel keynote lecture).

Publications

Review activity: Journals (144)

Physical Review E (12), Tribology Letters (11), **International Journal of Solids and Structures** (10), Tribology International (10), Journal of Engineering Tribology (8), ASME Journal of Tribology (8), **Physical Review Letters** (7), **Computer Methods in Applied Mechanics and Engineering** (6), Wear (5), Meccanica (5), Nonlinear Dynamics (4), **International Journal for Numerical Methods in Engineering** (4), Physical Review Materials (4), **Journal of the Mechanics and Physics of Solids** (3), Physical Review B (3), Friction (3), Advanced Modeling and Simulation in Engineering Sciences (2), Mechanics and Industry (2), Metallurgical Research and Technology (2), Journal of Nuclear Materials (2), MDPI Applied Sciences (2), Computational Mechanics (2), Surface Review and Letters (2), Scientific Reports (2), Modelling and Simulation in Materials Science and Engineering (2), Journal of Engineering Mechanics (1), Applied Surface Science (1), Tribology Transactions (1), MDPI Metals (1), MDPI Machines (1), Zeitschrift fur Angewandte Mathematik und Mechanik (1), Computational Materials Science (1), MDPI Materials (1), Journal of the Mechanical Behavior of Biomedical Materials (1), Journal of Mechanics of Materials and Structures (1), The Journal of Strain Analysis for Engineering Design (1), SAGE Journal of Mechanical Engineering Science (1), Applied Physics (1), Materials Research Letters (1), ASME Journal of Applied Mechanics (1), Computers and Structures (1), Mechanics of Advanced Materials and Structures (1), International Journal of Applied Mechanics (1), Smart Materials and Structures (1), The Journal of Adhesion (1), Biomimetics (1), Industrial Lubrication and Tribology (1), Journal of Alloys and Compounds (1)

Open Science

OVERLAY

Journal of Theoretical, Computational and Applied Mechanics

JTCAM

DIAMOND OPEN ACCESS

Activity

- Summer 2020 with V. Acary, M. Legrand, M. Montagnat, F. Gibier we launched JTCAM, the first overlay journal in mechanics
- Diamond Open Access: free for authors and readers
- Hosted at EpiSciences.org platform
- Open Reviews
- Five of us serve as technical editors
- 22 articles received, 7 published, 5 more accepted

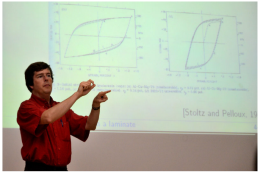
Elected Editorial Board

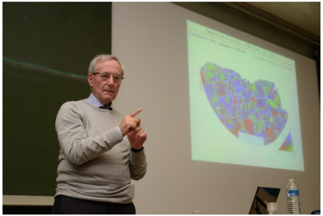
- Laurence Brassart [Univ.Oxford, UK]
- Laura De Lorenzis [ETHZ, Switzerland]
- Shaocheng Ji [Polytech. Montréal, Canada]
- Xianfeng Liu [Southwest Jiaotong Univ., China]
- Anil Misra [University of Kansas, USA]
- Anna Pandolfi [Politecnico di Milano, Italy]
- Alexander Popp [Univ. Bundeswehr München, Germany]
- Julien Réthoré [École Centrale de Nantes, France]
- Olivier Thomas [Arts et Métiers ParisTech, France]
- Laszlo S. Toth [Université de Lorraine, France]

Photography

- CSMA conference, 2013, 2019
- 5 CSMA Juniors workshops, 2016-2019
- Workshop "Micro/Nano Models for Tribology", Leiden, 2017
- Retirement party of Jean-Louis Chaboche, 2015
- Celebration of Alain Needleman's 70, Ecole des Mines de Paris, August 2014
- Journée "Aspects Critallographiques de la déformation et de la rupture des métaux", Ecole des Mines de Paris, June, 2014
- Int. Conf. on Computational Contact Mechanics, Lecce, Italy, July 2013
- Colloque Plasticité, Paris, France, April 2013
- Journées Int. Francophones de Tribologie, Aix-en-Provence, May 2012
- Int Conference on Computational Contact Mechanics, Lecce, Italy, Sept 2009

