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FLOW ANALYSIS OF EFFECT OF STRUTS IN AN ANNULAR DIFFUSER

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ABSTRACT

Some recent advances in computational gas dynamics of exhaust diffusers are presented. Numerical studies have been carried out for an annular type gas turbine exhaust diffuser with inlet guide vanes and with and without. Diffuser is the last expansion stage of the gas turbine used to increase the static pressure by consuming kinetic energy. A symmetric model of the entire section is considered and simulations are done to study the effect of struts placement on turbine efficiency. Numerical simulations were done to calculate the pressure recovery coefficient, for an optimum divergence angle of 13° by keeping the diffusion length as constant. In order to assess the effect of flow development within the passage, various flow conditions are applied and results are shown. The variation in inlet velocity is in steps of 40m/s from 80m/s to 200m/s. The outcome for with and without struts implies how the pressure recovery coefficient influence the efficiency of the turbine. Some individual ideas are also presented for consideration.

Keywords: Turbine efficiency, Annular diffuser, Exhaust diffuser, Struts, Numerical simulations, Gas turbine Pressure recovery coefficient

1. INTRODUCTION

A diffuser is a device that is generally applied to increase the pressure of fluid flowing through it at the expense of its kinetic energy. Along the direction of flow the cross section area of diffuser increases. As a result of which the fluid is decelerated as it flows through it which leads rise in static pressure along the stream. Applications of Annular diffusers can be largely seen in axial flow compressors and turbines where they convert the kinetic energy of the exhaust flow into pressure. This paper presents the performance of gas turbine annular diffuser in terms of pressure recovery coefficient measured in the scaled down model.

The recovery of static pressure in the exhaust diffuser of an industrial gas turbine is necessary and is brought about by decelerating the turbine discharge flow. Generally in turbines of current generation used for power generation the exhaust mach number ranges from 0.35 to 0.45 and variety of gas turbine models generate the power with output range between 5 and 53 MW with a resulting velocity of about 250 m/s and a kinetic energy of about 30 kJ/kg. The energy produced by a gas turbine is around 350 kJ/kg, and 10% of the energy of the entire turbine work wasted or lost at the exhaust by entering into surroundings. There weren't many citations regarding performance and flow investigation of exhaust diffusers in gas turbine. Various parameters of geometry are involved in proper designing of diffuser for obtaining optimum recovery of pressure and flow parameters.

A strut is generally designed to resist longitudinal compression of the members of the diffuser. They provide outwards-facing support in their vertical direction, which can be used to support shell and for other lubrication purposes. The presence of struts in annular diffuser may cause a flow blockage and overall performance of the diffuser is highly influenced by them.[2]

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2. GEOMETRICAL DETAILS

Diffuser Geometry Numerical investigations have been carried out in a gas turbine exhaust diffuser (Annular Diffuser) to study the effect of the divergence angle and the Reynolds number. A series of 24 guide vanes and 6 struts have been used, which provides a means of introducing swirl and aerodynamic blockage into the test section. The Diffuser assembly of the scaled down gas turbine exhaust diffuser with and without strut is as shown in Figure below. The geometrical details of 35% scaled down gas turbine exhaust diffuser is shown in below, where the diffusing length is 450mm, inlet and outlet diameters are 190mm and 320mm, respectively and half cone angle is 13°

