Modeling the Nonlinear Rheology of Reversible Double Dynamics Detworks

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Contents

- About me
- A brief review on past research experience
- Roles acting in the Double Dynamics Networks program

Education

- Ph.D. Polymer Rheology, Università degli Studi di Napoli Federico II, Sep.2018-Current.
- M.S. Mechanics, South China University of Technology, Sep.2015-Jun.2018.
- B.S. Engineering Mechanics, HeFei University of Technology, Sep.2011-Jul.2015.

China—a both old and young country

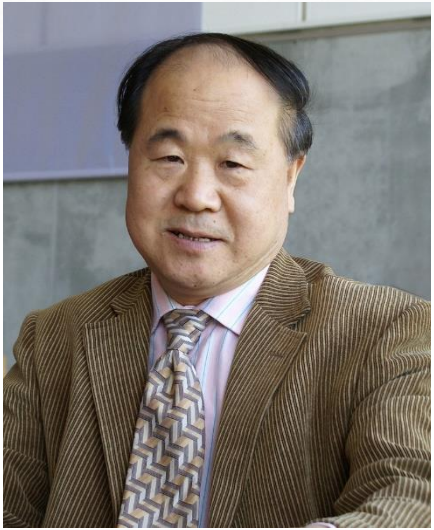
- Emerged as one of the world's earliest civilizations

Confucius

Army of Terracotta Warriors, Xian

China—a both old and young country

For Tu Youyou's works in the treatment of malaria, she received the 2015 Nobel Prize in Physiology or Medicine.

