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Blood Flow Analysis in Thoracic Aorta During Aneurysm

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Abstract: Blood flow measurement plays a vital role to identify and diagnosis of various diseases in different organs of the body. Depending on the change in geometry of aorta, blood flow rate will change depending on non- Newtonian fluid characteristics. Hence in this paper simulation of the aorta is designed and modulated using ANSYS 18.1 to calculate the shear stress of the thoracic aorta to identify aneurysm (weakening of aorta) which is major cause for coronary artery disease.

Keywords: ANSYS, Blood Flow, Thoracic Aorta, Aneurysm, Wall Shear

I. INTRODUCTION

ANSYS is a worldwide company which developed Multiphysics engineering simulation software for product design, testing and operation. ANSYS is a Finite Element Analysis software (FEA) which is use to solve the mathematical model for fluid flow, heat transfer, etc. Computational Fluid Dynamics (CFD) is use to analyze the problems which involves in fluid flow. Artery is a major blood vessel in our body. It is use to circulate oxygenated blood from heart to all other parts of the body, except pulmonary artery and umbilical artery. Aorta is a largest artery in our bo dy. Aorta consists of two sections such as thoracic aorta and abdominal aorta. The upper part of the aorta is known as thoracic aorta. The normal size of the aorta is between 3.5cm to 4.5 cm. It is present at heart and above the lungs diaphragm of human body. If the wall size of the aorta increases from 4.5cm to 6.5cm means it known as aneurysm part (defective). Aneurysm is cause by obesity, high cholesterol, smoking, high pressure, alcohol consumption. Due to aneurysm velocity of the blood gets decreases. It causes coronary artery disease, stroke, hyper tension, hypo tension and sometimes leads to sudden death. Hence if aorta aneurysm is find in earlier stage means doctors can cure this by giving proper treatment for blood pressure.

[1] The blood flow analysis had done for different shapes of aorta blood vessels; the variation in pressure is measured. The Navir Stokes and continuity equations are used to govern the flow of blood. [2] Aorta CAD model is created for normal aorta, aorta with plaque at descending side and aorta with bypass graft. The various parameters such as velocity, pressure and wall shear stress which affects the blood flow. It is useful at the time of bypass surgery to pre-defined the flow of blood. [3] The four different models of right subclavian artery are modelled. Complete and detailed analysis had done for the atherosclerosis conditions of the aorta. The evaluation of one cardiac cycle is studied. [4] The change in blood flow rate using waveform is investigated, the wall shear stress distribution in the aneurysms part is analysed. The comparison had made between steady state and transient blood flow. The valuable information can be provided by computational hemodynamic simulations. [5] The velocity variations in aorta with respect to time is measured. Using computational fluid dynamics, the aorta model of younger person is designed and analysed. Poisson's ratio and young's modules are taken to consideration and geometry model is created. [6] Biomechanics related functions of the aortic system from its geometric properties are experimented. The solution to the boundary value problems is identified using mechanical homeostasis in the vessel wall. [7] Using real case imaging data the parameter variations of aortic coarctation between normal and aneurysm aorta is studied. [8] The distribution of maximum principle stress in the aortic valve is studied using structural analysis. The basic saccular aortic aneurysm is created and studied. [9] Detailed analysis of aortic root aneurysm in the brachiocephalic trunk had done. Hence it helps to experiment the issues related to surgical treatment. The objective of this paper is to analyze the difference in blood flow rate for normal and aneurysm thoracic aorta using non-Newtonian fluid characteristics.

Section1 says about behaviour of non-Newtonian fluid with its principle. Section2 says about the geometrical properties of aorta with its dimensions. Section3 says about meshing process of aorta. Section4 says about properties of blood. Section5 explains about simulation output of aorta model.