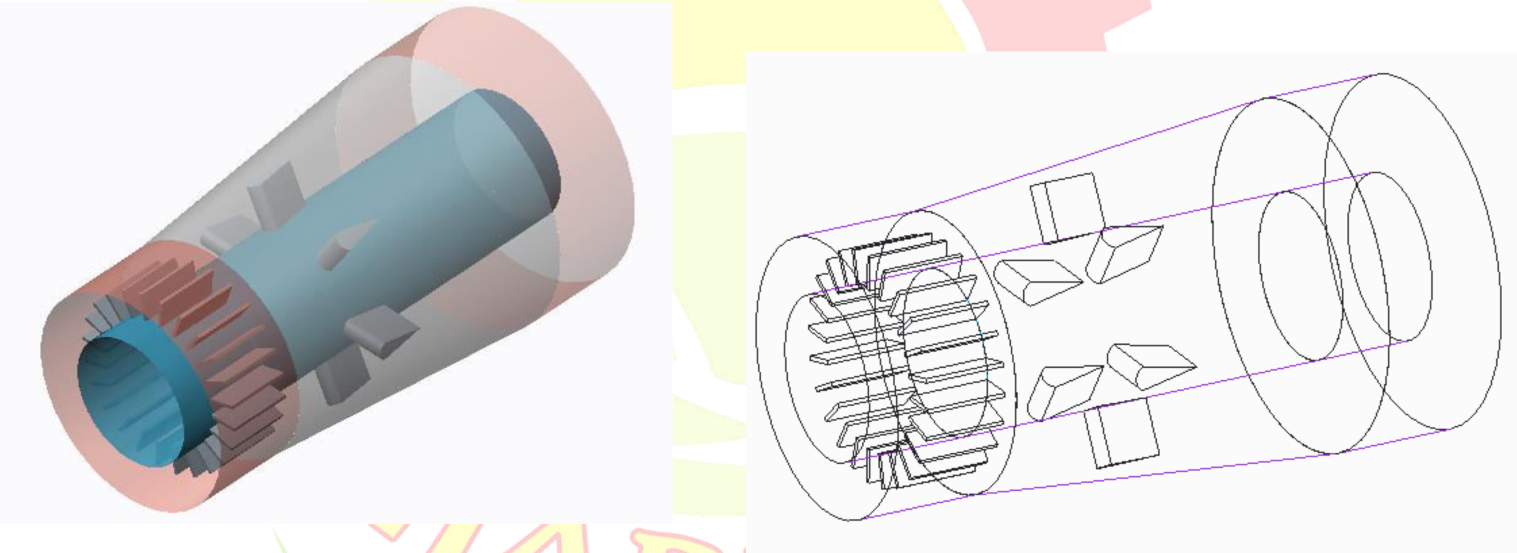
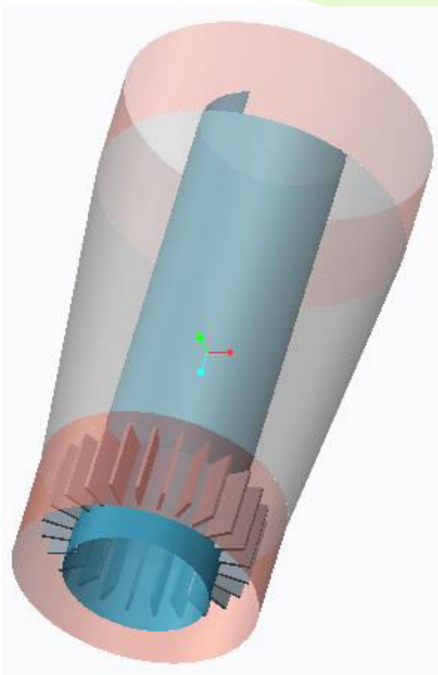
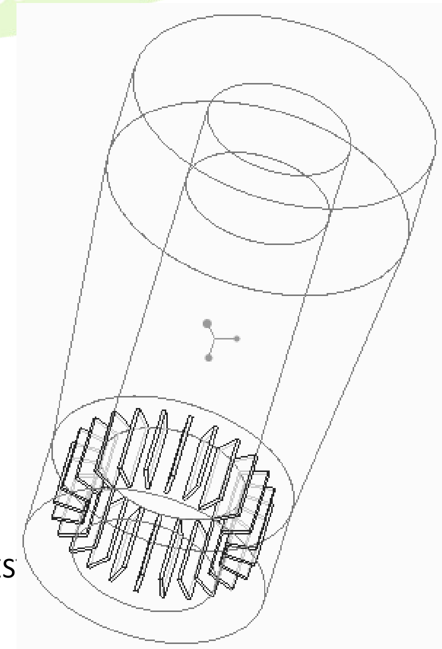


Fig.1a. Diffuser assembly without struts





3. Mesh Study

An open-source software that provides a generic platform for Pre- and Post-Processing for numerical simulation is used for generating the design. The meshing tool is used to generate tetrahedral cells. The mesh density is increased near the surface of the edges and struts to ensure accuracy, as velocity changes in the highly concentrated at the surface of the edges. The software starts from a coarse mesh and refines it until physical results are obtained.