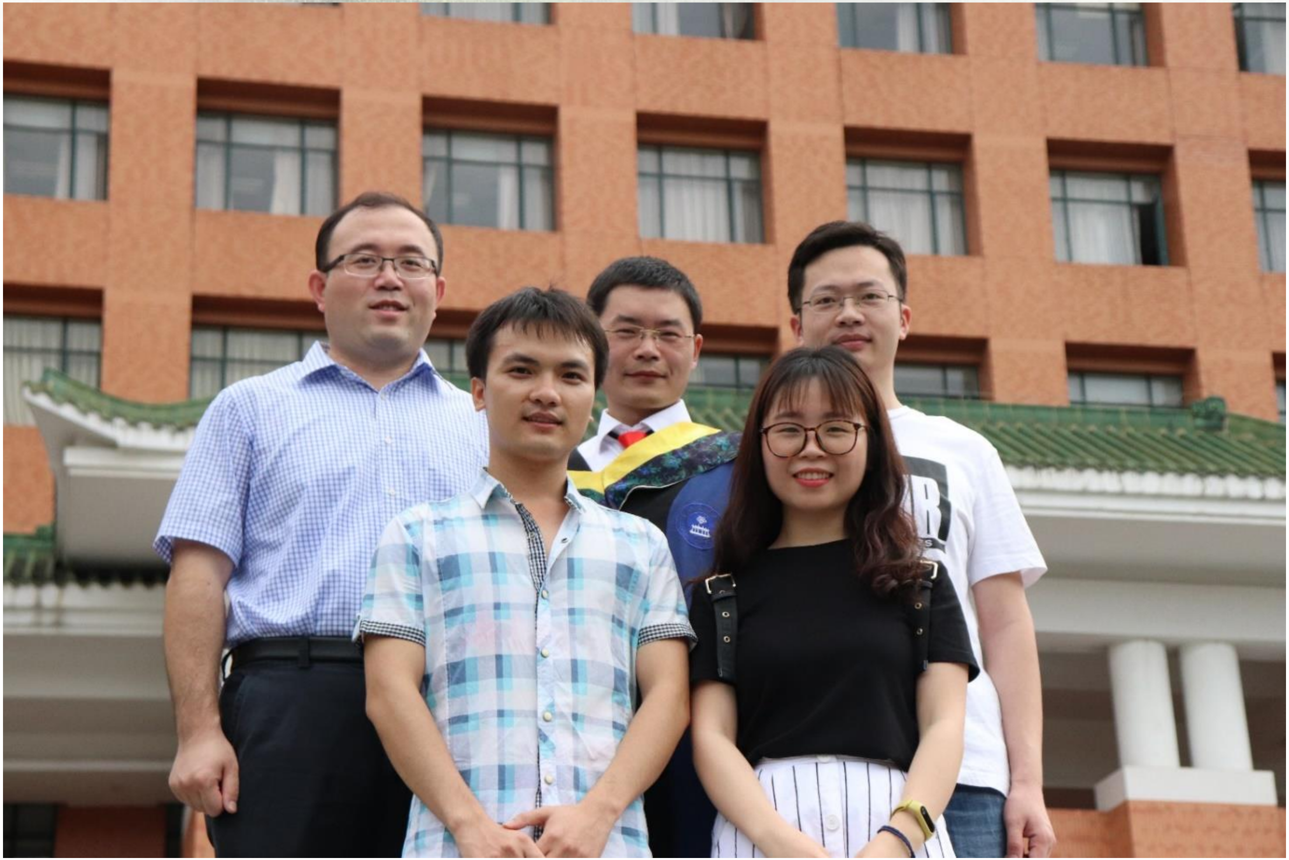


Mo Yan, a Chinese novelist and short story writer, was awarded the Nobel Prize in Literature.

South China University of Technology

- Located in the city of Guangzhou, a thriving metropolis in South China

Research group members of Ms.c program




MLMR
MY LIFE MY RULES

Classmates & Teachers

Analytical Study on Martensitic Transformation in Shape Memory Alloys

- SMA (Ni-Ti, AuCd, CuAlNi, InTl, etc) characterized by two unusual properties: **shape memory effect** and **pseudoelasticity** (be capble of being strained significantly（6%-10%）during loading and return to its unstrained configuration upon unloading.)

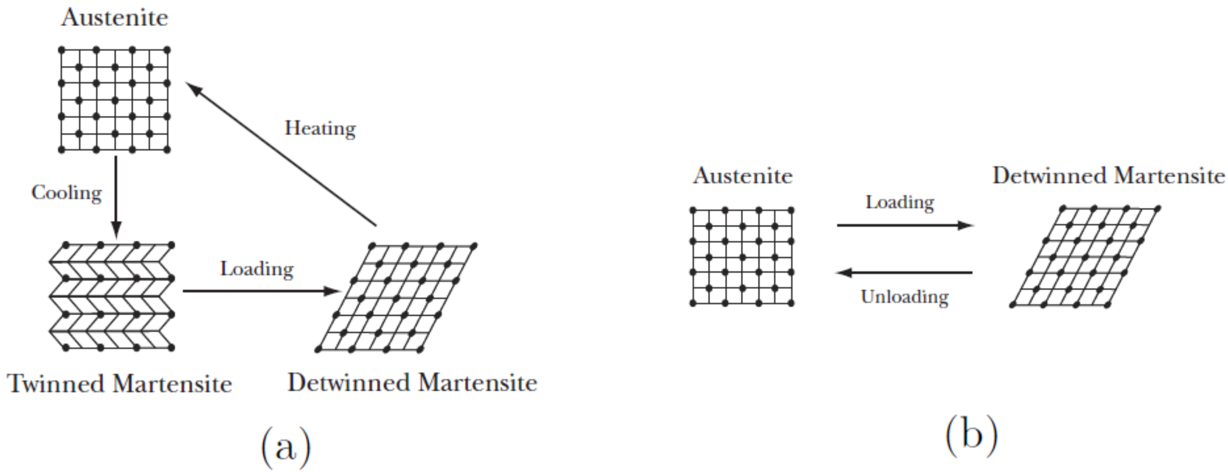


Figure 1: The microscopic mechemism of shape memory effect (a) and pseudoelasticity (b).

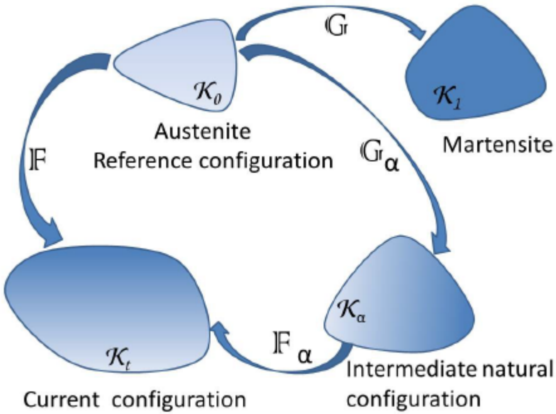


Figure 2: Different configurations and the corresponding deformation gradients.

- $\mathbb{F} = \mathbb{F}_\alpha \mathbb{G}_\alpha$,

where α is the phase state variable representing the volume fraction of martensite phase in κ_α.

- Constitutive equations

$$\mathbb{S} = \frac{\partial \widehat{\Phi}}{\partial \mathbb{F}}, \qquad \eta = -\frac{\partial \widehat{\Phi}}{\partial \theta}, \qquad -\frac{\partial \widehat{\Phi}}{\partial \alpha}\dot{\alpha} = \zeta, \tag{1}$$

where $\mathbb{S}$ is nominal stress, $\widehat{\Phi}$ is free energy, η is the entropy, θ is the temperature and ζ is the dissipation rate.

