FLOW ANALYSIS OF 3D-PRINTED VENTILATOR SPLITTER FOR ACUTE RESPIRATORY DISTRESS SYNDROME CAUSED BY COVID-19

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Abstract - *Mechanical ventilation is a device used in a way to manufactures instruction, to achieve adequate oxygen delivery. If it goes on hospital contain such many patients then oxygen supply to hospital acquires more space in infrastructure. In alteration to oxygen, the perfluorocarbon is used in a modern laboratory and it has proven that it carries 10 times of oxygen than the normal oxygen supply by the ventilator. When at surface tension of air-liquid interface of the lung increase as in lung injury rather than perfluorocarbon has nitrogen as an inert carrier of oxygen and carbon dioxide offer an advantage to the treatment of acute lung injury. Due to this COVID-19 situation, the design of a ventilator tube with material ABS-Plastic and supply fluid as Perfluorocarbon is taken for CFD analysis and the result was taken to show better performance in it.*

Key Words: *Covid 19, Pandemic, Ventilator, Respiratory Distress, 3D Printed Ventilators.*

1. INTRODUCTION

Aquatic beings use the gills for liquid breathing, which the human being doesn't have one, and also human lungs must able to overcome the force of surface tension from the water on lung tissue during inflation in order to compliant, and greater surface tension cause the lower lung compliance. This indicates the little pressure difference in pleural pressure is needed to change the volume of the lungs. So the scientists had an idea to fill the lung with fluid instead of air to reduce the surface tension and facilitate ventilation. Mechanical ventilation is a technique in which the lungs are insufflated with the Liquid Perfluorocarbon rather than the oxygen-containing mixtures. So in this article ventilator tube used for liquid ventilation with perfluorocarbon is investigated and briefly explained.

2. MATERIAL CONSIDERATION

The Liquid Perfluorocarbon (PFC) which is used for liquid ventilation is a form of respiration air-breathing organism breaths oxygen-rich liquids such as perfluorocarbon rather than breathing air has proven perfectly suitable as a breathing medium, as it not only dissolves the high amount of oxygen but also acts as an anti-inflammatory for human tissue.

2.1Perfluorocarbon Liquids

Perfluorocarbon Liquids (PFCLs) are the serial of fluoro chemicals in which all hydrogen atoms are replaced by fluorine. Several kinds of Perfluorocarbons Liquids are applied in different countries they are,

PFO → Per fluoro-octane
Vitreon → Perfluoro-perhydro-phenanthrene
PFD → Perfluoro-decalin
PFTB → Perfluorotributylamine
PFOB → Perfluoro-rooctylbromide

2.2 Perfluorocarbon Properties

Characteristically PFCs have a high specific gravity range 1.76 to 2.03, low surface tension and viscosity range 3 to 4, these physical properties make the perfluorocarbon ideal for intra-operative in vitreoretinal surgery

3. CAD MODELLING

The solid model is designed in CAD software CATIA, which is owned by the Dassault System. It is a copper sweat edge bend tube so, there is one inlet valve having the same 22mm diameter as two valves joint into one valve tube to ventilator mask which is also 22mm diameter. This ventilator tube is designed to withstand the specific gravity, viscosity, and surface tension of the perfluorocarbon.

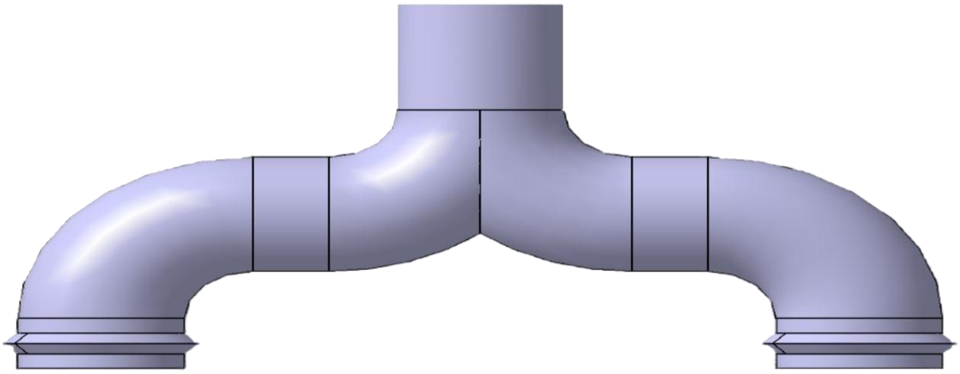


Fig 1: Ventilator Split modelled in CATIA Software

4. FLOW ANALYSIS

The designed model is converted into a suitable format for the analysis software as (stp, igs, step). Here the analysis is carried out in the ANSYS Fluent (Fluid Flow Analysis)

The STP format of the ventilator pipe is imported into ANSYS Fluent (Fluid Flow) as shown in figure2. After importing, the design file was opened in the geometry design modeller. After that ventilator pipe is sectioned in symmetry format to have a better view of analysis.