4. GOVERNING EQUATIONS

The calculation procedure is based on solution of equations governing the conservation of mass and momentum in the time averaged form for a steady incompressible flow.
Consider the control volume which is bounded by interior walls of the diffuser. The flow is steady and is incompressible. Conservation of mass for this control volume is given

$$U1A1 = U2A2$$

The average velocity is given by

$$U = \frac{1}{A}\int u\, da$$

5. BOUNDARY PARAMETERS

In annular exhaust diffuser, there are three definite boundary conditions to specify for the computation namely Inlet, Outlet, Wall parameter conditions. Code Saturn is based on a co-located Finite Volume approach. The governing steady-state equations for mass and momentum conservation are solved with a segregated approach. In this approach, the equations are sequentially solved with implicit linearization
After the velocity has been updated, the resolution of turbulent variables and scalars is done according to their time scheme. The pressure implemented using iterative reconstruction of the non-orthogonalities (initialization by zero or based on the least-square method)

Inlet: our current analysis in consideration involves the velocity at the inlet boundary condition is varied from 80m/s to 200m/s in the steps of 40m/s. Turbulence intensity is specified Turbulence

Outlet: Atmospheric pressure condition is applie applied at the outlet boundary where in the pressure at the exit of the diffuser is set to Atmospheric.

Wall: The no slip condition and smooth surface conditions are used for all walls .

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In the present analysis numerical simulations are carried out by choosing k-ε turbulence model.

THERMODYNAMIC STATE	GAS
DENSITY	1.17862 kg/m^3
SPECIFIC HEAT	1017.24 J/kg/K
THERMAL EXPANSION COEFFICIENT	0.003356 k^{-1}
DYNAMIC VISCOSITY	1.831□10-5 Kg $m^{-1}s^{-1}$
THERMAL CONDUCTIVITY	2.61□10-2 W m^{-1} k^{-1}

6. RESULTS AND DISCUSSION

This paper presents the performance of gas turbine annular diffuser in terms of pressure recovery coefficient measured in the scaled down model. In the graphs and contour plots, it is referred that the position of measuring point in terms of axial position, considering that:

- the leading edge of inlet of diffuser corresponds to Axial position of 0 mm.
- Results are produced in the diffuser model with and without struts for various section from inlet to outlet.

The diffusers performances have been also determined by the following parameters:

Pressure Recovery coefficient(Cp)

$$C_P = \frac{P - P_\infty}{\frac{1}{2}\rho {V_{avg\,1}}^2}$$

From the inlet of the diffuser, the velocity continuously decreases towards the outlet because of the diffusion. The pressure recovery coefficient and velocity distribution for with and without struts along the length of the diffuser for different values of velocity can be studied. The pressure recovery coefficient is slightly reduced in the case of struts compared to the diffuser without struts. This is because, as the fluid comes in contact with the strut interface, the pressure recovery coefficient decreases till the length of the strut. However, in the case of velocity distribution, the velocity increases with decrease in pressure
along the strut portion. The above mentioned is obtained from various research papers.

