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MODELING OF LARGE GAUGE ARTERIES WITH A SOFT ELASTIC MEMBRANE PIPE FINITE ELEMENT

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ABSTRACT

A simple axisymmetric membrane pipe element models approximately the deformation of large gauge human arteries. This finite element bears on large radial displacements when a soft and highly elastic tissue is stressed by internal pressure. Its formulation assumes a simplified axially inextensible membrane pipe, where the radial displacement is coupled with the axial one by the axial inextensibility of the pipe element. The element formulation was achieved from the equivalent large displacement stretched membrane theory (by Lagrange equation) with a weak formulation by Green theorem leading to a low order axisymmetric finite element. An experimental set up was also built to allow the measurement of the radial expansion of the vessel model under static pressure.

Keywords: artery model, blood pressure, finite element applications, membrane pressure interaction, biomechanics.

INTRODUCTION

Large gauge arteries or veins are similar to a straight fluid conductor at some parts of the circulatory system, namely in the abdominal cavity. In this work, an axisymmetric finite element based on the concept of a self-sustained thin pressurized membrane was developed. The strain and stress formulation field bear on large displacements and strain dependent mechanical properties for the highly elastic material. About this last perspective, a synthetic material (UHU® universal high-tech sealant: http://www.uhu.com/fileadmin/user_upload/pdf/produktkatalog.pdf), was selected for an experimental simulation of the strain and artery model distortion under hydrostatic pressure. The equilibrium equations for the infinitesimal element refers only to the radial direction, as the deformed shell geometry contributes with incremental values of the axial force projected over the radial direction; on other hand, the internal shell forces are in balance along the axial direction without first order incremental values, so generating a redundant equation for the internal force equilibrium.

RESULTS AND CONCLUSIONS

A sample of results for the axial section artery profile is depicted next (Figures 1 and 2). Pipe-artery model dimensions and properties are as follows:

Internal section radius r = 9mm; pipe thickness h = 2,5mm; pipe length L=200mm.

Polymer properties: Young Modulus E=0,673MPa.

Pressure from water pressure at 5m height (pipe-artery at internal pressure 50 KPa).

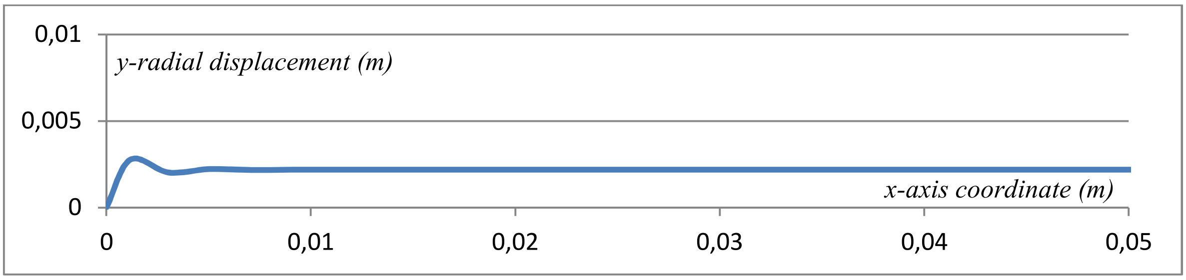

Fig. 1 - One pressure increment: radial displacement is 2.18mm (pipe detail at one edge: x=50mm)

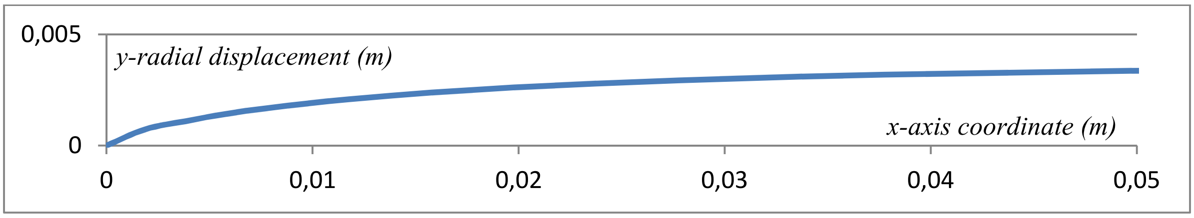

Fig. 2 - 100 pressure increments: radial displacement is 3.53mm (pipe detail at one edge: x=50mm).

Results from experiment with 5m water column height: maximum radial displacement 3,1mm.

Results with **Abaqus**® Software: 2.8mm.

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