COMSOL CONFERENCE
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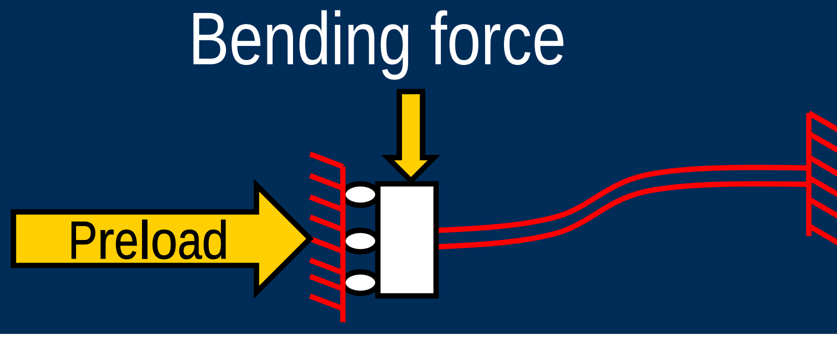

Sensitivity of the Compression-softening Effect to Mesh Imperfections in Compressed Flexures

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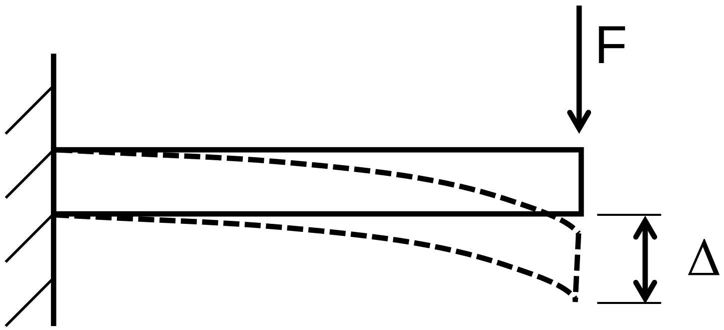
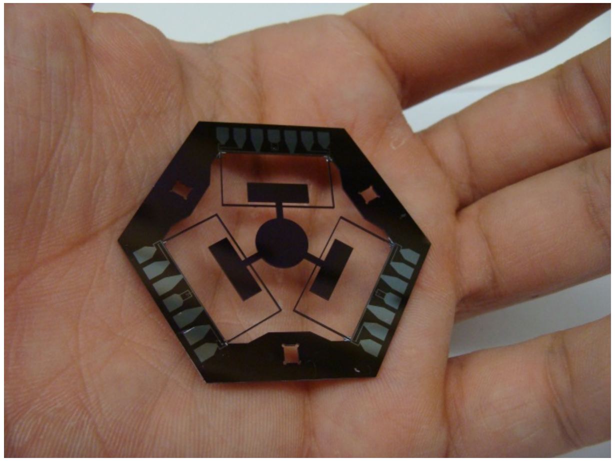
Flexures as low-cost precise bearings

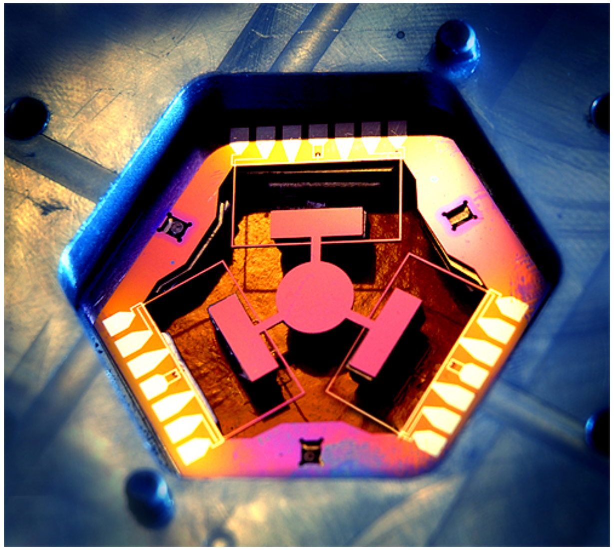
Flexures rely on flexing/bending of members



