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Analysis of Blood Flow through Viscoelastic Blood Vessel

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Abstract - Analysis of viscoelastic material can be done through ansys multi physics software. For modelling viscoelastic materials, prony series coefficients had been generated from the stress relaxation data (shear modulus vs. time) using prony series curve fitting. Also, Ansys was used to study the fluid interaction on viscoelastic materials.

First blood vessel was modelled using geometric modeller and it is exported to ansys and using prony series curve fitting, viscoelastic properties are given to the blood vessel. Blood flow was modelled in CFX. Two way coupling was established between Ansys and CFX. And the boundary conditions such as pressure pulse and mass flow rate was given to the blood flow. Then the model was solved in CFX. And the variation of pressure, von mises stress and total mesh displacement along the length of blood vessel is plotted.

***Keywords** - component; viscoelastic; prony series; two way coupling.*

I. INTRODUCTION :

For viscoelastic elements the combination of ideal liquid model and ideal spring model is used. The Maxwell element is a combination of a spring and a dashpot in series.

We consider the stress relaxation which occurs when the deformation is kept constant. At t = 0 the model is jump wise deformed to a strain ε. The instantaneous response is a stress $\sigma_0 = E \cdot \varepsilon$; the spring is strained, the dashpot does not yet respond. The dashpot is, at t = 0, subjected to the same stress, so it starts flowing, while it takes over an increasing part of the imposed strain so that the strain in the spring, and also the stress, decrease. [2]

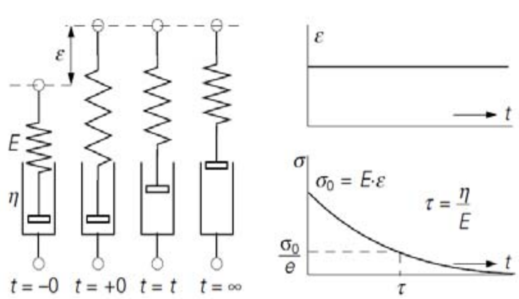

Fig.1: Stress Relaxation of a Maxwell Element

II. MODELLING OF BLOOD FLOW THROUGH VISCOELASTIC BLOOD VESSEL

For modelling blood flow through viscoelastic blood vessel, stress relaxation data is to be given. Using stress relaxation data, prony series curve fitting can be done and prony coefficients can be generated.

A. *Stress Relaxation Curve*

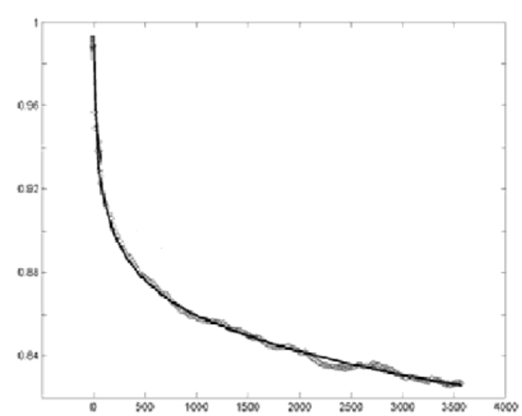

Fig.2: Stress Relaxation Curve

X-Axis: Time (s)

Y-Axis: Elastic Modulus (MPa) [7]

B. Data from the Curve

Sl. No	Time (s)	Elastic Modulus (MPa)	Shear Modulus (MPa)
1	100	.915	.305
2	200	.90	.3002
3	300	.89	.296
4	400	.885	.295
5	500	.879	.293
6	600	.872	.290
7	700	.866	.288
8	800	.862	.287
9	900	.861	.2871
10	1000	.860	.2868
11	1100	.859	.2865
12	1200	.856	.2855
13	1300	.854	.2848
14	1400	.851	.2838
15	1500	.850	.2835
16	1600	.850	.2835
17	1700	.849	.2831
18	1800	.848	.2828
19	1900	.845	.2818