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10.Flow Analysis

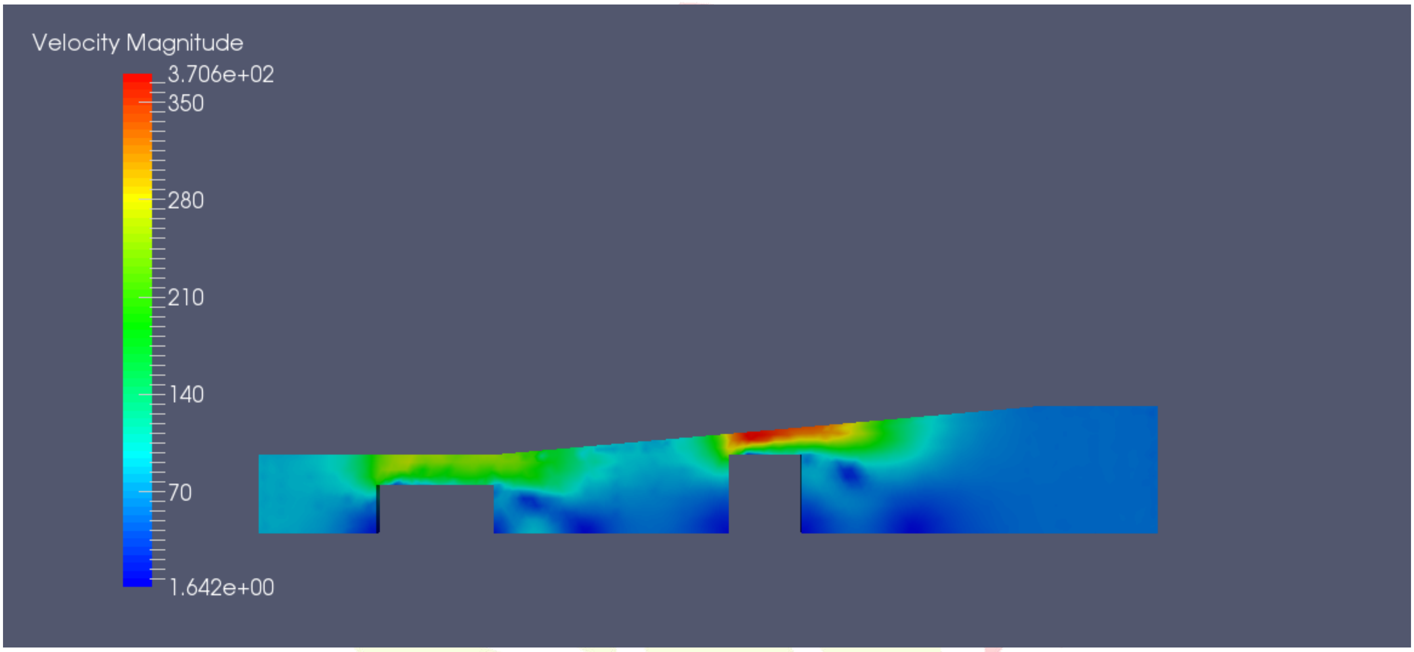

Fig. 2(a): Velocity contour for 13° casing angle with strut and velocity at 80m/s