II. NON-NEWTONIAN FLUID

Blood is non - Newtonian fluid. So, it doesn't obey the Newton law of viscosity. Hence velocity is not constant. Velocity is depending upon shear stress. Due to aneurysm wall of the thoracic aorta get increase, area become larger and shear stress decreases. Velocity and viscosity of the blood is directly proportional to the shear stress. So, velocity and viscosity of the blood get decreases. The following equation states the relation between shear stress and area.

$$\tau = F/A$$

Here, τ – Shear stress;
F – Force applied;
A – Cross sectional area

III. SIMULATION OF THORACIC AORTA USING ANSYS

1. Geometry: For the geometry of fluid flow analysis, we create geometry in ANSYS design modeller, or import the appropriate geometry file. The thoracic aorta is created using ANSYS sketching tools with the diameter of 4.5cm. Ascending thoracic aorta is look like hairpin bend which is called as aorta arch. The geometry model is also created for descending thoracic aorta. Aorta arch looks like an inverted 'U' tube structure. It contains one inlet & four outlets named as outlet, outlet1, outlet2, outlet3.Inlet has a diameter of 4.5cm, Outlet has a diameter of 4.5cm, Outlet1 has a diameter of 0.2cm, Outlet2 has a diameter of 0.15cm & Outlet3 has a diameter of 0.18cm, Aneurysm part diameter is 6cm

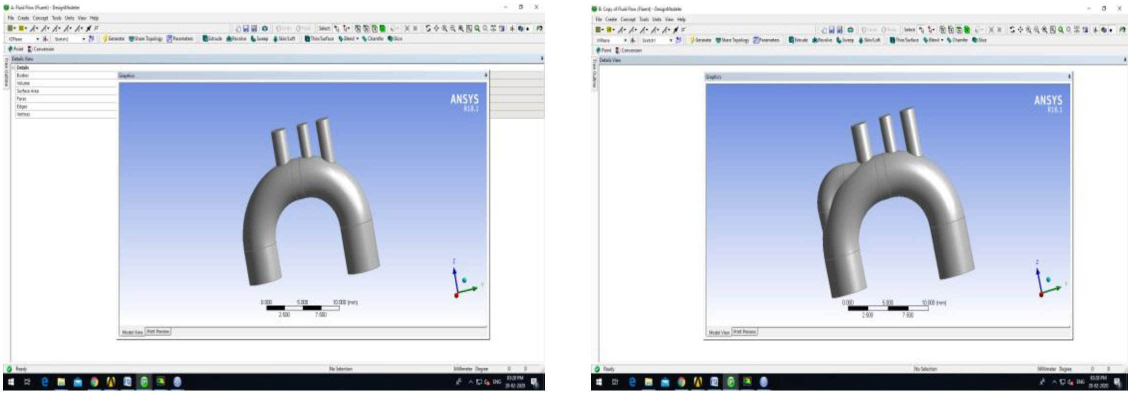

Fig.1 is a geometry representation of aorta arch without and with aneurysm.

Descending thoracic aorta looks like a 'straight' pipe structure. It contains one inlet and outlet part with a diameter of 4.5cm and has a length of 8cm, Aneurysm part diameter is 6cm

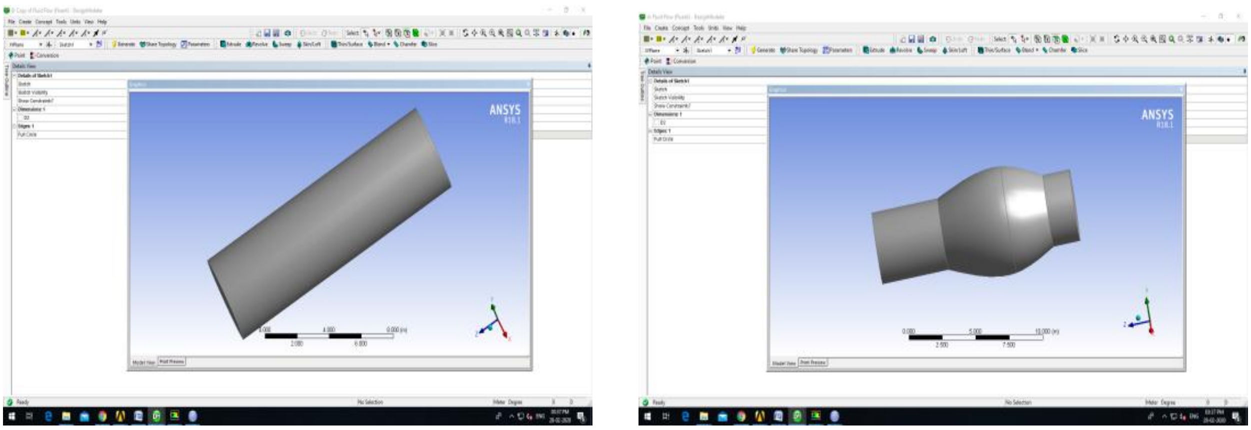

Fig.2 is a geometry representation of thoracic aorta without and with aneurysm.