- Helmholtz free energy *Rajagopal & Srinivasa ZAMP. 2004.*

$$\begin{aligned}\widehat{\Phi}(\mathbb{F}, \alpha, \theta) = {} & \mathrm{Det}\mathbb{G}_\alpha \left[(1-\alpha)\Phi_0(\mathbb{F}_\alpha) + \alpha\Phi_1(\mathbb{F}_\alpha)\right] + B\alpha(1-\alpha) \\ & + (1-\alpha)\phi_0(\theta) + \alpha\phi_1(\theta).\end{aligned} \tag{2}$$

- The mechanical dissipation rate is adopted by the following form

$$\zeta(\alpha, \dot{\alpha}) = \begin{cases} R^{+}(\alpha)|\dot{\alpha}|, & \text{if } \dot{\alpha} > 0, \\ 0, & \text{if } \dot{\alpha} = 0, \\ R^{-}(\alpha)|\dot{\alpha}|, & \text{if } \dot{\alpha} < 0. \end{cases} \tag{3}$$

- The phase transition criteria can be derived as the following form

$$-R^{-}(\alpha) < -\frac{\partial \widehat{\Phi}}{\partial \alpha} < R^{+}(\alpha) \Rightarrow \dot{\alpha} = 0 \tag{4a}$$

$$\dot{\alpha} \neq 0 \Rightarrow -\frac{\partial \widehat{\Phi}}{\partial \alpha} = \begin{cases} R^{+}(\alpha), & \text{if } \dot{\alpha} > 0, \\ -R^{-}(\alpha), & \text{if } \dot{\alpha} < 0. \end{cases} \tag{4b}$$

Equilibrium equations

$$\frac{\partial S_{11}}{\partial X} + \frac{\partial S_{21}}{\partial Y} = 0, \tag{5a}$$

$$\frac{\partial S_{12}}{\partial X} + \frac{\partial S_{22}}{\partial Y} = 0. \tag{5b}$$

On the upper and the lower sides of the SMA layer, we have the following traction-free boundary conditions

$$\mathbb{S}^T \mathbf{N}_u|_{Y=A(X)} = 0, \quad \mathbb{S}^T \mathbf{N}_l|_{Y=-A(X)} = 0, \tag{6}$$

where the unit normal vectors $\mathbf{N}_u$ and $\mathbf{N}_l$ are given by

$$\mathbf{N}_u = \frac{1}{A'(X)^2 + 1}\left(-A'(X), 1\right), \quad \mathbf{N}_l = \frac{1}{A'(X)^2 + 1}\left(A'(X), 1\right). \tag{7}$$

By using the **Coupled Series-Asymptotic Expansion** (CSAE) method, the equilibrium equations and stress-free boundary conditions can be reduced into one single ODE, which can be solved by WKB methods.

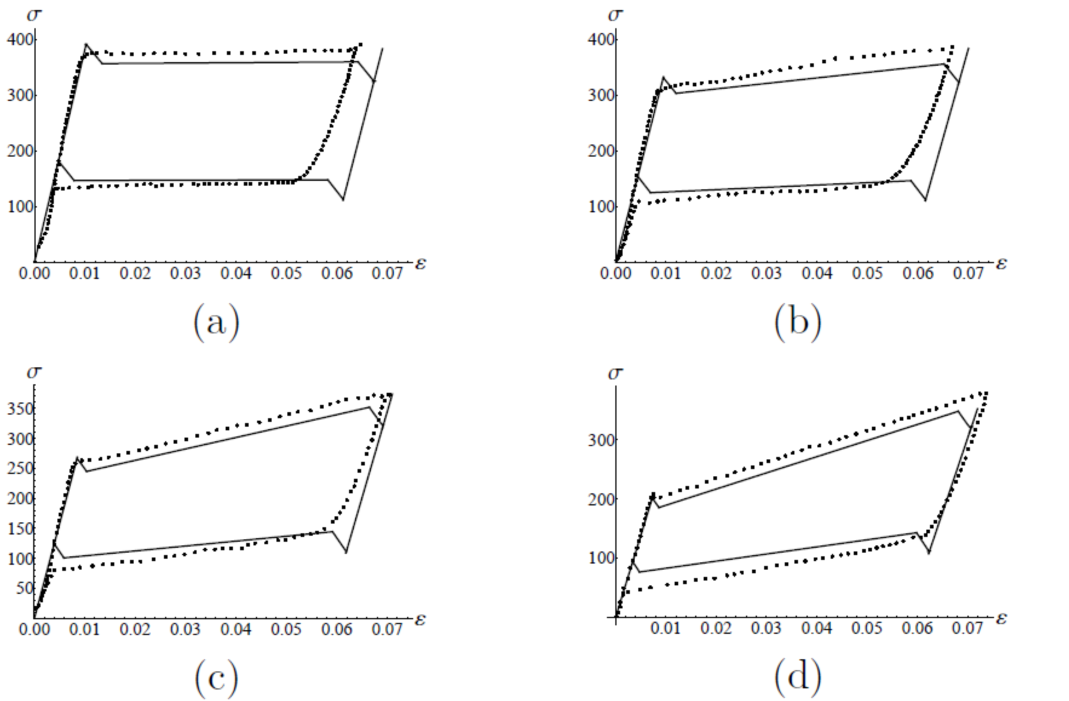
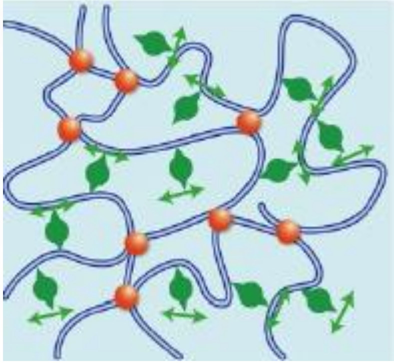