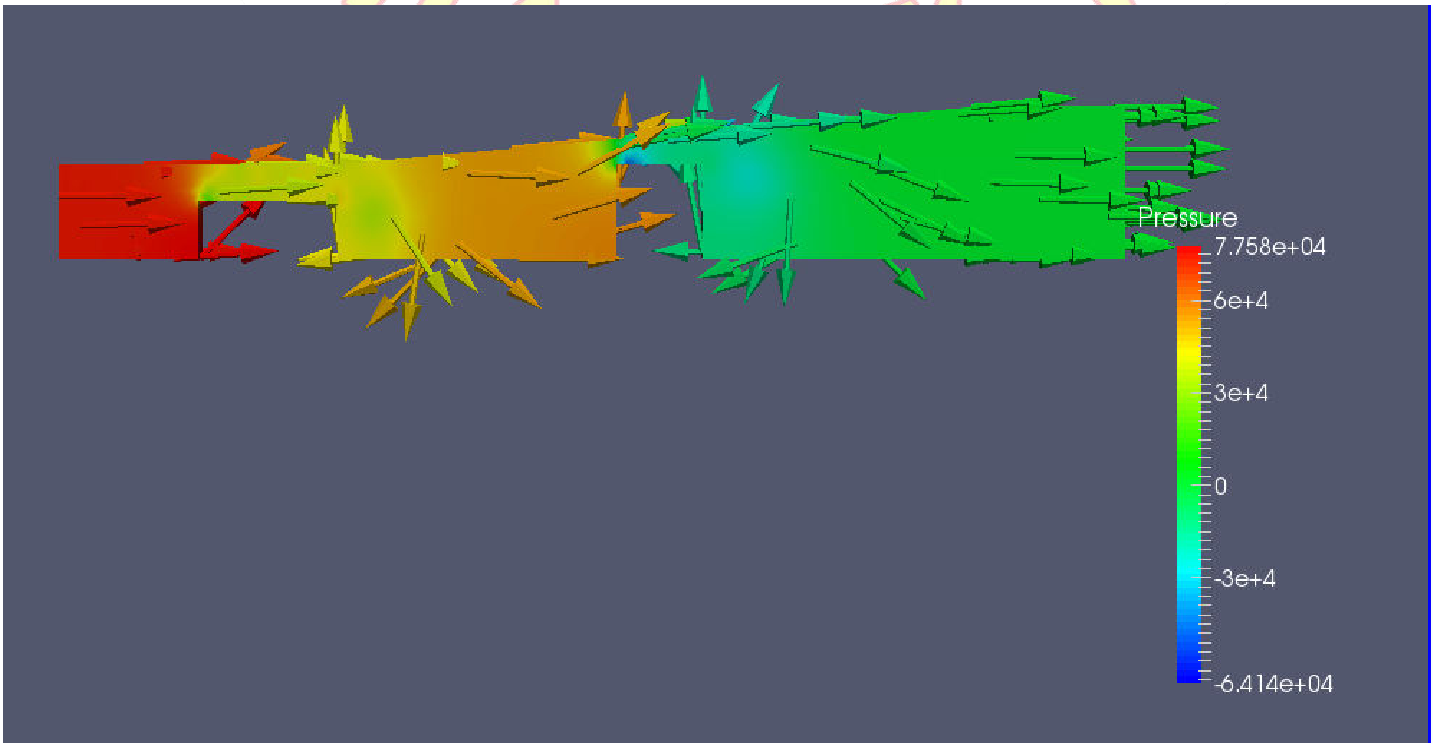

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Fig. 2(b): Flow path for 13° casing angle with strut and velocity at 80m/s

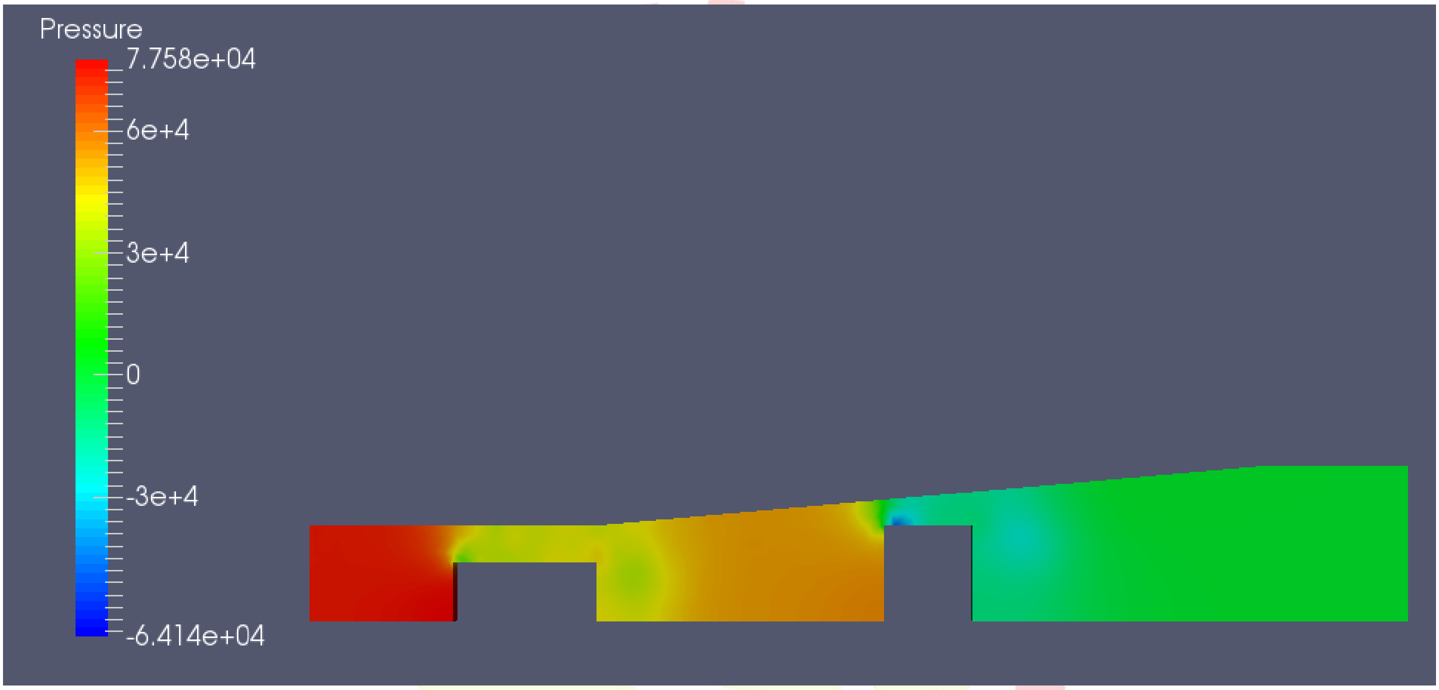

Fig. 2(c): Pressure contour for 13° casing angle with strut and velocity at 80m/s