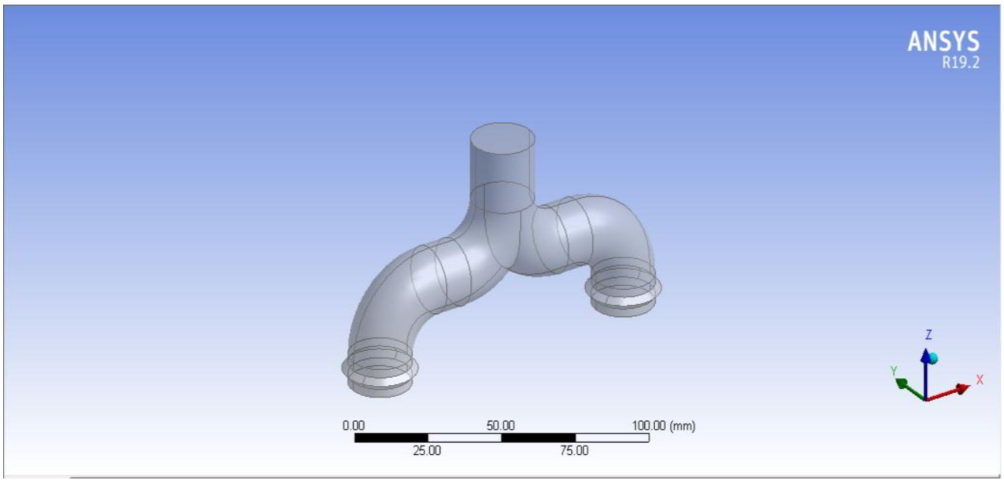


Fig 2: Ventilator Split modelled in CATIA Software

After the sectioned symmetry view is completed. Meshing is performed, here the mesh size is 2mm and an adaptive mesh sizing is given. Then, the boundary conditions are given to the faces to be exposed to velocity inlet and outlets, fluid body and symmetry.

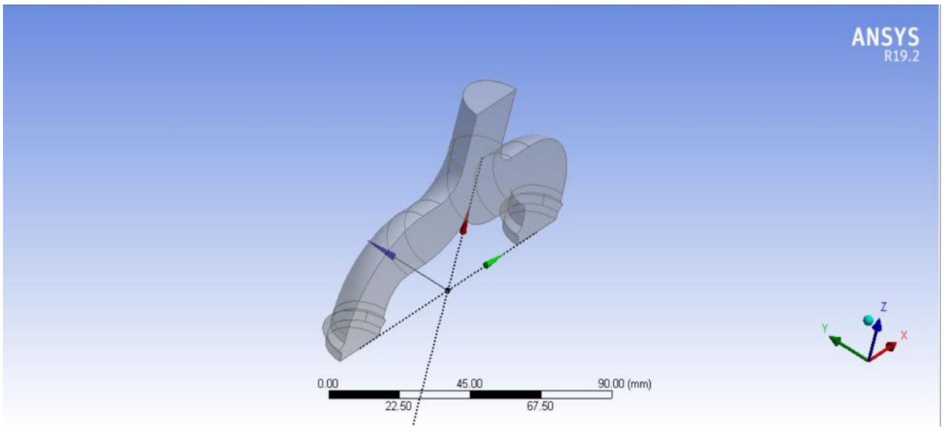


Fig 3: Sectioned Symmetry View

Here the flow type is taken as laminar by Reynolds number formula. The velocity is given under three values according to the patient conditions. After the report taken from patient have between 80-85 is considered as low so 55.2 lit/min supply is given or if it between 92-96 is considered as a medium so 37.2 lit/min supply is given or if it above 98 is considered as high and 25.2 lit/min supply is given. It was calculated by using Flowrate(v)= Tidal volume(Vt)/ Inspiration time(It). Finally, fluid material is taken as Perfluorocarbon and solid material is abs plastic.

