A POLYNOMIAL HYPERELASTIC MODEL FOR THE MIXTURE OF FAT AND FIBROGLANDULAR TISSUE IN FEMALE BREAST

José L. Calvo, Javier Martínez-Reina, Jaime Domínguez

Departamento de Ingeniería mecánica y de los Materiales, Universidad de Sevilla, España

Introduction

In adults, the female breast is composed of fat and fibroglandular tissue. In many cases, both tissues are intermingled, what makes the segmentation of both a hard problem. They can be treated as a composite tissue with a random distribution of each compound, at least in a first approximation. This work proposes a mechanical model for the behaviour of that composite tissue.

Methods

A simple FE model was built: a cube of equally sized elements, randomly assigned to fat or glandular tissue. Both tissues have been assumed as quasi-incompresible hyperelastic materials, modelled with a polynomial strain energy function with 5 constants, obtained from the literature [Samani et al., 2004]. Then, the suitability of the same polynomial model has been checked for the composite tissue. Several fat volume ratios (0%, 10%, 30%, 50%, 70%, 90% and 100%) have been analysed, with 8 FE models of different random distributions of tissues for each fat ratio. Each FE model was subjected to compression, tension and shear load cases and the constants of the polynomial model were fitted by minimizing the error committed in predicting the three load cases altogether. Two additional distributions of tissues have been simulated, with series and parallel layers arrangements of fat and fibroglandular tissue.

Results

The constants of the polynomial model were fitted for each FE model and the mean (shown in figures 1 and 2) and standard deviation was computed for each fat ratio in the 8 models with random distribution of tissues. Linear correlations were proposed between the 5 constants and the fat ratio. A comparison between random, series and parallel distribution was made.

Discussion

The small errors found in the fitting of the constants with the three load cases applied show the suitability of the polynomial model for the composite tissue, provided that the individual compounds are well modelled with a polynomial model.

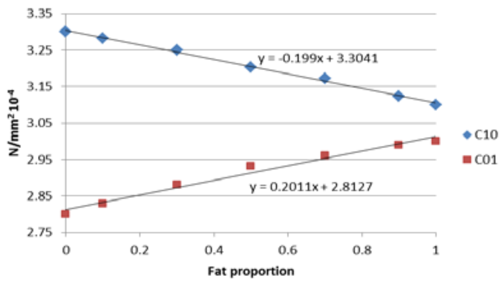

Figure 1:C_{01} and C_{10} for each fat ratio.

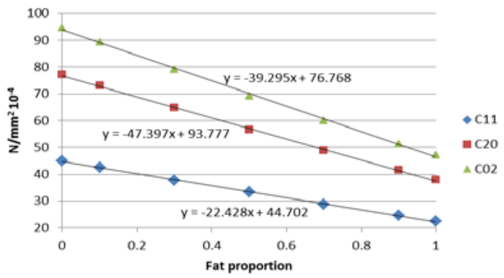

Figure 2: C_{11}, C_{20} and C_{02} for each fat ratio.

The mean values of the constants vary much with the fat content but the standard deviations are small, confirming that the fat volume ratio is a key factor in determining the properties of the composite tissue, but the distribution of fat is not. The parallel distribution has a similar behaviour to the random one, but the series distribution shows differences in some of the constants. These differences are being investigated in models of a real breast, where the distribution of tissues is somehow ramified. If this independence of the properties with the distribution of tissues is confirmed, modelling of the breast would be really simplified: only the fat ratio would be necessary and not the segmentation of both types of tissue.

References

A.Samani *et al*, Phys. Med. Biol., 49:4395-4405, 2004.