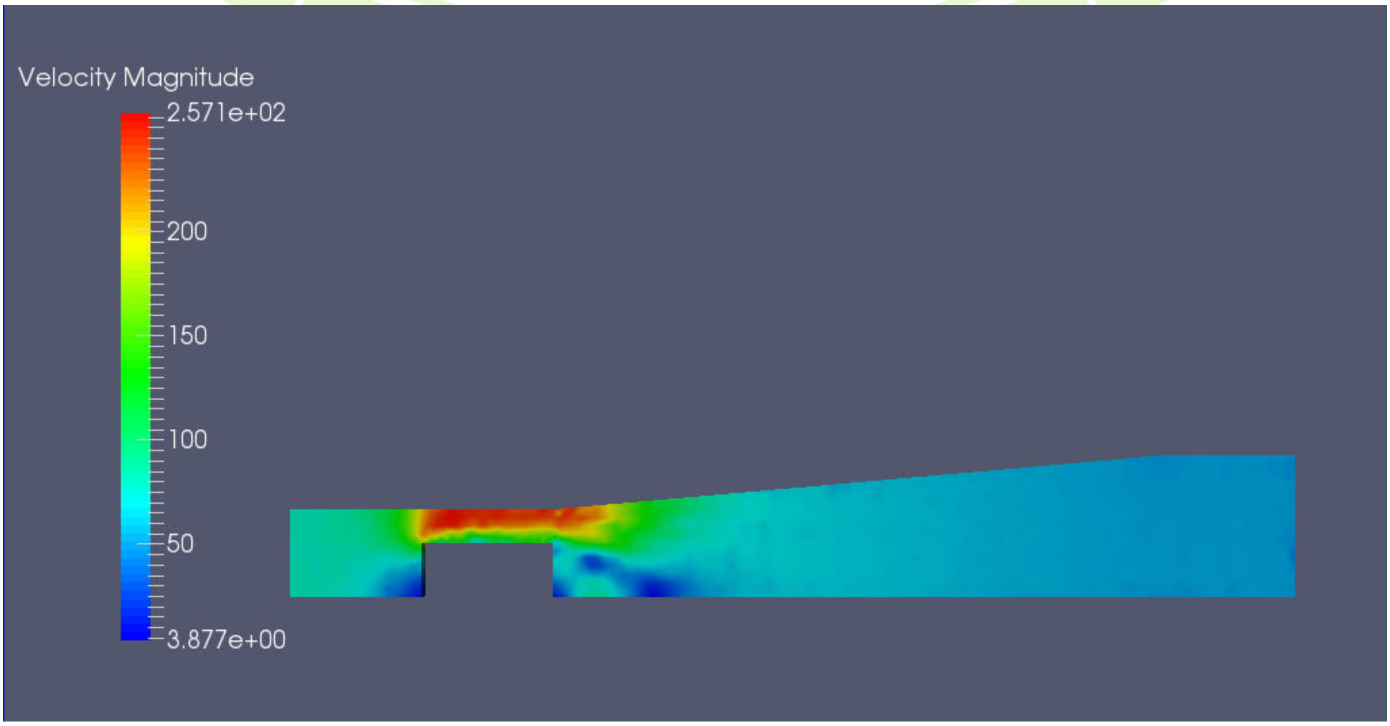

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Fig. 3(a): Velocity contour for 13° casing angle without strut and velocity at 80m/s