Table.1: Data From Stress Relaxation Curve

C. Wall Modelling [7]

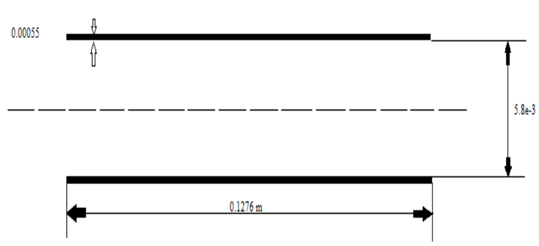

Fig. 3: Wall Modelling

1) Material properties:

Blood Vessel: Density: 1050 kg/m^3

Elastic Modulus: 0.4e6 Pa

Poisson's Ratio: 0.499

Blood: Density: 1040 kg/m^3

Dynamic Viscosity: 0.004 Pas [7]

D. Modelling Of Viscoelastic Blood Vessel

The geometric modelling of blood vessel was done in ansys workbench using geometry-design modeller. Only half section of tube was drawn for easiness. Then the geometry was exported to Mechanical APDL(ANSYS) as parasolid text. Viscoelastic properties are applied to the blood vessel using prony series curve fitting. Solid 8-node 185 was taken as the element type. Meshing of geometry was done.

Then boundary conditions were applied, both ends of the tube were constrained with no longitudinal movement and a node on both ends was fixed. Then symmetry was applied to the sectioned faces and fluid structure interaction on areas was done.

1) Viscoelastic curve fitting

a) Objective: Generate Ansys Prony Series model and Shift model coefficients from experimental data.

b) Input: Experimental data includes Shear Modulus as a function of time and bulk modulus as a function of time, the latter is optional.

c) Output: Two Prony Series data are generated one for Shear and one for bulk. The Experimental data and data generated from the calculated coefficients can be compared to estimate the quality of the curve fit.

The Coefficients are finally saved to Ansys database.

E. Solution Controls and Multifield Set Up

Analysis was conducted for a time period of 0.1seconds, which was being divided into 100 time steps. Each time step was further divided into 10 sub steps. Sparse direct was chosen as the equation solver. In order to get optimum convergence the maximum iterations were taken as 10 and equilibrium iterations were taken as 15.

Coupling of Ansys and CFX was done in the next step. The order of solution was such that CFX was solved first. The current file in Ansys was written as mechanical input file for CFX.

F. Fluid Modelling

Fluid modelling was done in Ansys Work Bench. The geometry was opened in geometry-design modeler and fluid was filled in the cavity. This geometry was coupled with the geometry of CFX. In the next step meshing of fluid was done using CFX mesh, after suppressing the solid part.

The already written mechanical input file was called by the CFX. The properties of blood were given to the fluid. The boundary conditions were applied to the fluid model, they are:

1) Pressure pulse was applied at the inlet. The pressure pulse also closely resembles sine wave which was given by the equation;

   18000[Pa]*step((0.1[s]-t)/1[s])*sin(pi*t/0.1[s]).

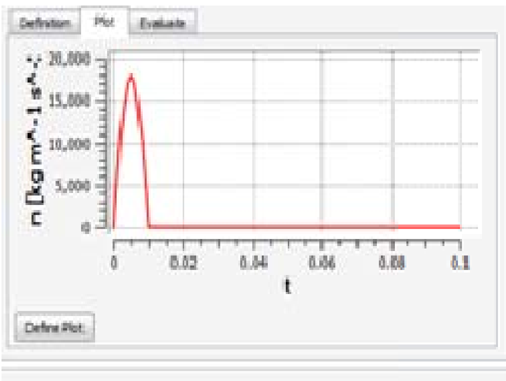

Fig .4: Pressure pulse

2) The fluid was assumed to be symmetric about the central longitudinal plane.

3) Fluid structure interaction was applied on areas of the fluid element which is in contact with the solid. The forces and displacements acting on these areas were transferred to the Ansys via multifield set up.

Then the model was solved in CFX and the results were obtained.