Photography





CNRS Bronze Medal 2018

Present & Future

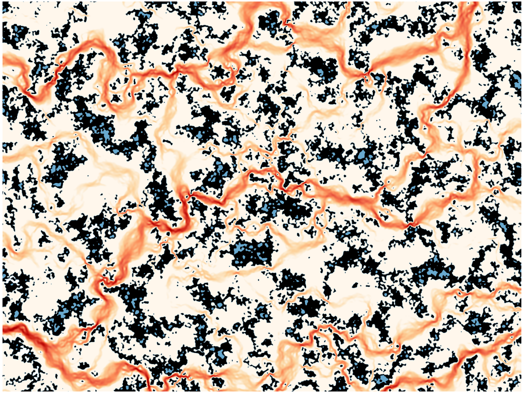
Present

In the final stage

- Three papers on sealing
- Two papers on glacial earthquakes
- Three papers on MorteX method
- Two papers on slip in faults

Projects & current work

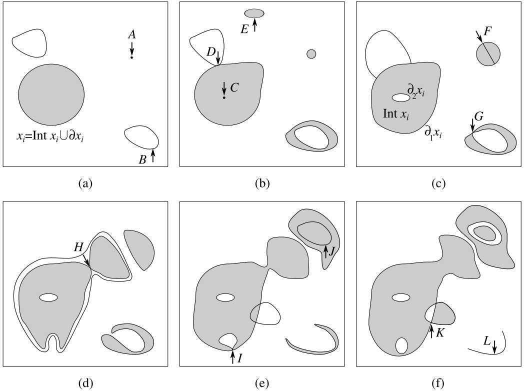
- Thermo-electrical contact
- ANR MESOCRYSP with L. Truskinovsky et al
- Payne effect modelling
- Organization of 5th CSMA Juniors workshop
- Copy editing at JTCAM



Fluid flow through contact interface between rough surfaces

Future

- Topological changes in physics: from cells to black holes
- Anisotropic asymmetry in architected materials
- Engineering computational tool for finite-size metal-to-metal static contact seals



Future

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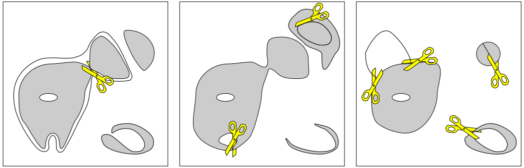
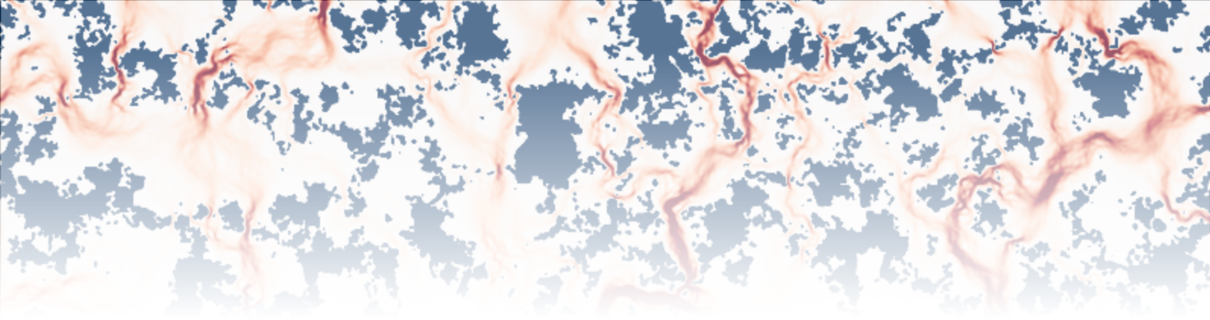


(a) (b) (c)



Thank you for your kind attention!

HDR.yastrebov.fr