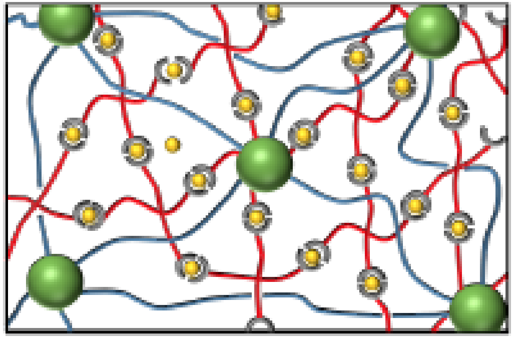
Figure 3: Comparisons of the stress-strain curves (unit of σ: MPa) of the five layers obtained from the model predictions (solid line) and the experimental results (dotted line): (a) $\varpi = 1$, (b) $\varpi = 5/6$, (c) $\varpi = 2/3$, (d) $\varpi = 1/2$.

Modeling the nonlinear rheology of reversible DDNs

Single networks with dual crosslinks



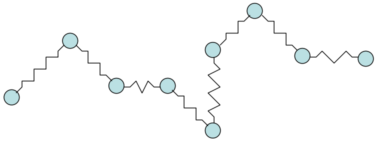
Double networks



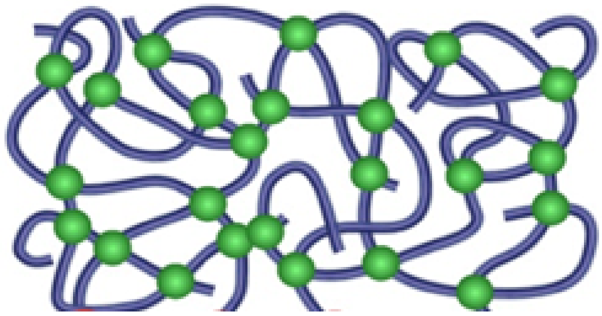
We will resort to Brownian dynamics simulations, starting from 2D networks, to then consider the 3D case

A simple model

- Phantom Rouse chains with sticky beads

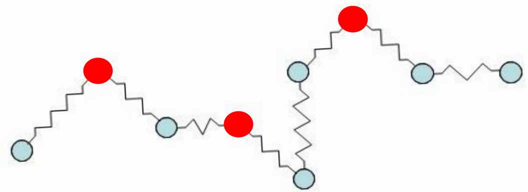


Single (unentangled) networks

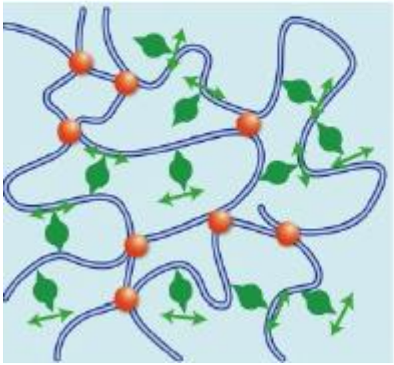


Double Networks

- Rouse chains with different sticky beads



Double (unentangled) networks



It is always a pleasure to greet friends from afar

--Confucius