Simple flexure: Cantilever beam



Stage for nano-positioning



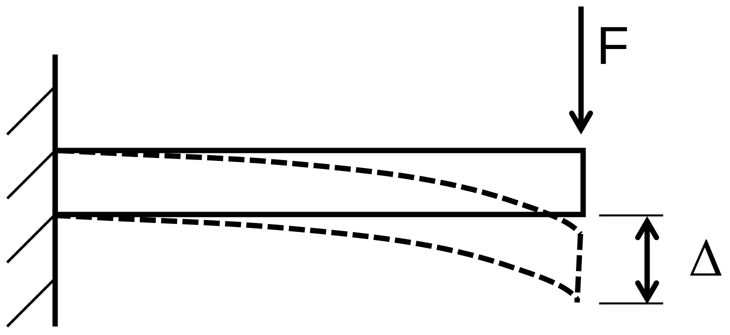
Advantages of flexures:

- Very low friction
- Inexpensive fabrication

Limitation:

- Small range

Range of flexures is limited by stiffness



Simple flexure: Cantilever beam

$$\Delta = F / k$$

Range can be increased by decreasing stiffness

Stiffness is determined by Young's modulus and geometry

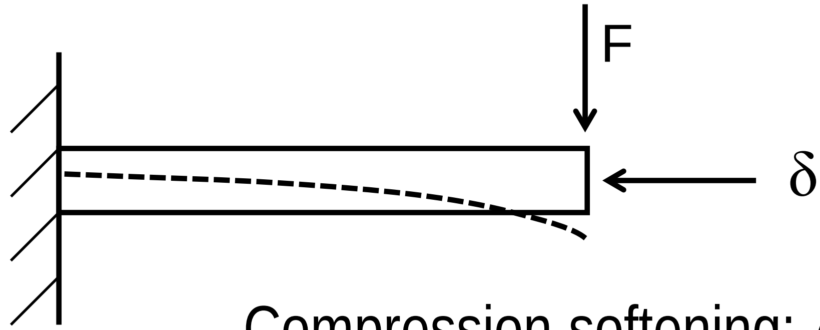
$$k = \frac{1}{4} E b \left(\frac{h}{l} \right)^3$$

Young's modulus   Geometry

Q: Can stiffness be decreased without changing geometry or materials?

