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Solute Drag on Dislocations

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Overview

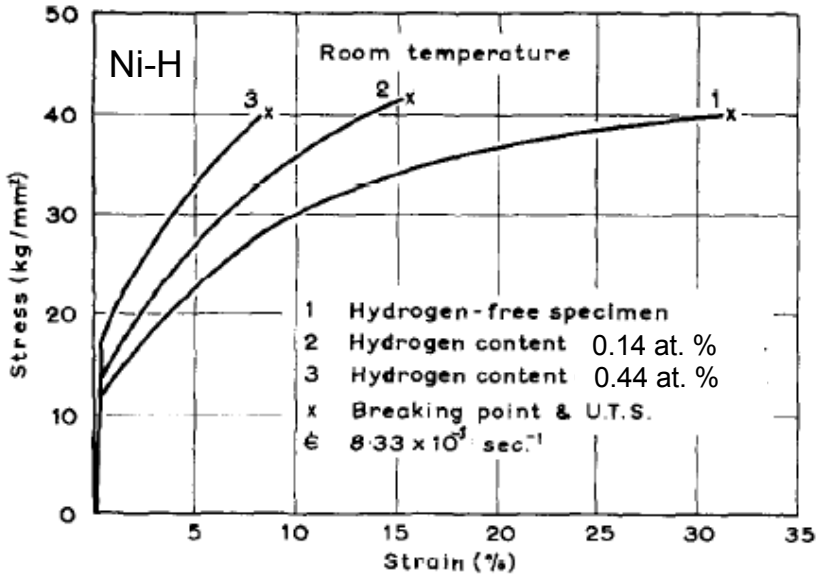
- What is solute drag and why do we care about it?
- Problem setup and solution methodology
- Results and future work

Solute drag is ubiquitous

- Plastic deformation = dislocation motion

http://www.numodis.fr/tridis/TEM/index.html

- Mixing in *solute atoms* produces *solid solutions*
  - ➢ Alloying
    - Steel = Fe + C
  - ➢ Contaminants
    - Hydrogen embrittlement



Boniszewski and Smith, Acta Metall. (1963)

- These solutes interact with dislocations and alter mechanical properties

Steady-state drag calculation

Concentration field calculation

$$\frac{\partial c}{\partial t} = -\nabla \cdot \mathbf{J} = \mathbf{0}$$

Finite difference and solve with Newton's method

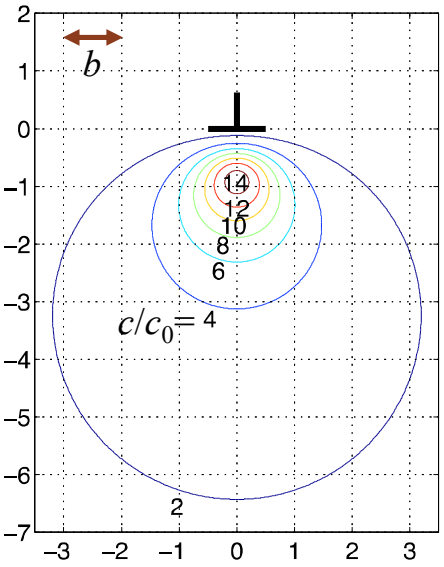
Drag force calculation

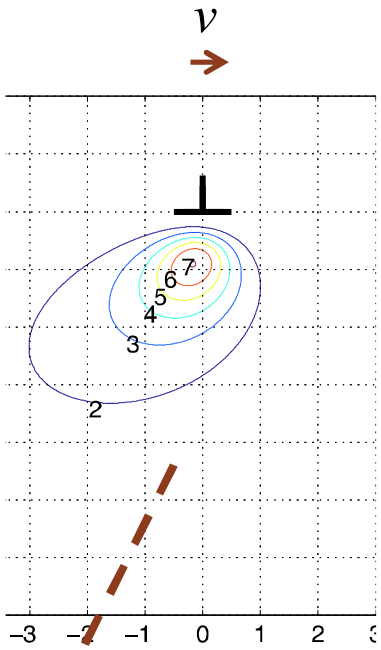
$$\sigma_{xy} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} [c(x', y') - c_0]\, \underbrace{\sigma_{xy}^{\text{solute}}(x_c - x', y_c - y')}_{\text{Stress field of a solute}} dx' dy'$$

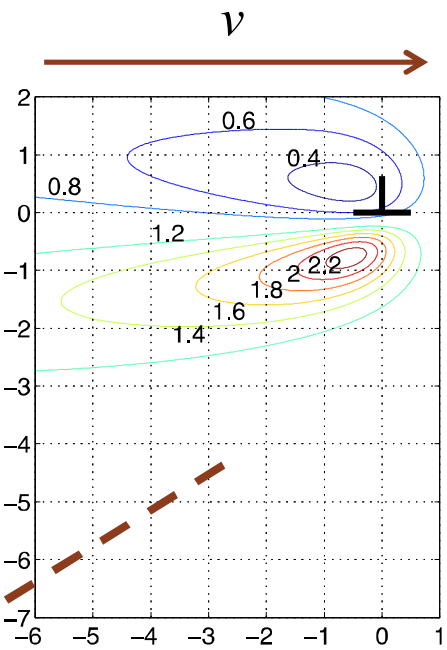
Evaluate with adaptive quadrature in MATLAB

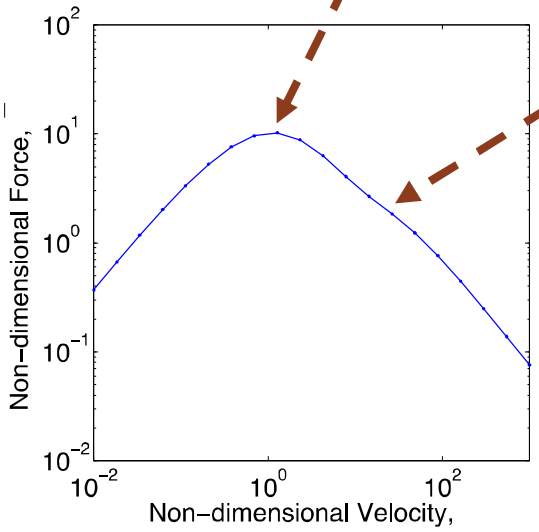
$$F = (\sigma_{xy}\mathbf{b}) \times \xi$$

Results









$$\overline{F} = \overline{F}\left(q, c_0, S, \theta, \frac{\hat{\gamma}}{\mu b}, \frac{a}{b}\right)$$

Non-dimensional Force Expression

Future work

- Consider transient cases

- Use drag expression to model solid solution strengthening with dislocation dynamics simulations

R. B. Sills and W. Cai, *Solute drag on perfect and extended dislocation,* In-Preparation.