COBEM-2017-1273
MECHANICAL CHARACTERIZATION OF A CELL BY AFM: COMPUTATIONAL APPROACH

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Abstract: Living cells are subjected to mechanical stimuli during all their lifetime. The cellular responses to these stimuli have an important role in cellular behavior. Although, how they respond or convert these signals are open questions. It is known that some cells do not work correctly with some alteration in its physiological stiffness and that makes this parameter crucial to cell functions. Then, the mechanical model proposed here can give us an insight into inner stress-strain distribution and cell structures that are more important to maintain the cell stiffness during AFM (Atomic Force Microscopy) tests.

Keywords: Cellular Mechanics, Mechanical Stimulus, Cell Stiffness, Mechanical Model, Structural Properties.

1. INTRODUCTION

Cells are subjected to mechanical stimuli all the time during their lifetime. These stimuli may originate from the external environment or come from the cellular functions themselves (Lim, *et al.,* 2006). The cellular response to these stimuli has a crucial role in cellular behavior, such as cell adhesion, growth, migration and differentiation (Tartibi, *et al.*, 2015). The mechanisms by means of cells resist these stimuli and how they are converted into biological signals are still open questions in cell mechanics (McGarry and Prendergast, 2004).

Suresh (2006) studied the elasticity of red blood cells (RBCs) and discovered that RBCs infected by malaria-inducing parasite P exhibit higher stiffness than healthy RBCs (Lim, *et al.,* 2006). The cellular stiffness is associated with cellular motility because cells with high stiffness have more difficult to migrate. Therefore, infected RBCs will have more difficult to migrate and consequently it will bring a lot of problems in the human body due to its high stiffness. Thus, mechanical models could give an insight into the structural properties of the cells and an understanding of cell mechanics. Then, it could be possible to create more efficient medicines and/or techniques that attack specifically pathologies.

Basically, there are two type of cell modeling. Considering all the inner structures as Newtonian fluid (Tartibi, *et al.*, 2015), or it is modeled some of the internal structures like cytoskeleton (composed by microtubules and microfilaments), nucleus and cytoplasm (McGarry and Prendergast, 2004). To make possible modeling cells under mechanical stimuli there are some methods to probe mechanical properties of the cell. The most common physical methods are bulk rheology, magnetic bead cytometry, traction force microscopy, AFM, microrheology and whole cell stretching (Kasza, *et al*., 2007)

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2. COMPUTATIONAL PROCEDURE

Our computational models were proposed in Abaqus. They represent an adherent cell under concentrated force as in an AFM (Figure 1).
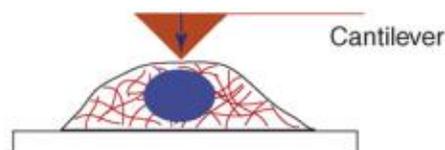

Figure 1: Guide do understanding the AFM mechanism (Kasza, *et al*., 2007)

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It was created two models in two different approaches. The first one was an axisymmetric model with membrane and cytoplasm (treated like a Newtonian fluid) of an adherent cell.

The second one was a 3D model with membrane, cytoplasm, nucleus (both treated like a Newtonian fluid) and cytoskeleton (composed by microtubules and microfilaments). We were adding structure by structure and simulating the load trying qualitatively to identify the influence of each structure in the mechanical behavior of the cell.
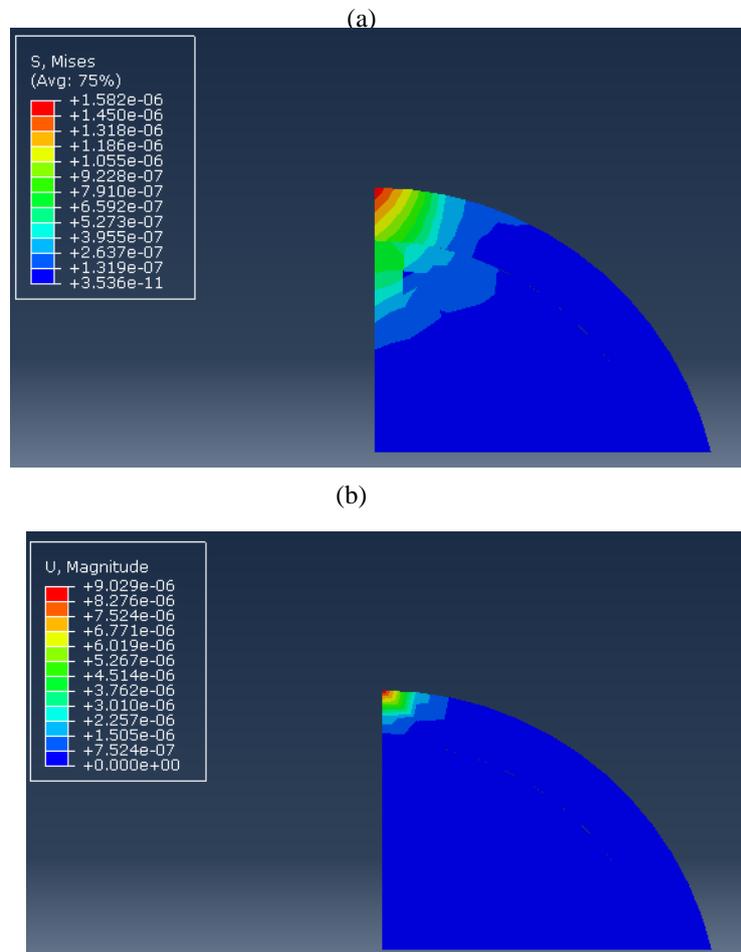
3. RESULTS AND DISCUSSION