Axial compression reduces transverse stiffness

“Perfectly” straight beam



Compression softening: Axial load introduces additional moment

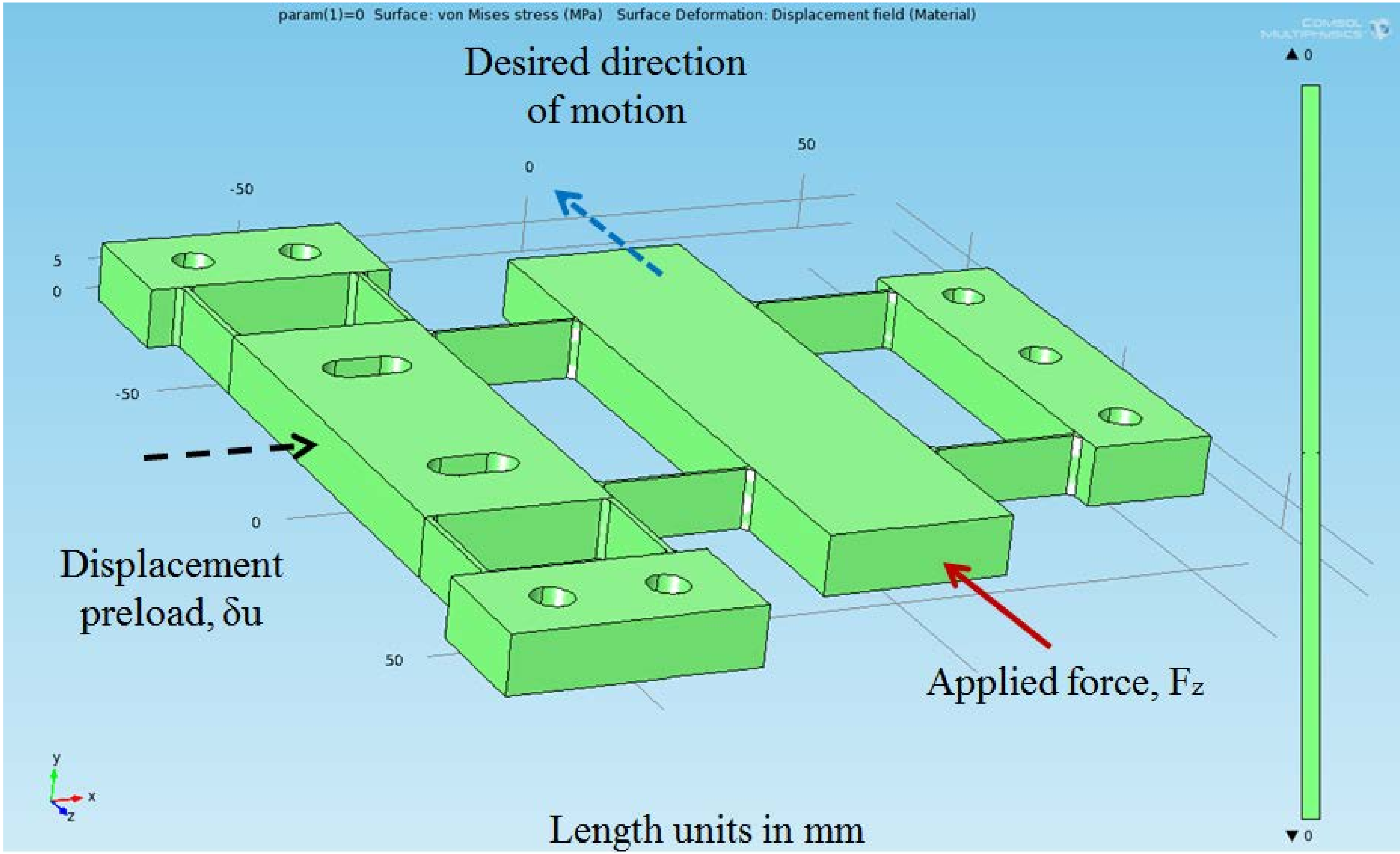
Close to buckling: theoretical stiffness reduction ~ 1000 times

Non-straight “imperfect” beam

Softening effect decreases with imperfection amplitude

Q: How sensitive is compression-softening to imperfections?