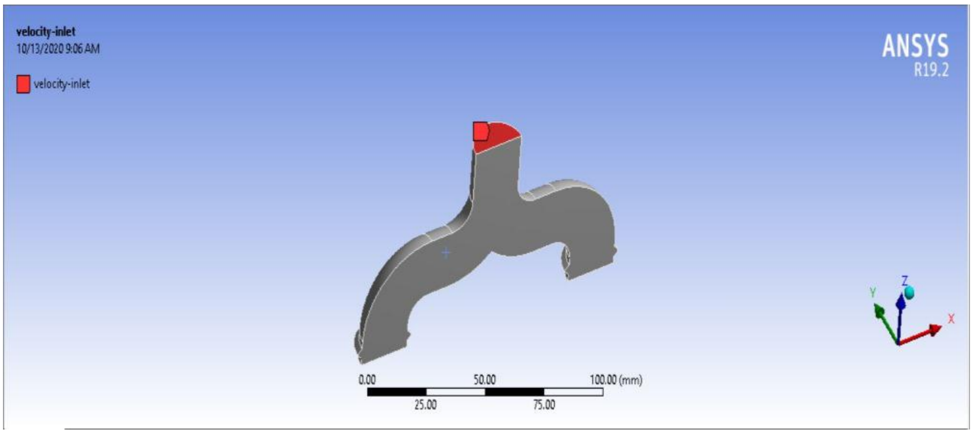
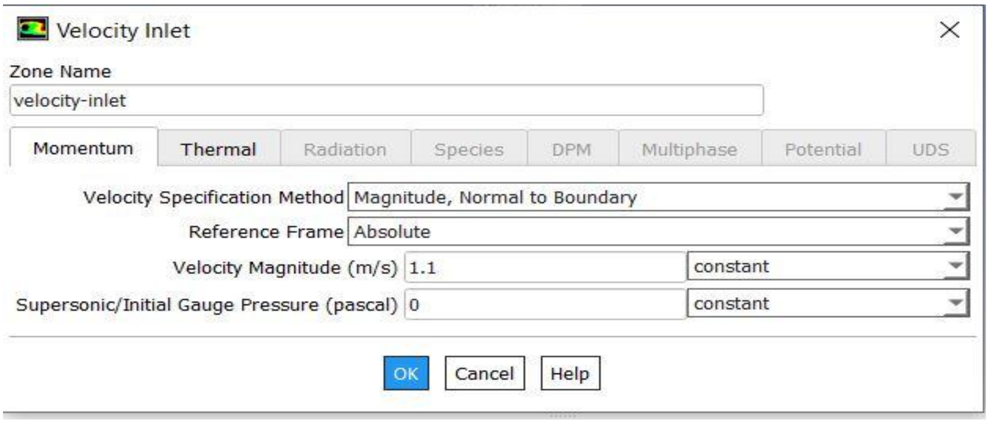


Fig 4: Velocity at Inlet

Here the three flow analysis is taken over for three different inlet values as 25.2lit/min, 37.2lit/min and 55.2lit/min.


Velocity Inlet

Zone Name: velocity-inlet

Velocity Specification Method: Magnitude, Normal to Boundary
Reference Frame: Absolute
Velocity Magnitude (m/s): 1.1 constant
Supersonic/Initial Gauge Pressure (pascal): 0 constant

Fig 4: Velocity at Inlet at 25.2lit/min

After that hybrid initialtion is done and result was taken for 20 iterations. Then post processing is done.

5. RESULT AND DISCUSSION

After the analysis is completed post processing is done. The output values are obtained compared with each other. The figure shows a comparison between the values.

5.1 SCALED RESIDUALS

The figure shows the scaled residuals on the ventilator pipe for Computational fluid dynamics and material abs plastic at different inlet velocity.