2. Meshing: Meshing is an integral part of simulation process where complex geometries are divided into simple elements. Generation of mesh is used to create subdivisions in the thoracic aorta to analyze the fluid flow in thoracic aorta using finite element analysis. It consists of named sections such as input, output and wall.

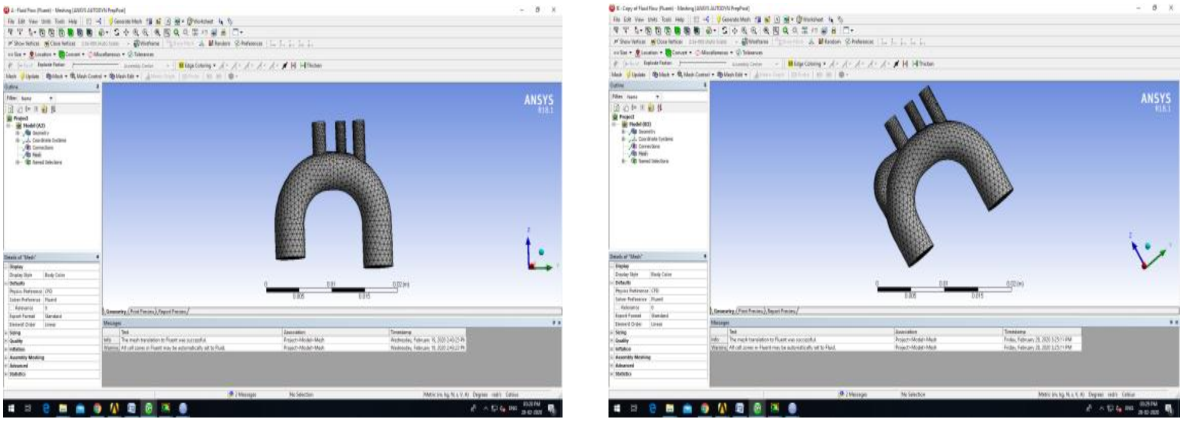

Fig.3 is a mesh representation of aorta arch without and with aneurysm.

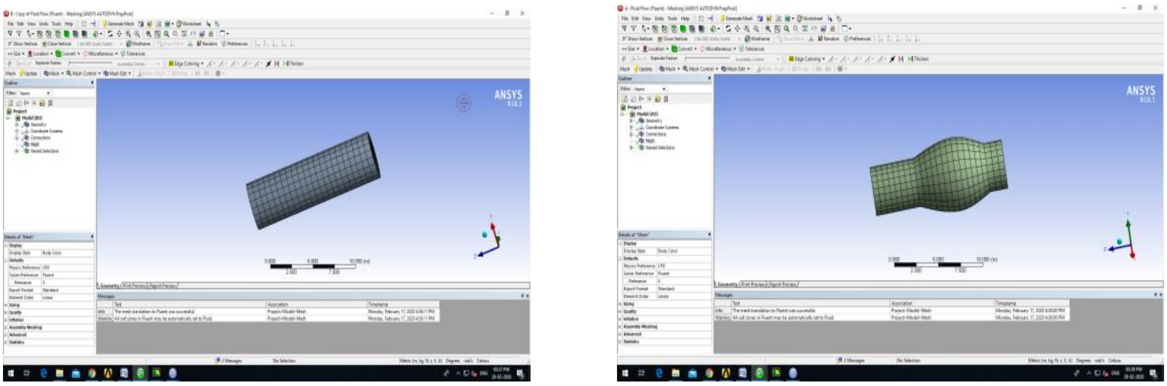

Fig.4 is a mesh representation of thoracic aorta without and with aneurysm.

3. Properties of Blood

Here fluid is treated as blood. The properties of the blood are mentioned here. Density of the blood is 1060kg/m^3. Specific heat of the blood is 3513 j/kg-k. Thermal conductivity of the blood is 0.44w/m-k. The velocity is considered to minimum at the age between 40 – 50 (0.25m/s). We consider inlet blood pressure as 10000pa (75mmhg) and outlet pressure as 16000pa (120mmhg)

4. Output Analysis

After initialization process, we get the result panel. Stream line is generated to view the velocity variations in blood flow with respect to created geometry model of thoracic aorta. Contour is use to show wall shear in wall of the thoracic aorta. Animation shows how the flow change occurs during normal and aneurysm stages of thoracic aorta.