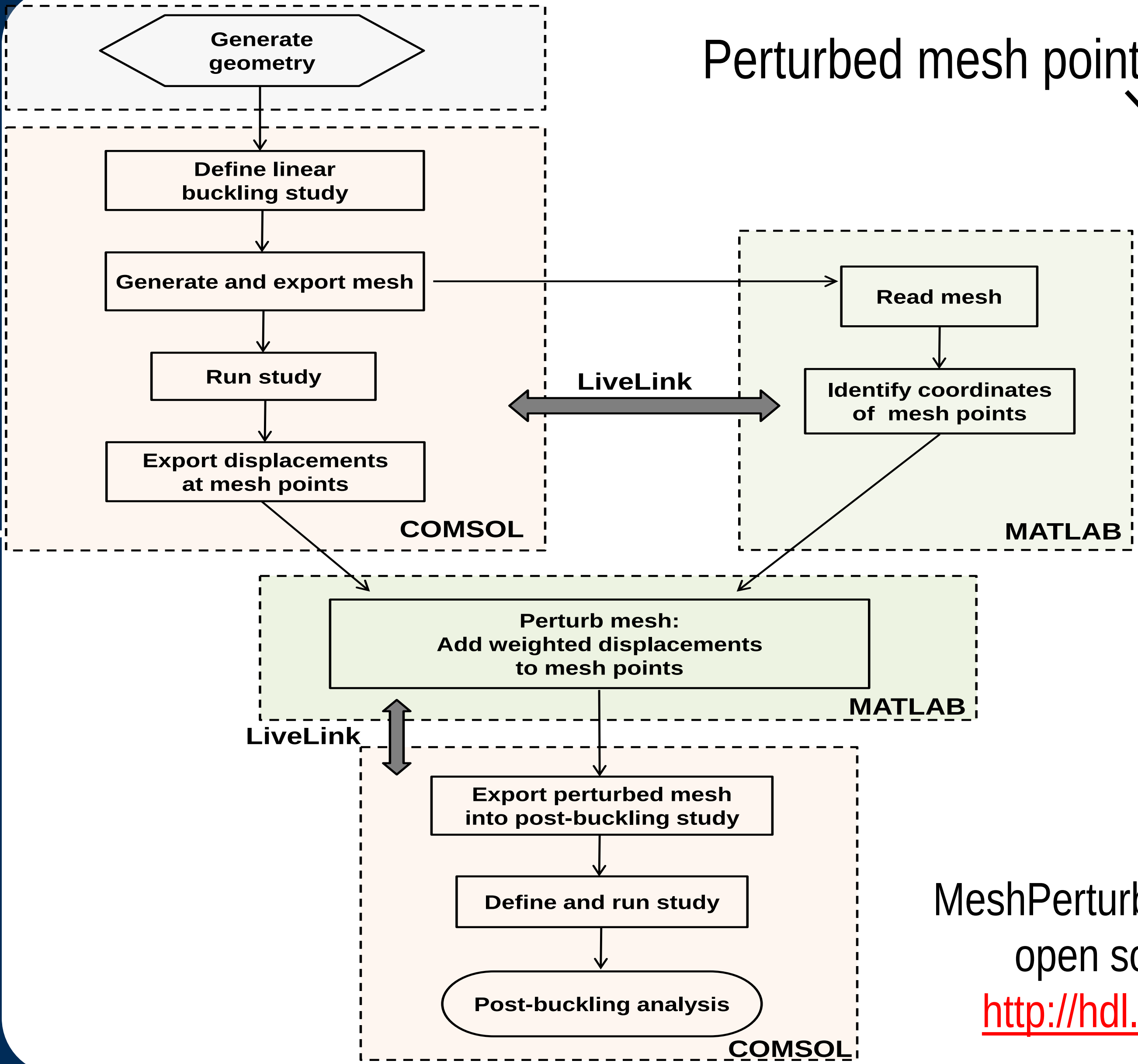
Case study: flexure for linear motion guidance

