School of Civil Engineering

High Performance Computing Laboratory

“Multiscale Simulation of Soft Bio-mechanical Tissues”

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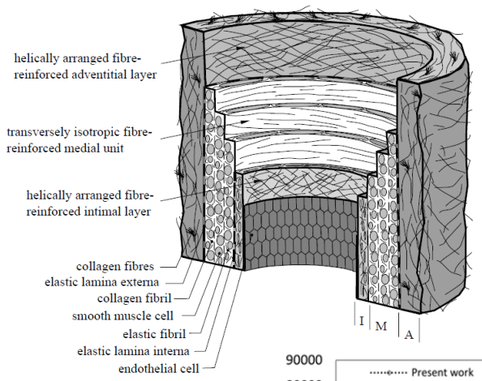
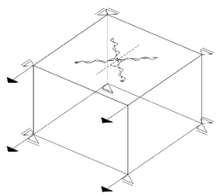
Phenomenological inelastic model:

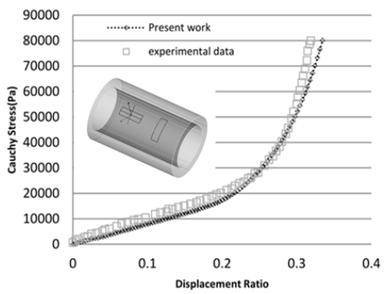
-Abdominal Aorta:

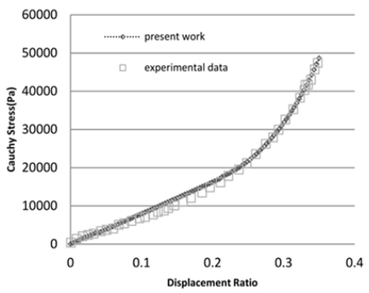
$$\psi^{\text{iso}} = c_1\left(\frac{I_1}{I_3^{1/3}} - 3\right) + \varepsilon\left(I_3^{\gamma} + \frac{1}{I_3^{\gamma}} - 2\right),\ c_1 > 0,\ \varepsilon > 0,\ \gamma > 1.$$

$$\psi^{\text{aniso}} = \begin{cases} \sum_{a=1}^{2}[\alpha_1(I_4^{(a)} - 1)^{\alpha_2}] & \text{for } I_4^{(1)} \geq 1 \wedge I_4^{(2)} \geq 1, \\ \alpha_1(I_4^{(1)} - 1)^{\alpha_2} & \text{for } I_4^{(1)} \geq 1 \wedge I_4^{(2)} < 1, \\ \alpha_1(I_4^{(2)} - 1)^{\alpha_2} & \text{for } I_4^{(1)} < 1 \wedge I_4^{(2)} \geq 1, \\ 0 & \text{for } I_4^{(1)} < 1 \wedge I_4^{(2)} < 1. \end{cases}$$



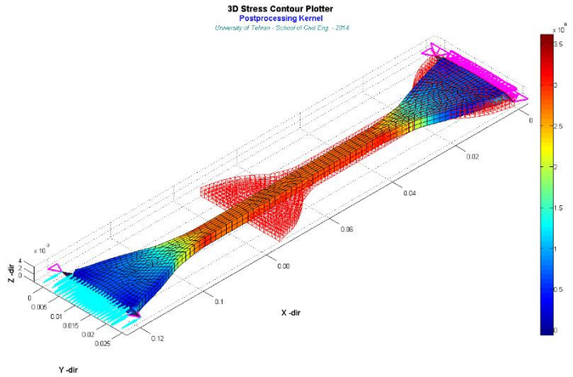


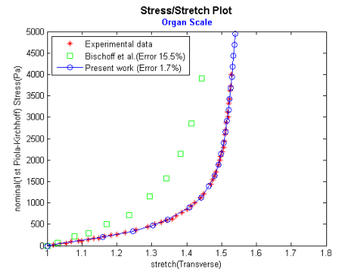


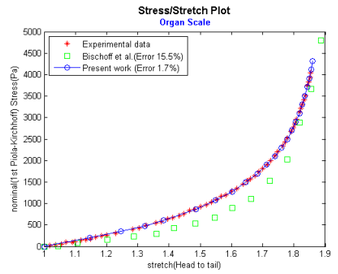


-Skin:

$$\Psi = \frac{1}{4}\sum_{r=1}^{s}\mu_r\left\{\frac{1}{\alpha_r}\left(\exp\left[\alpha_r\left(\tilde{I}_r - 1\right)\right] - 1\right) + \cdots \right.$$
$$\left. \frac{1}{\beta_r}\left(\exp\left[\beta_r\left(\tilde{J}_r - 1\right)\right] - 1\right) + \frac{1}{\gamma_r}\left(III_c^{-\gamma_r} - 1\right)\right\} + \frac{1}{2}\kappa(J-1)^2$$

