Orthopedic Biomechanics
Fall 2017

MINI MATLAB PROJECT 2
DUE IN CLASS ON OCT. 24

Bone implants, such as hip replacements, often change the stress distribution within a bone.

In this project, we will examine the effect of a steel implant placed in the medullary cavity of a femur on the stress distribution in the proximal femoral diaphysis using asymmetric composite beam theory.

We will examine this for 5 implant locations (including no implant) over 3 test cases:

1. A *homogenous* young bone
2. A *homogenous* old bone
3. A *heterogeneous* young bone in which the Young's Modulus is a function of the local bone mineral density (BMD)

In all cases, the bone is subjected to a pure moment with components (using the coordinate system in Figure 1): $M_y = 46\ Nm; M_z = 28\ Nm$

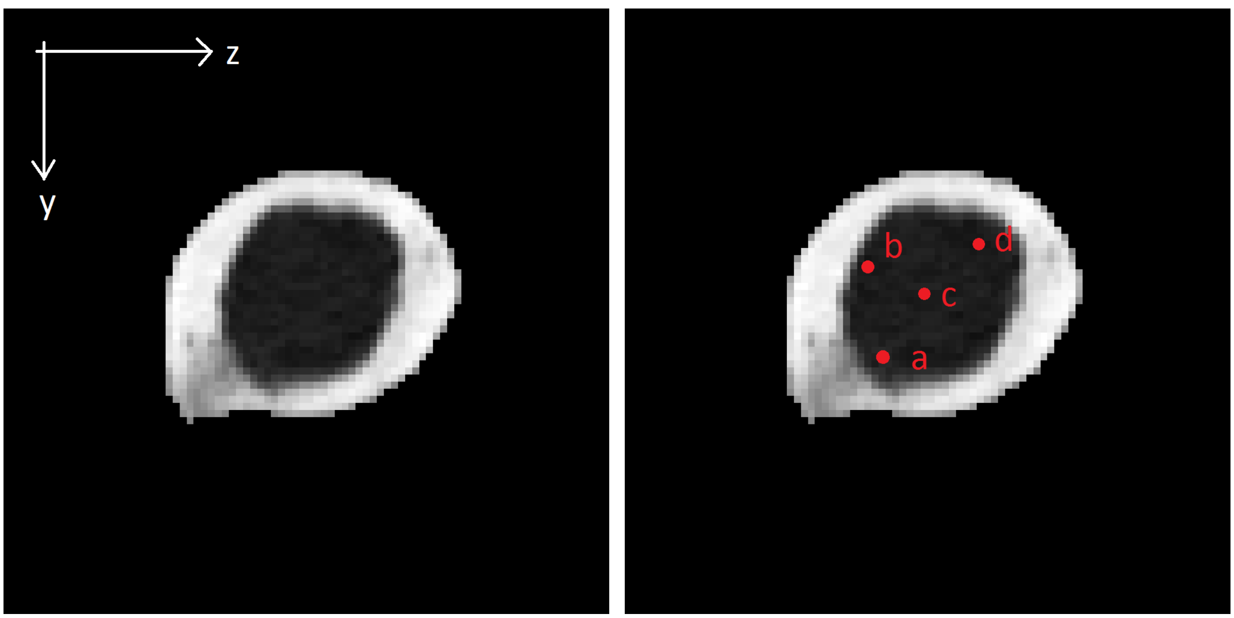

FIGURE 1. (LEFT) CROSS SECTION OF A FEMORAL DIAPHYSIS, APPROXIMATELY 10 MM BELOW THE LESSER TROCHANTER. (RIGHT) POSSIBLE LOCATIONS OF THE STEEL ROD IMPLANT.

On bCourse, you will find the MATLAB file **asymmetric.m,** the above left image (**femur.png**), and the steel implant cross section (**implant.png**).