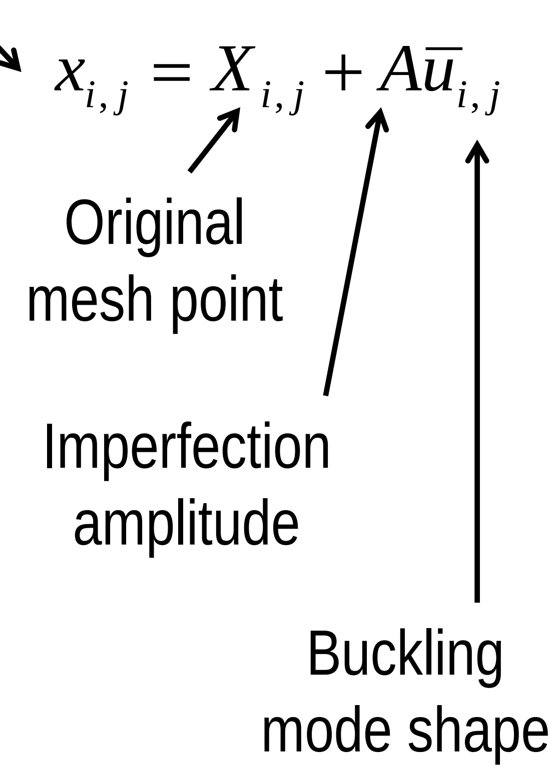


Preload displacement and applied force can be varied without re-meshing

Need mesh perturbation to vary geometric imperfection

MeshPerturb: Mesh perturbation toolbox

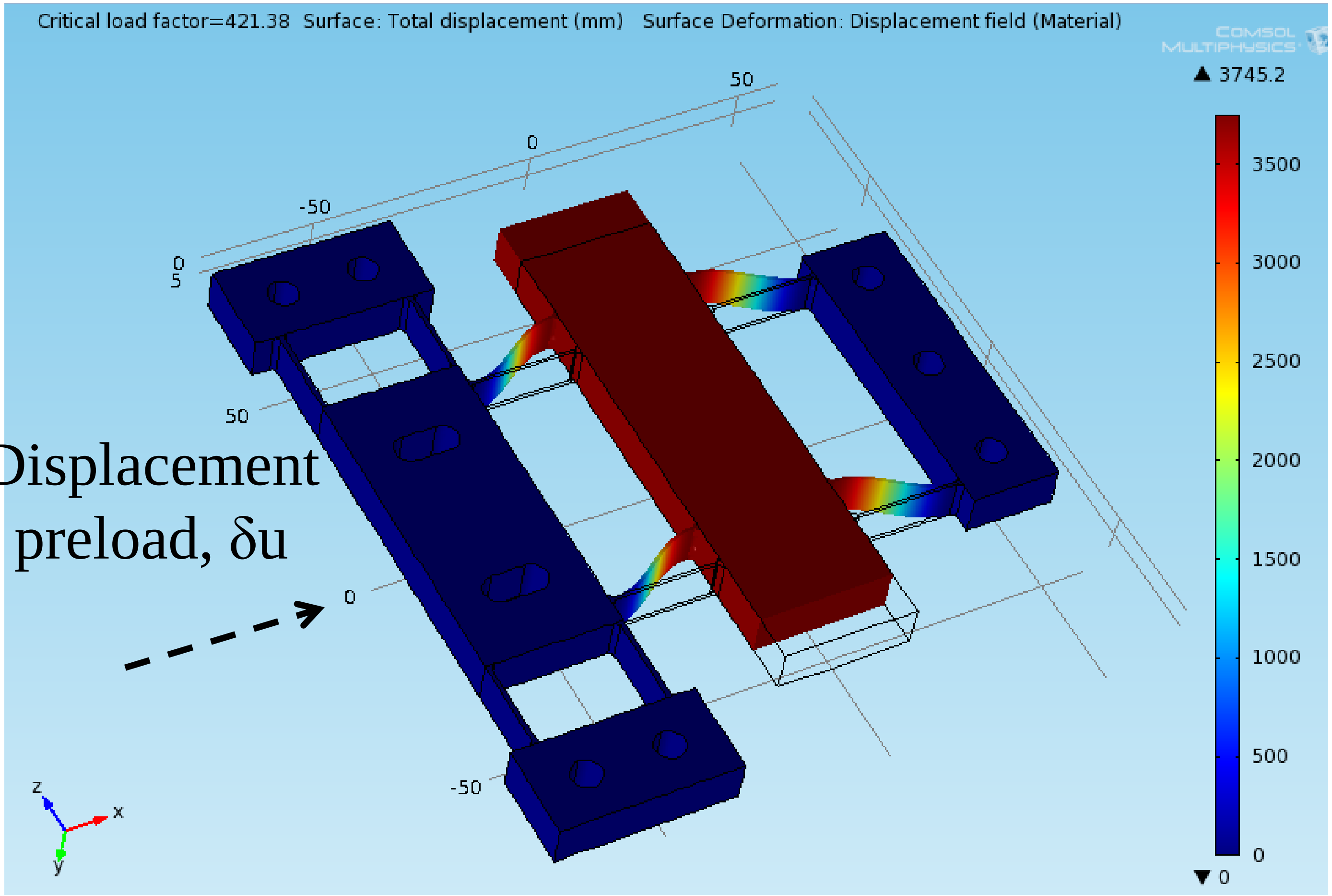




$$x_{i,j} = X_{i,j} + A\bar{u}_{i,j}$$

MeshPerturb available for download with open source GPL license from: http://hdl.handle.net/1721.1/86934.