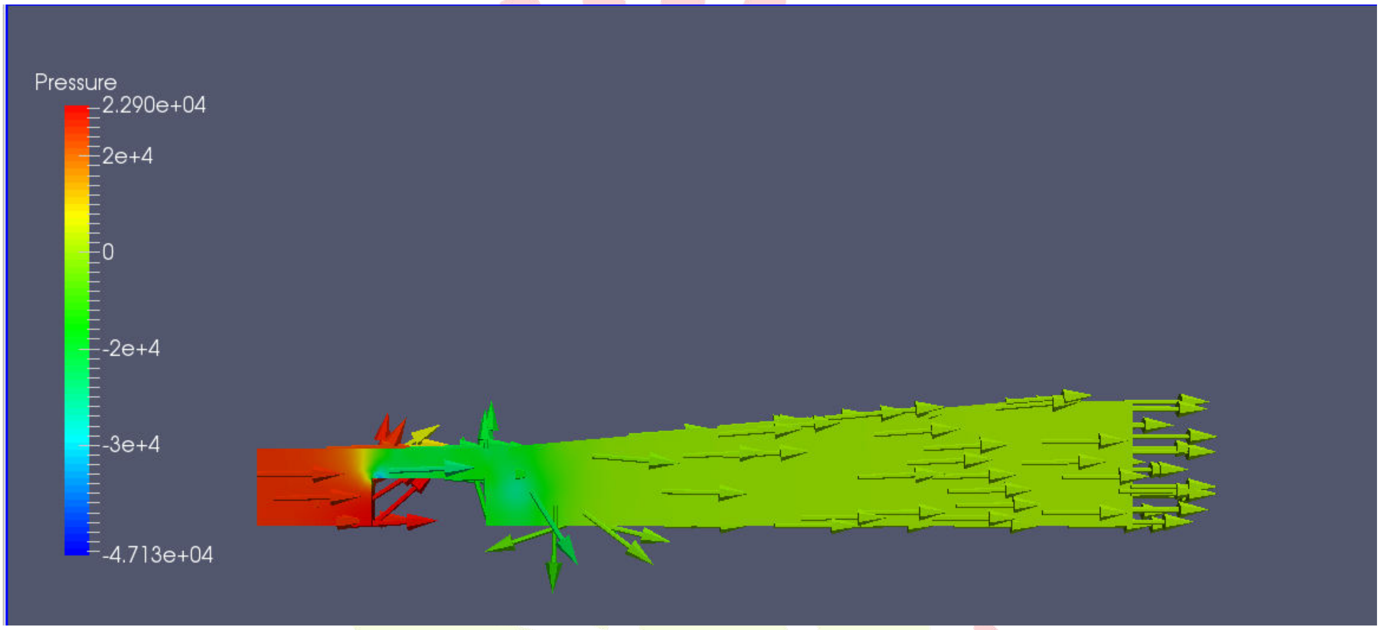

Fig. 3(b): Flow path for 13° casing angle without strut and velocity at 80m/s

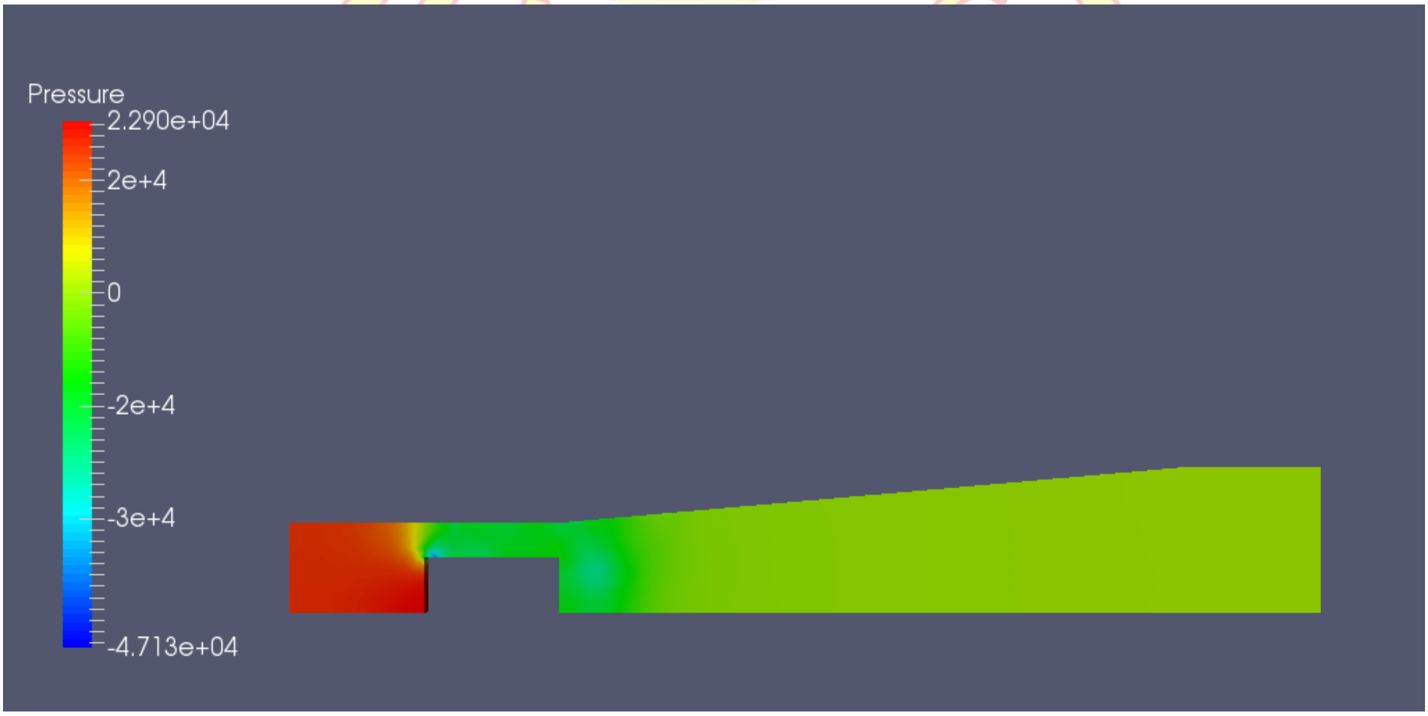

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Fig. 