Implant.png is an 8-bit grayscale (0-255) image. It is 86 × 86 pixels and has a resolution of 0.78 mm/pixel. A grayscale value (GS) of 0 represents a bone mineral density (BMD) of $0g/cc$. A grayscale value of 255 represents a pixel BMD of $2g/cc$. Assume BMD varies linearly with grayscale value:

(i.e. BMD $= \frac{2}{255}GS$)

Implant.png shows the implant cross section with the center highlighted in red. It measures 15 × 15 pixels and, like **femur.png**, has a resolution of 0.78 $mm/$pixel.

Presently, **asymmetric.m** plots the femur.png image and calculates the BMD weighted centroid. Assume the elastic modulus of the steel implant is 200 GPa.

The steel rod implant center locations are (z, y) listed below with corresponding location in the MATLAB image matrix A(i,j):

Point A: $(28.08\ mm, 38.22\ mm)$ → A(50,37)
Point B: $(26.52\ mm, 28.86\ mm)$ →A(37, 35)
Point C: $(32.76\ mm, 31.98\ mm)$ → A(41, 43)
Point D: $(15.60\ mm, 25.74\ mm)$ → A(34, 51)

For cases 1 and 2 (homogenous bones):

Consider only cortical bone. To do this, threshold the image such that you only consider bone with BMD over 1 g/cc (grams per cubic centimeter). Anything under $1g/cc$ is considered to be empty space.

Assume the young bone has an elastic modulus of 17 GPa.

Assume the old bone has an elastic modulus of 13 GPa.

For case 3 (heterogeneous bone):

1. The modulus of bone is related to the BMD with the following relationship:
   $$E_{bone} = a \cdot (BMD)^b \quad \text{(Equation 1)}$$
   This is of the same form as the power relationships of ultimate stress (Figure 3.18 in textbook).
2. Using two extreme values of BMD and E_{bone}, determine coefficients a and b in Equation 1.
   i. $(BMD,\ E_{bone})^{[1]} = (0.26\ g/cc, 1.107\ GPa)$
   ii. $(BMD,\ E_{bone})^{[2]} = (2\ g/cc, 17\ GPa)$

Some General Hints

Recall that MATLAB stores its rows as the first index and columns as the second index. Additionally, MATLAB starts its numbering at 1.

It may be easiest to edit **femur.png** to show the plate (using an image editing program or even MATLAB). However, you will need to differentiate between implant and bone.

Alternatively, you can use a separate image (of same size as **femur.png**) to keep track of the implant cross sections and then superpose that image with **femur.png**.

Your specific tasks for this project are to:

1. [45 Points] Fill out the table* (see below)
2. [10 Points] For the heterogeneous young bone case with an implant located at D, plot the stresses (using *contourf()*) throughout the bone *and* the steel implant. Make sure to also include the neutral axis, and a colorbar legend.
3. [10 Points] For the heterogeneous young bone case with no implant, plot the stresses (using *contourf()*) throughout the bone. Make sure to also include the neutral axis, and a colorbar legend. For comparison purposes, *use the same stress scale as in part 2!*
4. [30 Points] Write a one page (1.25 spacing) discussion. Specifically include at least a paragraph on:
   a. From part 2 and part 3, compare distribution of tensile/compressive stresses and implications for bone fracture.
   b. Stress shielding and its implications on bone remodeling (with implant versus without).
   c. Long term effects for an implant located at A, versus an implant located at C.
   d. Which implant location is ideal and why.
5. [5 Points] Attach your commented MATLAB code.

*For the table, max stress refers to the maximum *tensile* stress *in the bone*. Express max stress *as a percentage of the "no implant" case* ***for that location***. Express all locations in millimeters using the coordinate axis in Figure 1 – i.e. the upper-left corner is (z = 0, y = 0).

		Implant Center Location				
		A	B	C	D	No Implant
Homog. Young	Normalized Max Stress					100 %
	Max Stress Location (z,y)					
	Centroid Location (z,y)					
Homog. Old Bone	Normalized Max Stress					100 %
	Max Stress Location (z,y)					
	Centroid Location (z,y)					
Heterog. Young Bone	Normalized Max Stress					100 %
	Max Stress Location (z,y)					
	Centroid Location (z,y)					