5. Wall Shear Analysis

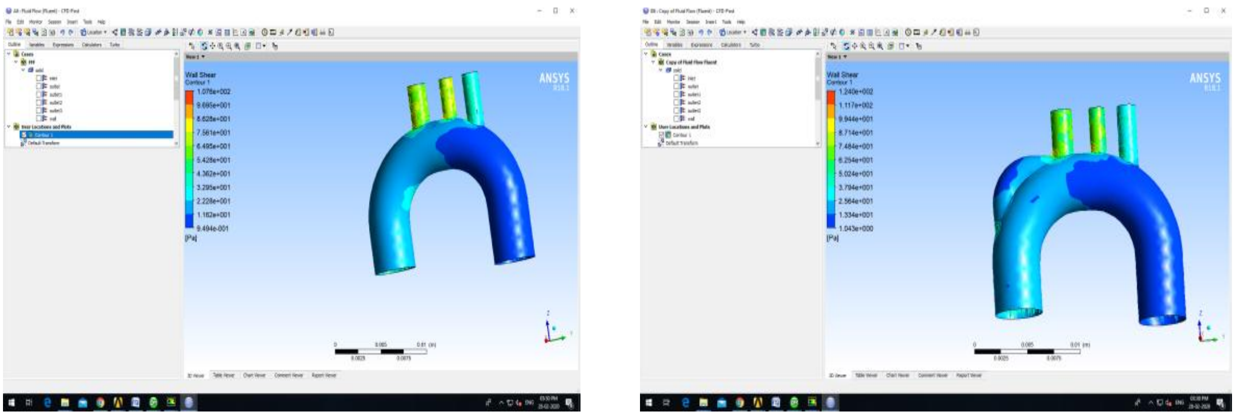

Fig.5 is a shear stress representation of aorta arch without and with aneurysm.

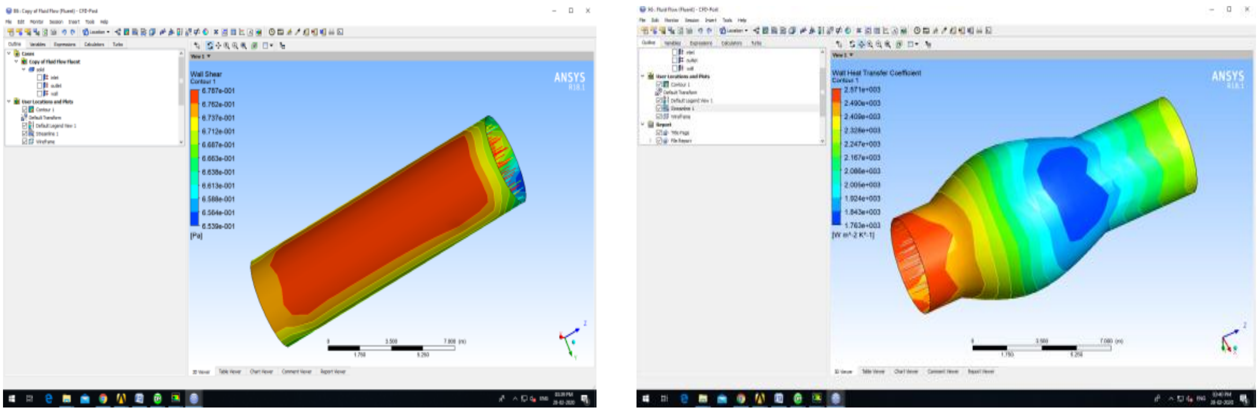

Fig.6 is a wall shear representation of thoracic aorta without and with aneurysm.

Using above obtained results it is clearly understand that wall shear changes due to aneurysm. Hence it causes change in velocity of blood flow with respect to change in viscosity of blood which is directly proportional to wall shear.