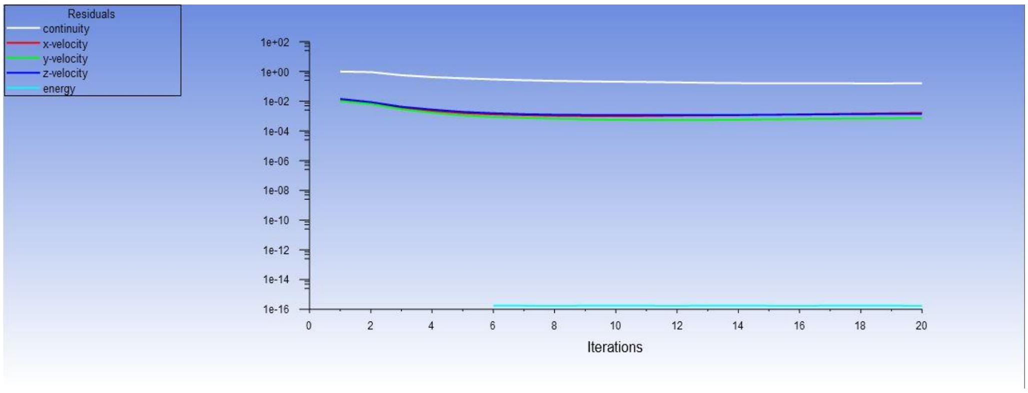


Fig5. Scaled residual for 25.2lit/min

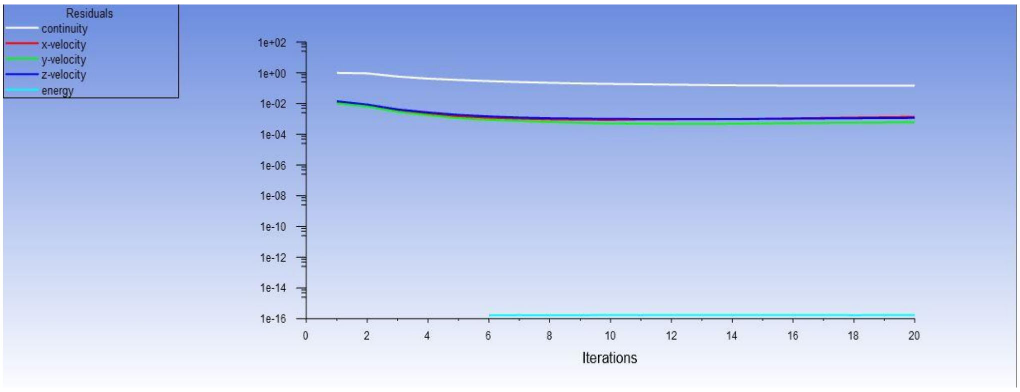


Fig6. Scaled residual for 37.2lit/min

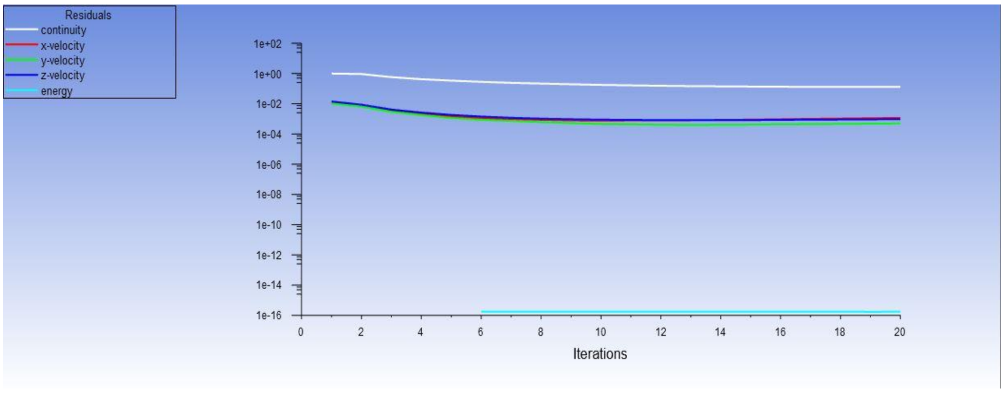


Fig7. Scaled residual for 55.2lit/min

5.2 PRESSURE CONTOUR

The figure shows the pressure contour on the ventilator pipe for Computational fluid dynamics and material ABS .

