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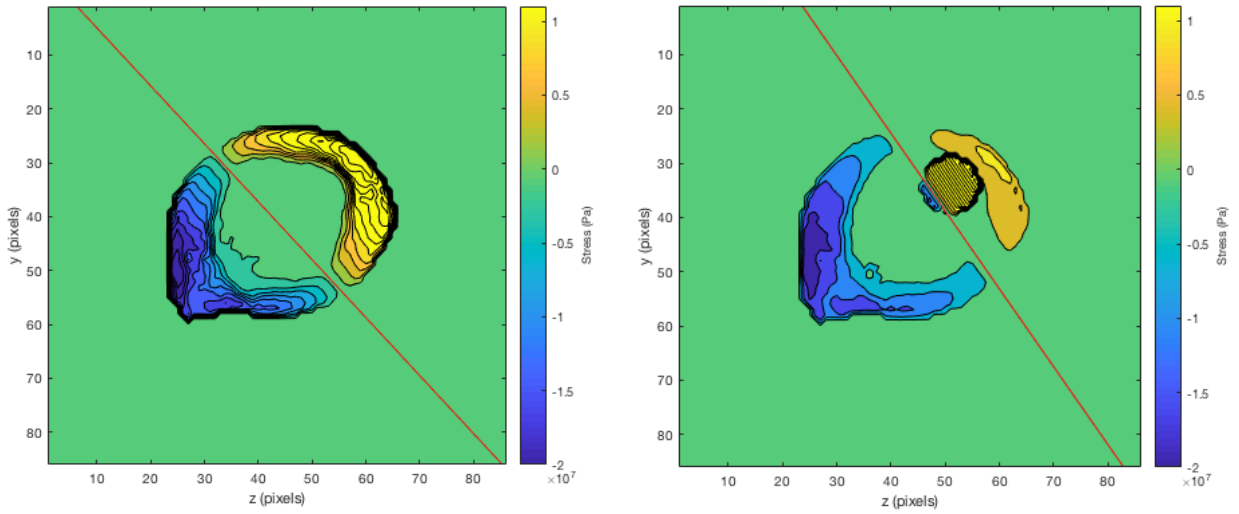
ME 176

Mini MATLAB Project #2

(left) Contour plot of stresses in heterogeneous young bone without implant
(right) Contour plot of stresses in heterogeneous young bone with implant at position D (34, 51)



4)

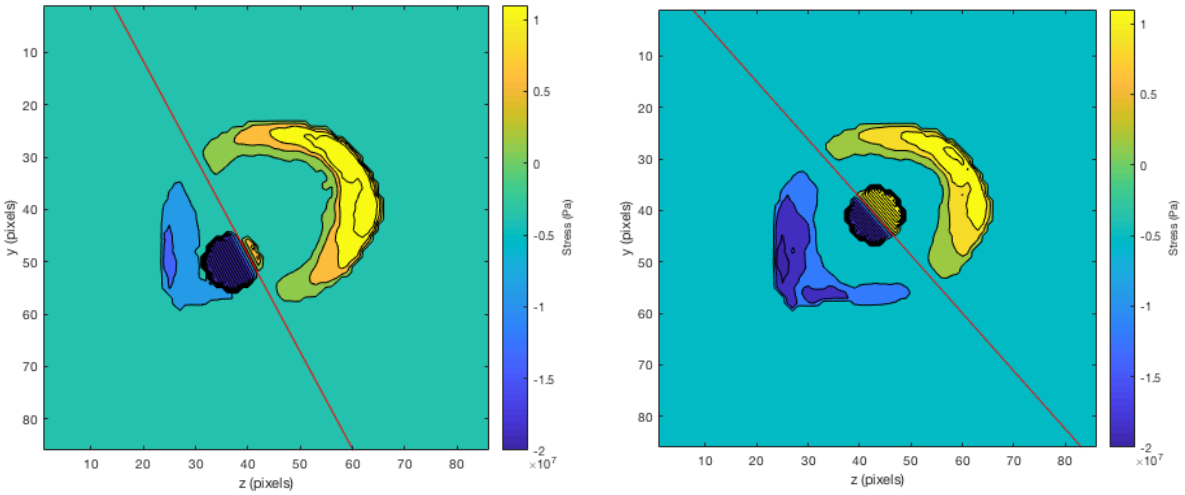
a) In the plot above without an implant (call this plot A), the neutral axis splits the femoral diaphysis cross section in two, fairly even sections. On the other hand, the addition of the implant (call this plot B) shifts the neutral axis toward the implant location so that more of the bone is under compressive stress than tensile stress. The magnitude of stresses in plot A is highest in the regions farthest from the neutral axis as expected, but the implant's significantly higher Young's modulus skews the stress equation so that the implant experiences the highest stresses despite being close to the neutral axis in plot B. As a result, the implant takes a significant amount of stress off the portion of the bone that originally was under tensile stress. This is reflected graphically by the shrinking of the bright yellow contour bands in the bone from plot A to B (no implant to implant added). Less of the bone is under tension, which is a benefit because bone is stronger under compression than tension and thus less likely to fail. However, there is also stress shielding… (next part)

b) The bone also experiences lower levels of stress overall due to the implant, and this stress shielding (osteopenia) is detrimental in the long term because the decrease in typical bone stress leads to reduction in bone density. By Wolff's law, bone remodels according to the stresses it experiences, which means that a reduction in stress is reflected by a reduction in bone density because there is less stimulus for remodeling to maintain the original bone mass.

c) An implant in position C is more beneficial in the long run than an implant in position A, despite both having similar normalized max stress percentages. This is due to the stresses they shield the bone from:

Position A is in the area of the femur cross section expected to experience compression, whereas position C is close to the center.

(left) Contour plot of stresses in heterogeneous young bone with implant at position A (50, 37)
(right) Contour plot of stresses in heterogeneous young bone with implant at position C (34, 51)



This means that an implant in position A would relieve the bone of more of its compressive stress rather than tensile stress, leaving the bone to shoulder the brunt of tensile stress. The implant location also pulls the neutral axis farther from the cross-section's center, skewing the stress distribution so that more bone is under tension. Bone is weaker under tension than in compression, making this an unfavorable situation.

However, an implant in position C would relieve both compressive and tensile stress (shown in plots above). The neutral axis' location does not change significantly from the no implant case, which means that the bone is still evenly split between compression and tension. The bone would still experience typical loads (albeit at a slightly lowered magnitude), which is good for bone remodeling.

d) Position B is the ideal implant location (or at least under this loading condition for M_y and M_z). This isn't intuitive because the first instinct would be to put the implant close to the femur's center to achieve radial symmetry, but from the calculations, the normalized max stresses with the implant at B are closest to 100% for the different bone cases (hetero/homogeneous, young/old). Insertion of a steel implant inevitably takes some stress off the bone as part of load transfer asymmetric beam biomechanics, but close-to-100% normalized max stresses indicate that an implant at B does not change the original stress distribution as significantly as putting the implant at the other locations. The bone would experience similar typical stresses post-implantation at B, which is important for bone remodeling so that the bone will not experience a reduction in bone density (explained in part b).