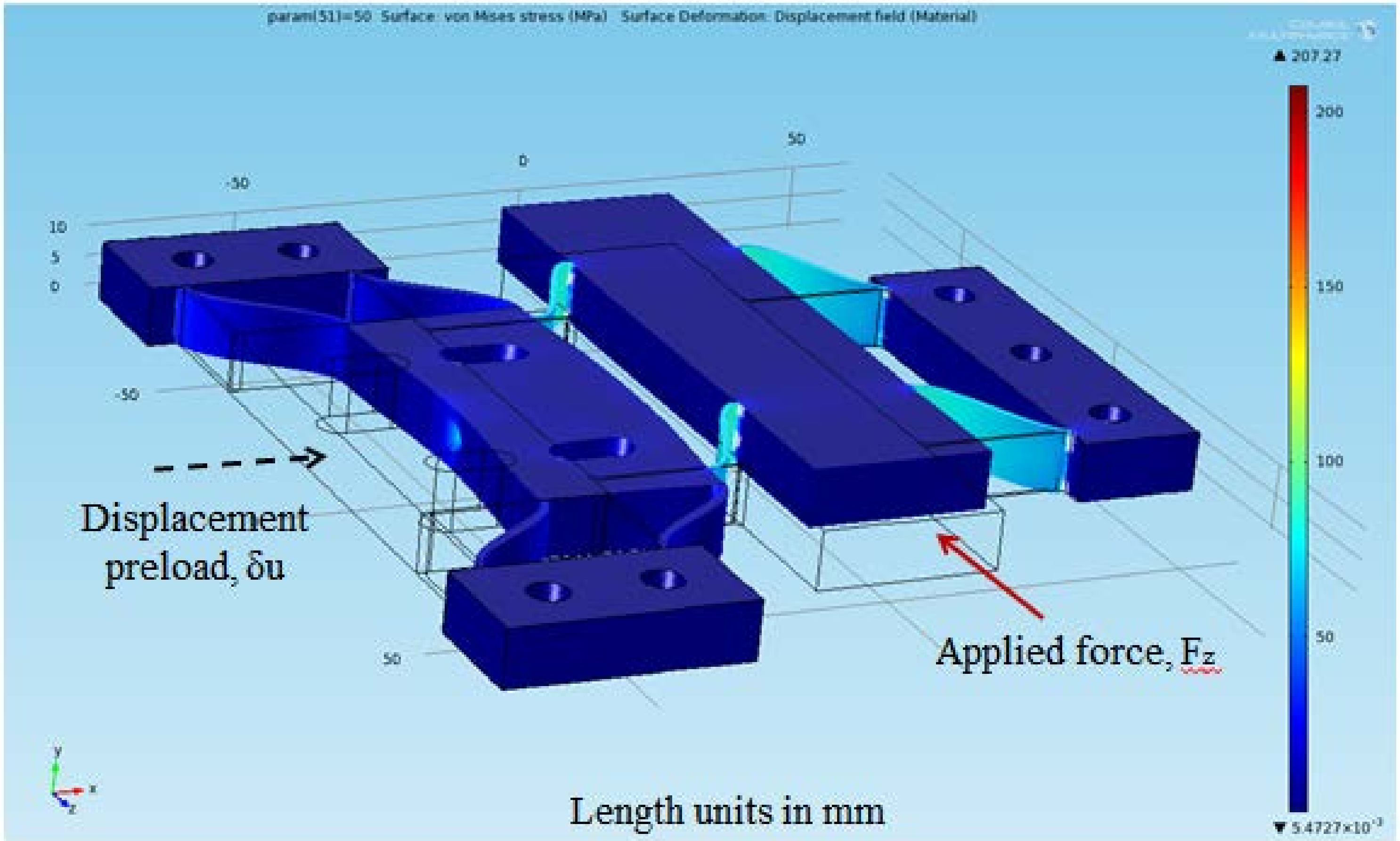
Step 1: Linear buckling for imperfection shape