III. RESULTS

A. Pressure Variation

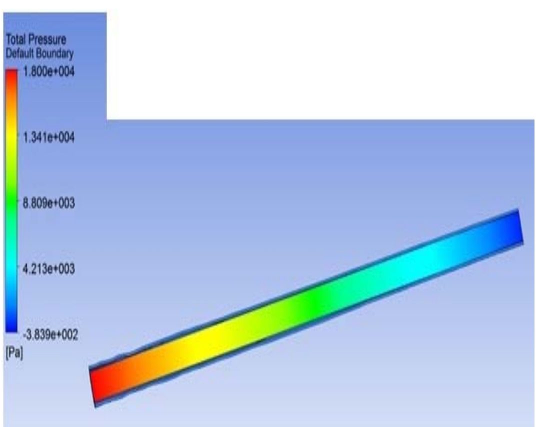

Fig.5: Pressure Variation

The figure shows the pressure variation along the length of blood vessel at time t=.005s. The maximum pressure obtained is 18 kPa.

B. Von mises stress

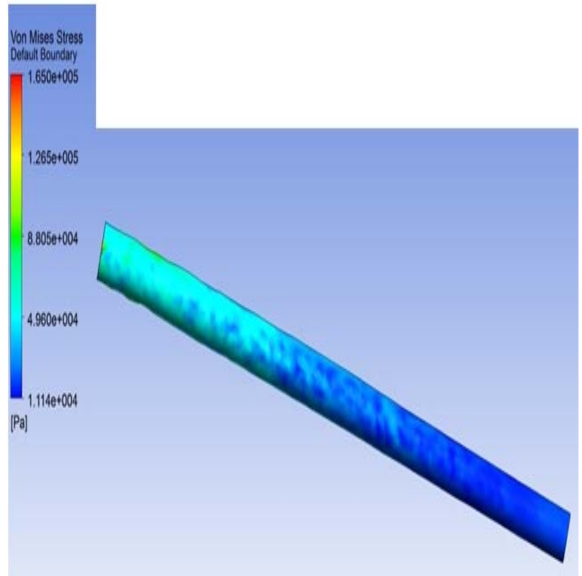

Fig.6: Von mises stress

The figure shows the Von mises stress variation along the length of blood vessel at time t=.005s. The maximum pressure obtained is 165 kPa.

C. Total mesh displacement

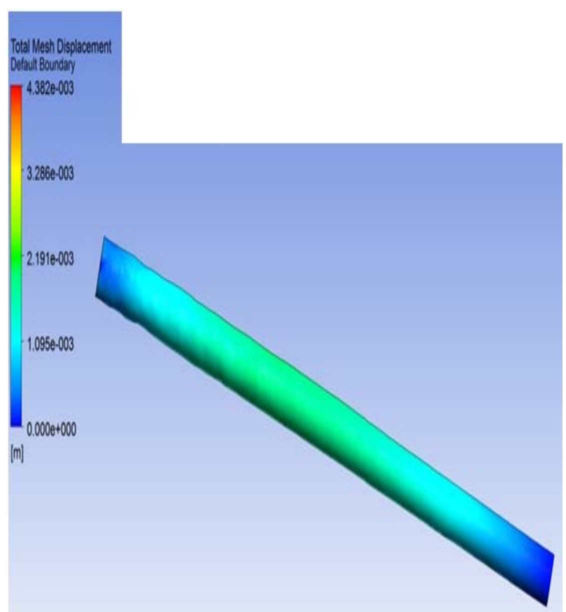

Fig.7: Total Mesh Displacement

The figure shows the total mesh displacement along the length of blood vessel at time t=.005s. The maximum mesh displacement obtained is 4.382 mm.

IV. CONCLUSION

A detailed study on the analysis of visco elastic materials had been conducted and modelling of viscoelastic materials had been done. Prony series curve fitting was used to model viscoelastic materials. Adequate study was done on prony series and its application on ansys. Then a viscoelastic blood vessel had been modelled using the above method and the results like von mises stress, pressure distribution and total mesh displacement were obtained. The same method can be used to determine other parameters related to blood flow.

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