(a)

(b)

Figure 2: (a) Cell stress under a concentrated force. (b) Cell strain under a concentrated force.

Figure 2 (a) and (b) show the stress and strain in the adherent cell when it is applied a concentrated force by the axisymmetric model. This model helped to understand the inner stress distribution giving qualitatively information about the location of high stresses during the stimulus. Then, to verify if the model was giving coherent results it was compared its strains with the experimental data of an AFM from Tartibi *et al.* (2015). The results were in the same order of magnitude. Therefore, the model is able, qualitatively, to give the stress-strain distribution and magnitude.

Adding structure by structure in the model it was possible to measure qualitatively the influence of each one for the cell stiffness using the same material properties used by McGarry and Prendergast (2008). Figure 3 shows the inner stress distribution when it is considered the cellular membrane, cytoplasm and nucleus. Like McGarry and Prendergast (2008) the model was able to show that some structures have more important roles than others. For example, in the model showed at Figure 3 if the concentrated load was applied in a point far from the nucleus the stress-strain distribution were quite differently. This proves qualitatively that the nucleus has a considerable influence in local cell stiffness. The structure with the most important role in cell stiffness is the cytoskeleton. When it is added cell stiffness changes substantially. Changing the location where the force is applied (with cytoskeleton in the model) it was noted more changes than when the cytoskeleton was absent. Furthermore, the results are in a qualitatively agreement with the computational results of McGarry and Prendergast (2008).
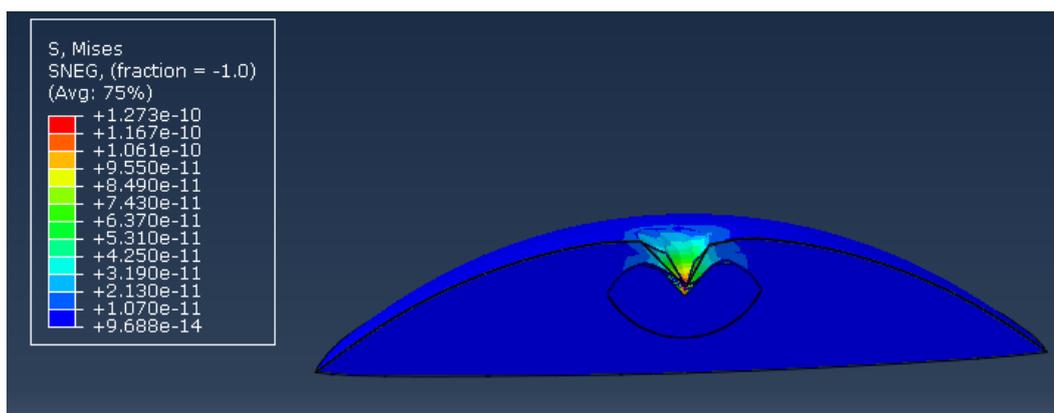
Figure 3: Inner stress distribution in an adherent cell by a 3D model
with cell membrane, cytoplasm and nucleus.

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4. ACKNOWLEDGEMENTS

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6. RESPONSIBILITY NOTICE