Displacement preload, δu

Imperfection shape is obtained from linear buckling analysis

Step 2: Bending of compressed imperfect beam

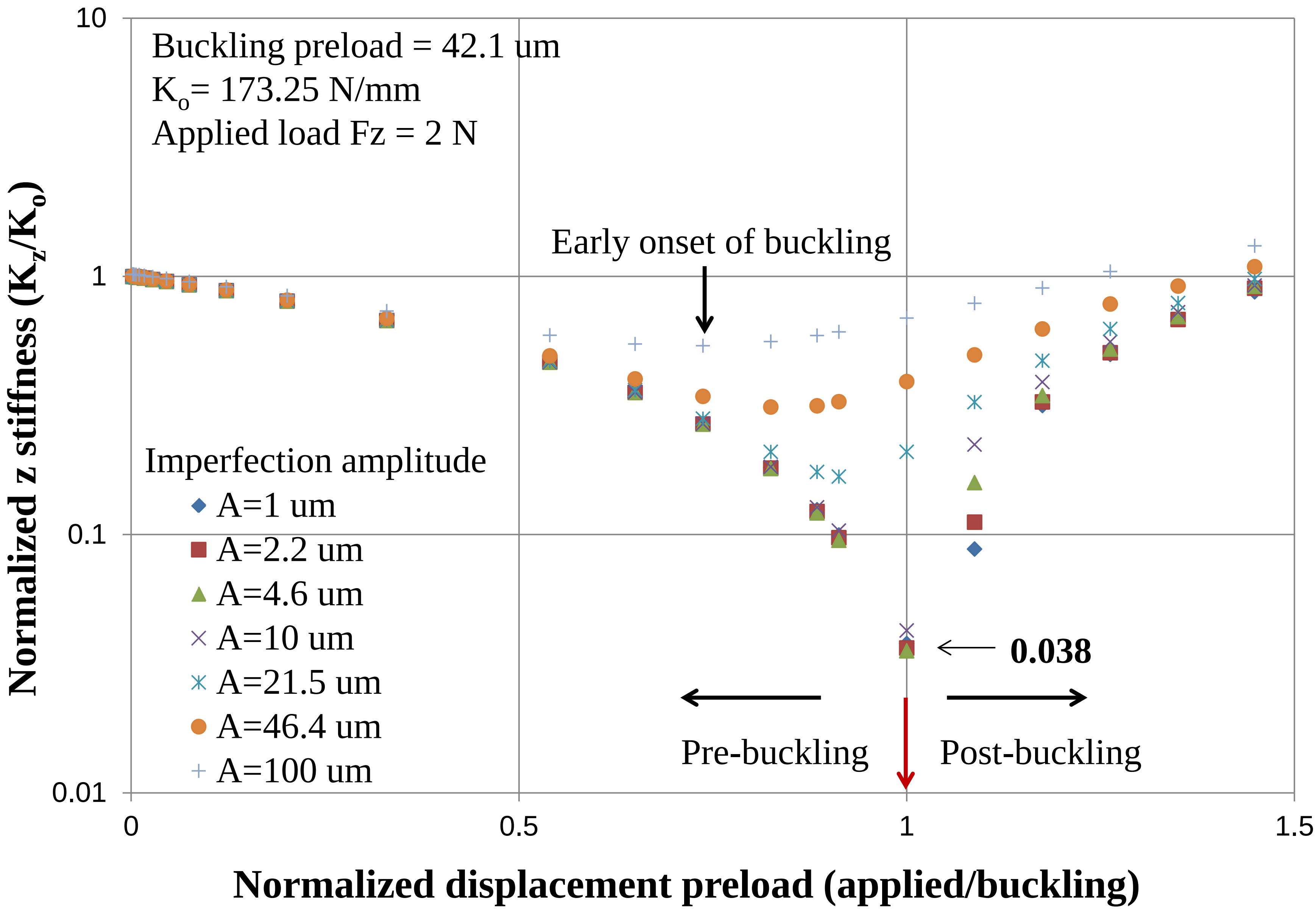


Controllable parameters:

