GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1998

Bioengineering
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

- **Please sign your name on the back of this page—**

Please **print** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

Bioengineering Qualifying Exam Spring 1998

1. Flow through an artificial heart valve can influence hemodynamics.

a. What are the primary biological drawbacks of the current design of artificial heart valves?

b. Describe the flow characteristics just downstream of the stenosis.

c. How can pressure drop across the valve be measured or estimated?

d. Under what conditions would you expect turbulence to occur?

e. How can turbulence be characterized and quantified?

Bioengineering Qualifier Written Question

2) The micropipette aspiration technique is a standard method for determining the mechanical properties of cells. As in most techniques, the underlying model determines the type of data and how it is interpreted. In the micropipette experiments, a simple relationship is desired between the experimentally measured parameters (pressure, ΔP, and aspirated length, L), the pipette diameter, R, and the mechanical properties of the cell.

Part a: Given that the relationship between radial strain, circumferential strain, and radial stretch ratio is $e_r - e_\phi = 0.5(\lambda_r^2 - 1/\lambda_r^2)$ for this model applied to red blood cells, what are the assumptions implicit in this relation?

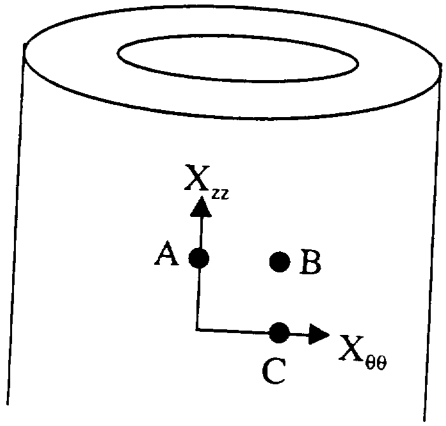
Part b: The equation relating measured parameters to unknowns for the red blood cell micropipette aspiration studies is $\Delta P = \frac{\mu}{R}\left[\left(\frac{2L}{R} - 1\right) + \ln\left(\frac{2L}{R}\right)\right]$, where $L > R$. What is μ in this equation and what are the assumptions implicit in the derivation of this model?

Part c: Given the assumptions above, how would you determine if the model was an accurate description of the actual physical system? Please describe an experiment that could be performed to answer this question. Name an experiment or situation in which this model would not hold.

3. Biosolid Mechanics

The coefficients of a deformation gradient can be determined from the movement of three points marked on the surface of a cylindrically shaped biological tissue under externally applied loading conditions.

$$Aij = \begin{bmatrix} 1.4 & .02 & 0 \\ .02 & 1.2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



A. The relationship between the deformed (x_i) and reference coordinates (X_i) is given below. A_{ij} represents the deformation gradient. What does the term b_i represent?

$$x_i = A_{ij} X_j + b_i$$

B. Find all non-zero components of the Green strain tensor, E_{ij}, and the corresponding infinitesimal strain tensor, ε_{ij}.

C. You would like to determine stresses in the biological tissue using a strain energy density function approach. Compare and contrast the material behavior assumptions associated with the strain energy density functions given below. Are there any assumptions common to all of the functions? Based on what you know about the biological tissue above, which of the strain energy density functions would you select and why?

1) $\rho_0 W = a_1\, E_{\theta\theta}{}^2 + a_2\, E_{\theta\theta} E_{zz} + a_3\, E_{zz}{}^2$

2) $\rho_0 W = a_1\, \varepsilon_{\theta\theta}{}^2 + a_2\, \varepsilon_{\theta\theta} \varepsilon_{zz} + a_3\, \varepsilon_{zz}{}^2$

3) $\rho_0 W = a_1\, E_{\theta\theta}{}^2 + a_2\, E_{\theta\theta} E_{zz} + a_3\, E_{zz}{}^2 + a_4\left(E_{\theta z}{}^2 + E_{z\theta}{}^2\right)$

4) $\rho_0 W = a_1\, E_{\theta\theta}{}^2 + a_2\, E_{\theta\theta} E_{zz} + a_3\, E_{zz}{}^2 + a_4\, E_{\theta\theta}{}^3 + a_5\, E_{\theta\theta}{}^2\, E_{zz}$
$+ a_6\, E_{\theta\theta}\, E_{zz}{}^2 + a_7\, E_{zz}{}^3$

5) $\rho_0 W = C \exp\left[a_1\, E_{\theta\theta}{}^2 + a_2\, E_{\theta\theta} E_{zz} + a_3\, E_{zz}{}^2 + a_4\left(E_{\theta z}{}^2 + E_{z\theta}{}^2\right)\right]$

6) $\rho_0 W = a_1\, E_{\theta\theta}{}^2 + a_2\, E_{\theta\theta} E_{zz} + a_3\, E_{zz}{}^2 + a_4\left(E_{\theta z}{}^2 + E_{z\theta}{}^2\right)$
$+ C \exp\left[a_5\, E_{\theta\theta}\, E_{zz}{}^2 + a_6\, E_{\theta\theta}\, E_{zz} + a_7\, E_{zz}{}^2 + a_8\left(E_{\theta z}{}^2 + E_{z\theta}{}^2\right)\right]$

where C & a_i are coefficients