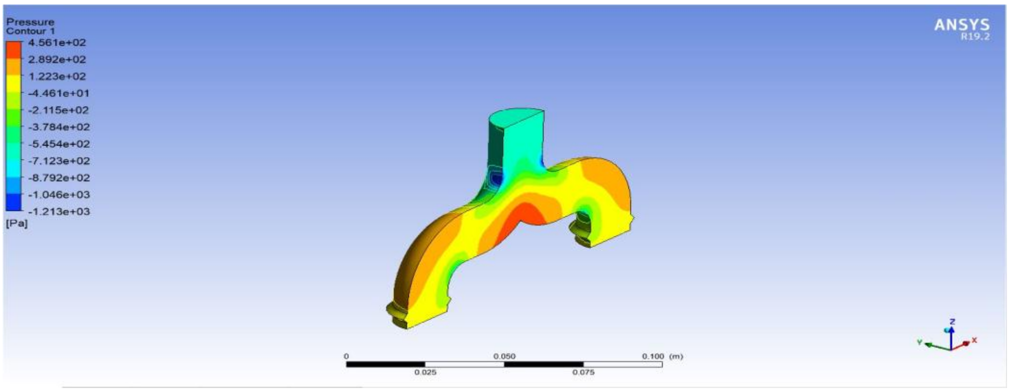


Fig8. Pressure contour for 25.2lit/min

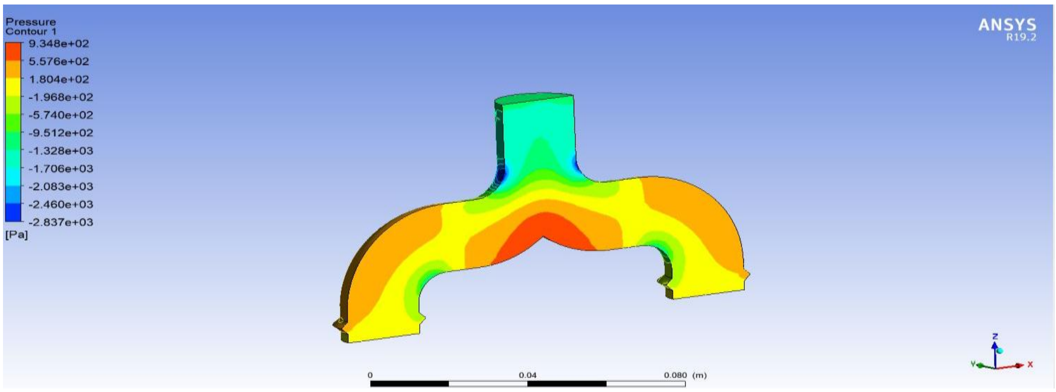


Fig9. Pressure contour for 37.2lit/min

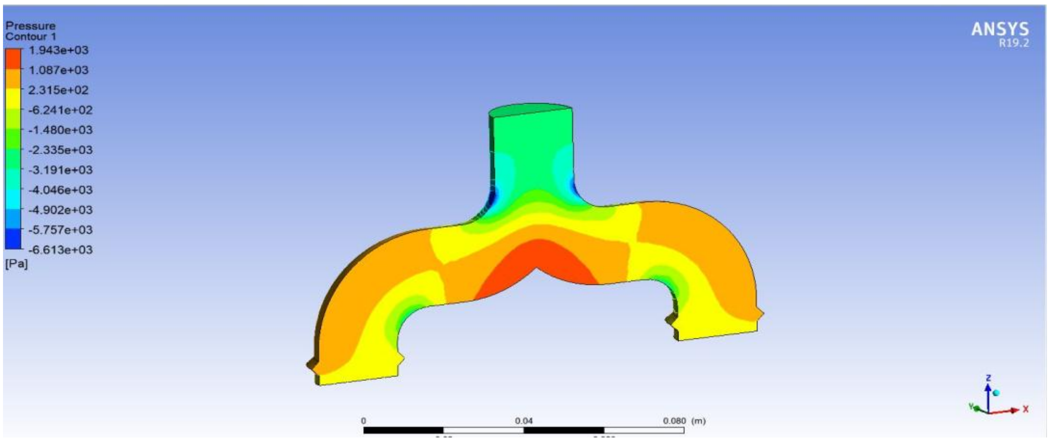


Fig10. Pressure contour for 55.2lit/min

5.3VELOCITY CONTOUR

The figure shows the velocity contour on the ventilator pipe for Computational fluid dynamics and material abs plastic