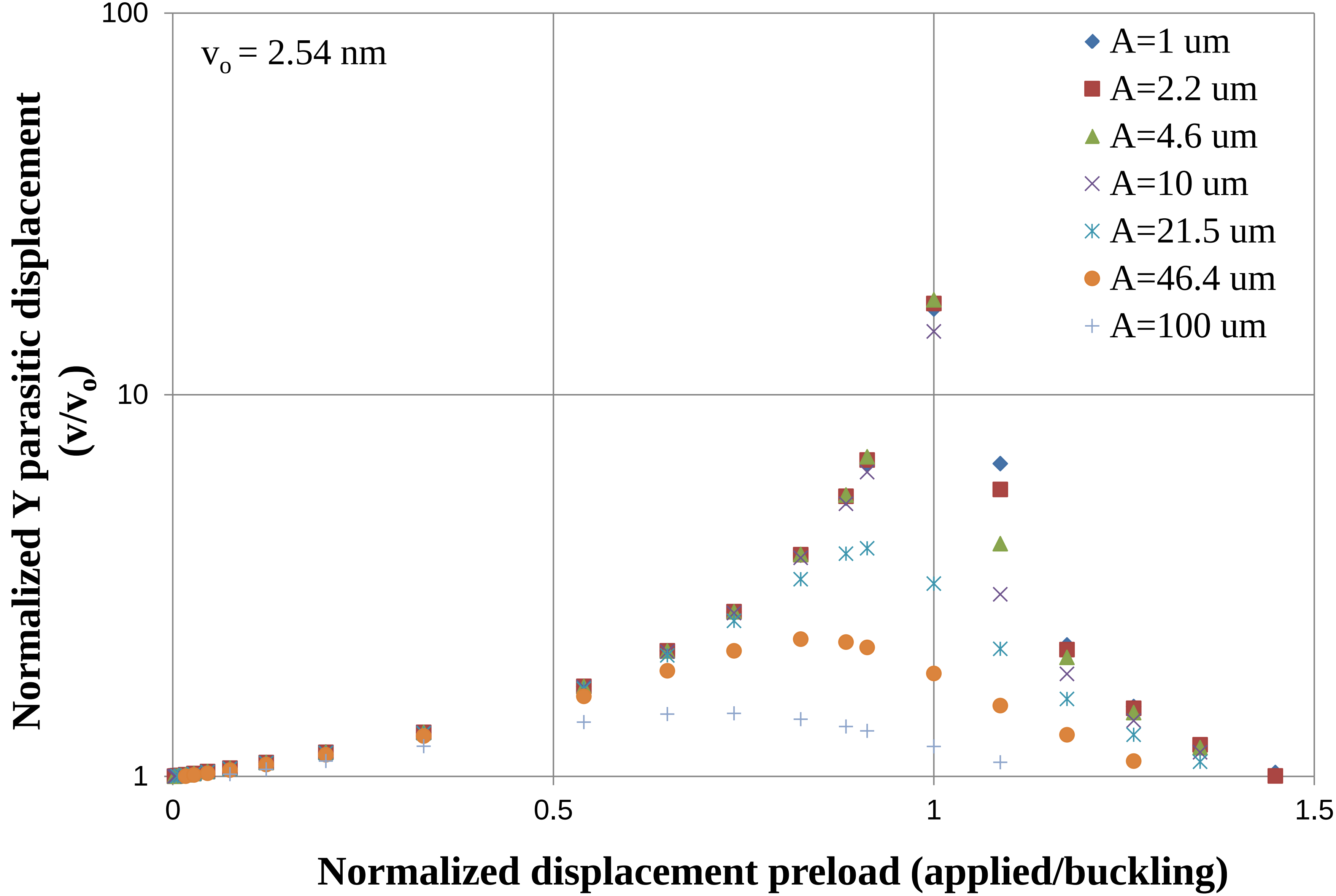
(1) Amplitude of imperfection
(2) Preload displacement
(3) Actuation force

Observable parameter:
Displacement field

Softening is imperfection sensitive near buckling



Motion guidance is preserved near buckling



Conclusions

Axial compression reduces transverse stiffness by:

- ~25 X for near-perfect straight beam
- ~ 2X for beam with 100 um imperfection

Geometric imperfection leads to:

- Early onset of buckling
- Reduced compression-softening effect

Results applicable to:

- Prediction of softening for predetermined imperfection
- Performing engineering trade-off: fabrication tolerance versus performance

Questions?