6. Velocity Analysis

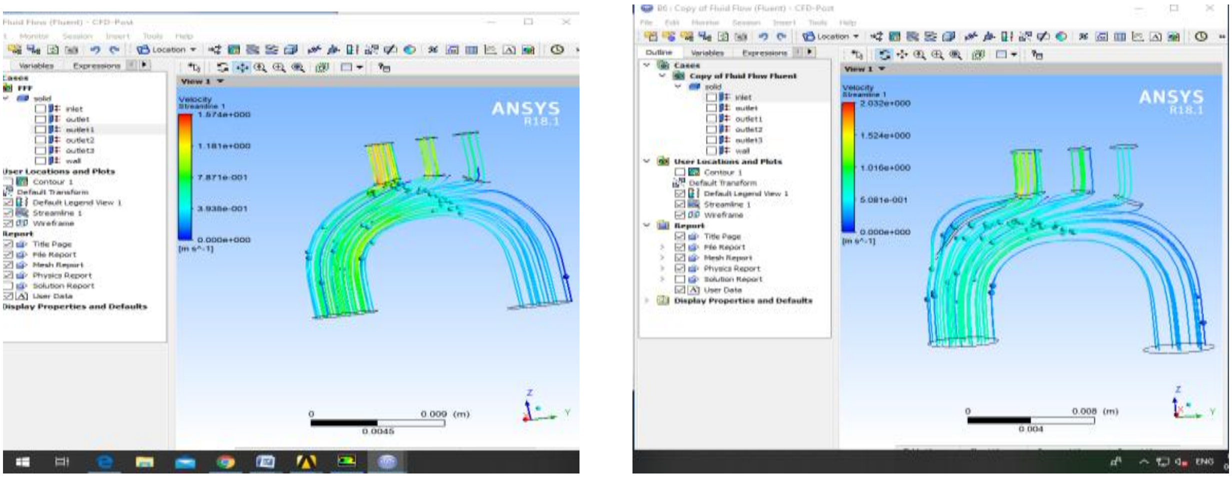

Fig.7 is a velocity representation of aorta arch without and with aneurysm.

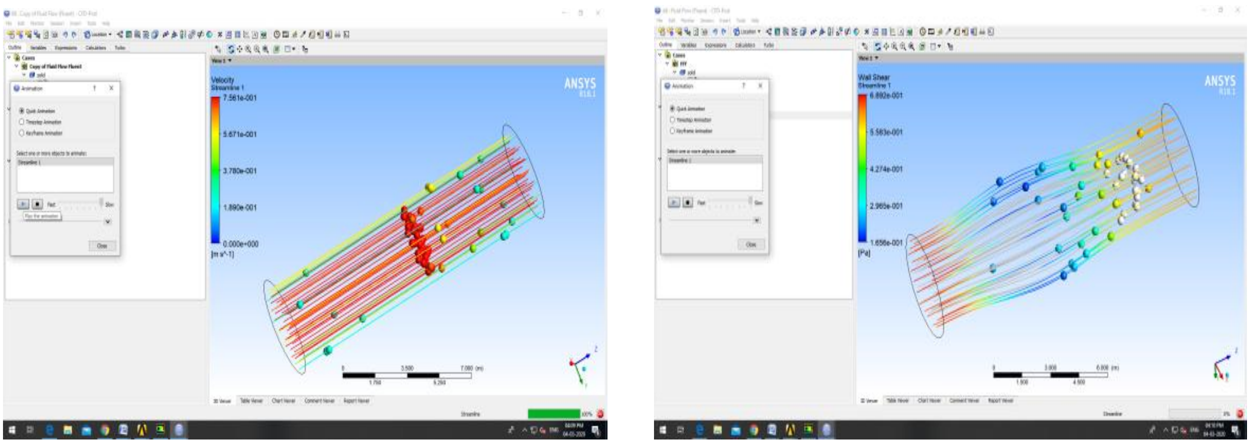

Fig.8 is a velocity representation of thoracic aorta without and with aneurysm.

From above obtained results it is clearly understand that velocity changes due to aneurysm. Hence it cause change in wall shear of the blood flow with respect to change in viscosity of the blood which is directly proportional to velocity.

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IV. RESULT

The wall shear stress of the thoracic aorta is inversely proportional to area of the thoracic aorta. Due to change in wall shear of the thoracic aorta blood velocity also change. From this we can examine the blood velocity is directly proportional to the wall shear stress depending on the characteristics of non Newtonian fluid.

V. CONCLUSION

This work demonstrates the behaviour of thoracic aorta subject to shear stress. From the results obtained, it is come to know that the variation in blood flow during aneurysm is examined. It is helpful for doctors to find the aneurysm stage of the thoracic aorta using difference in blood velocity. By analyzing the stage of aneurysm proper treatment should be given by the doctors such as treatment for pressure, open heart surgery, endovascular surgery, etc.

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