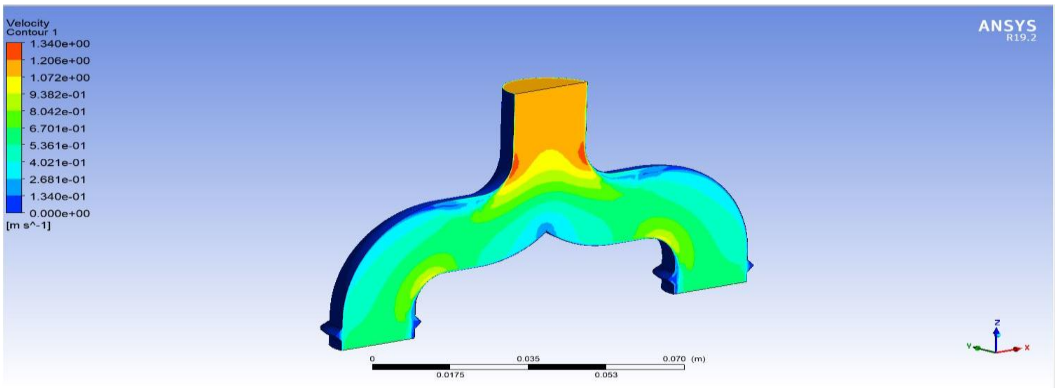


Fig11. Velocity contour for 25.2lit/min

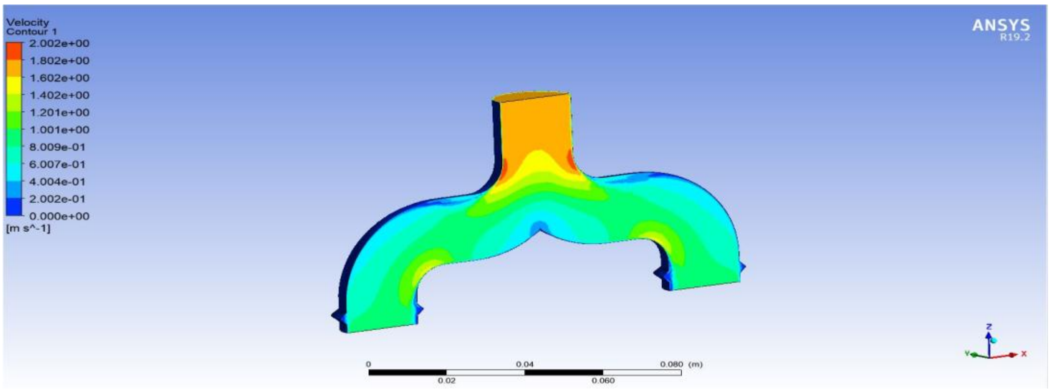


Fig12. Velocity contour for 37.2lit/min

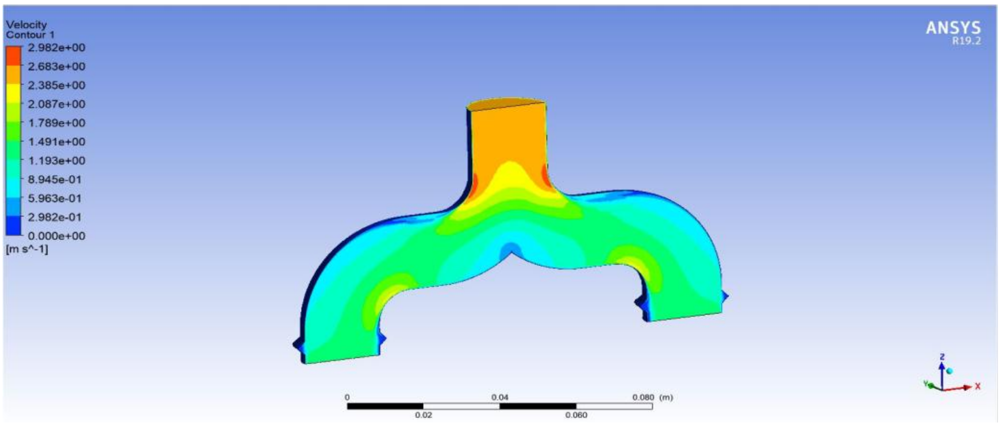


Fig13. Velocity contour for 55.2lit/min

Table-1. Comparison between various results

Parameters	**Low (25.2lit/min)**	**Medium (37.2lit/min)**	**High (55.2lit/min)**
Pressure	456.145 Pa	934.794 Pa	1942.63 Pa
Velocity	1.34029 m/s	2.00223 m/s	2.98156 m/s
Velocity U	0.90084 m/s	1.33176 m/s	1.96666 m/s
Velocity V	0.17764 m/s	0.22872 m/s	0.29003 m/s
Velocity W	0.30105 m/s	0.42522 m/s	0.55728 m/s
Wall Shear	9.604 Pa	15.588 Pa	24.715 Pa

6. CONCLUSION

From the above analysis, the outcome acquired is evident that materials abs plastic and perfluorocarbon are best to use in the mechanical ventilator tube respectively. The study was carried out in the Ansys fluent software and modeling is done by the CATIA software. Thus the analysis proves it the best combination to use in a mechanical ventilator.

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