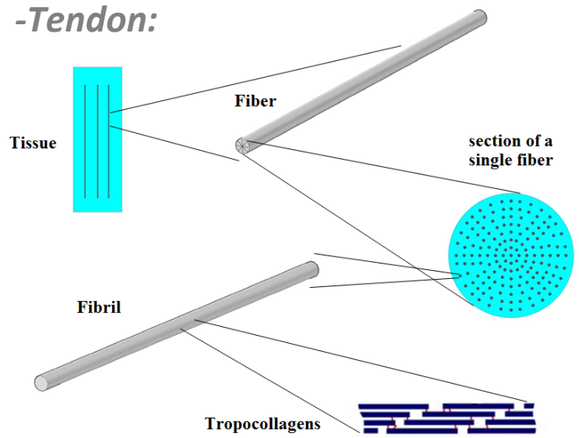


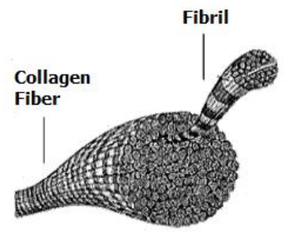




Multiscale analysis:

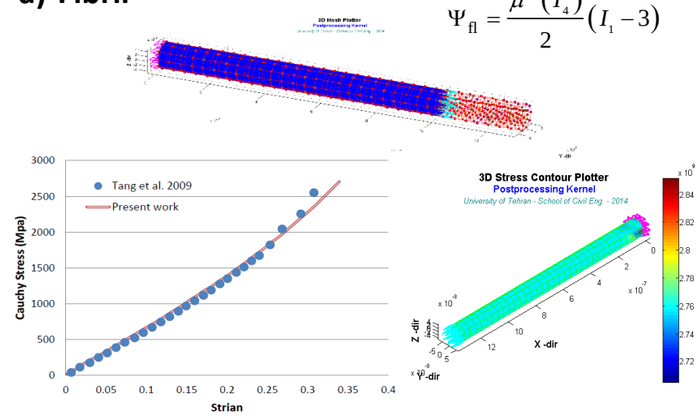
-Tendon:





a) Fibril

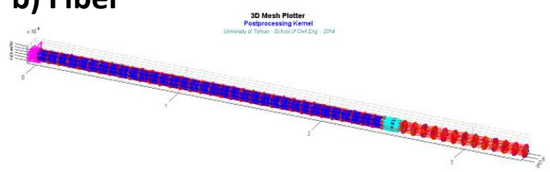
$$\Psi_{\text{fl}} = \frac{\mu^{\text{fl}}(I_4)}{2}(I_1 - 3)$$

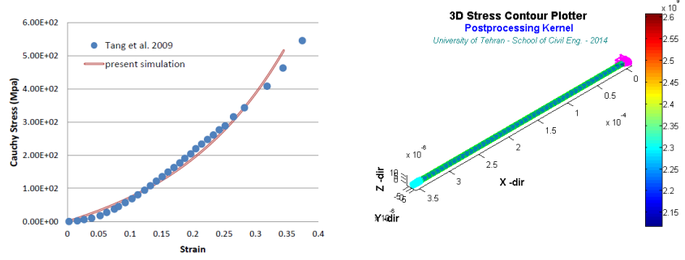


$$\Psi_{\text{fiber}} = \upsilon^{\text{fl}}\Psi_{\text{fl}}\left(I_1(\mathbf{F}_{\text{f}}), I_4\right) + \upsilon^{\text{fm}}\Psi_{\text{fm}}\left(I_1(\mathbf{F}_{\text{f}})\right) + \Psi_{\text{s}},$$

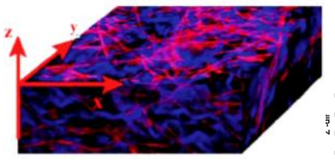
where $\Psi_{\text{fm}} = \frac{\mu^{\text{fm}}}{2}(I_1 - 3)$ and $\Psi_{\text{s}} = \frac{\mu_{\text{eff}}^{\text{fb}}}{2}\left[I_1 - I_1(\mathbf{F}_{\text{f}})\right]$

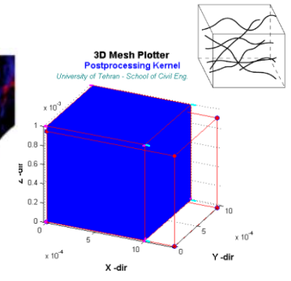
b) Fiber

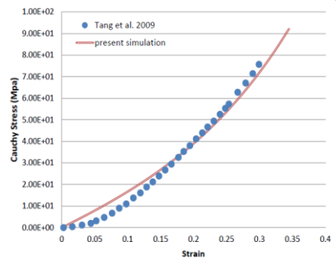
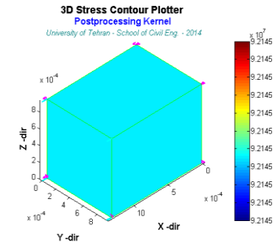




c) Tissue







$$\Psi_{\text{tissue}} = \upsilon^{\text{f}}\Psi_{\text{fiber}} + \upsilon^{\text{m}}\Psi_{\text{m}} + \Psi_{\text{s}}$$