3(c): Pressure contour for 13° casing angle without strut and velocity at 80m/s

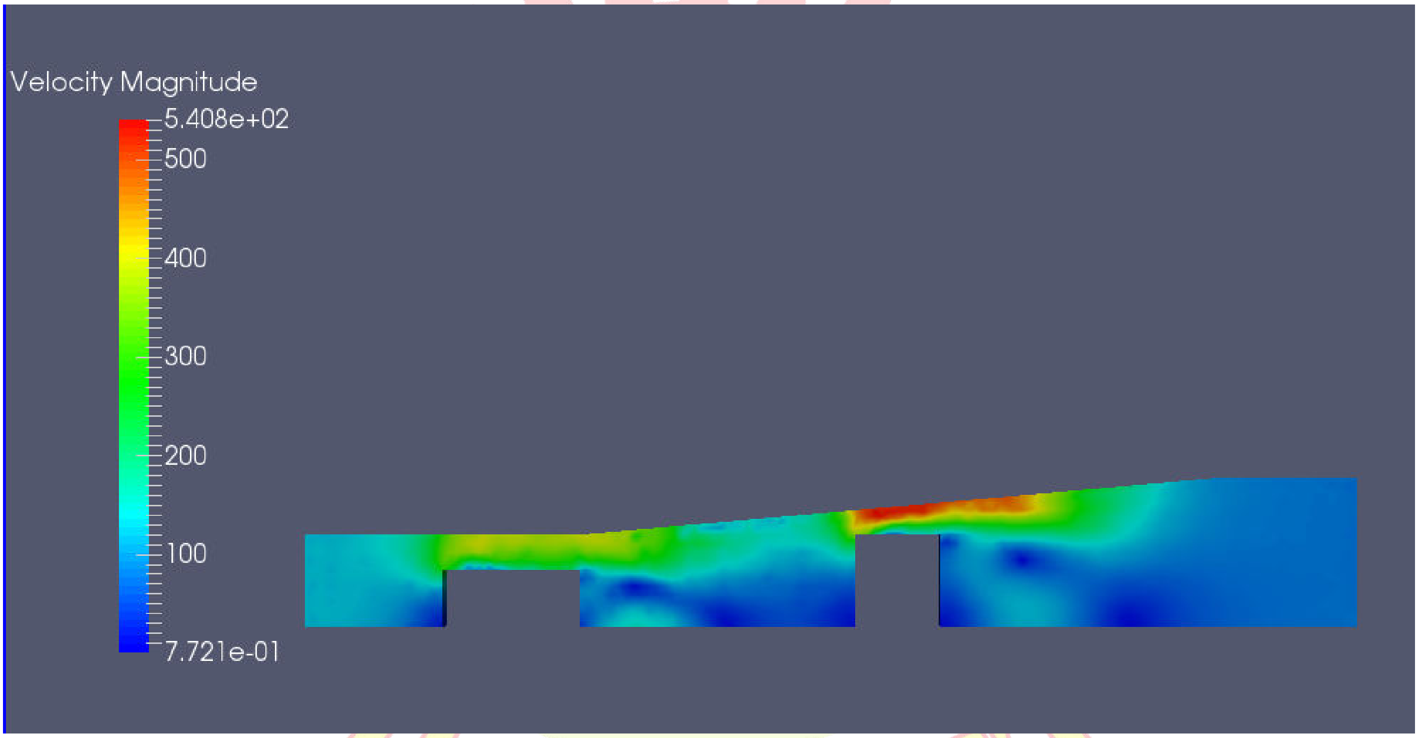


Fig. 4(a): Velocity contour for 13° casing angle with strut and velocity at 120m/s

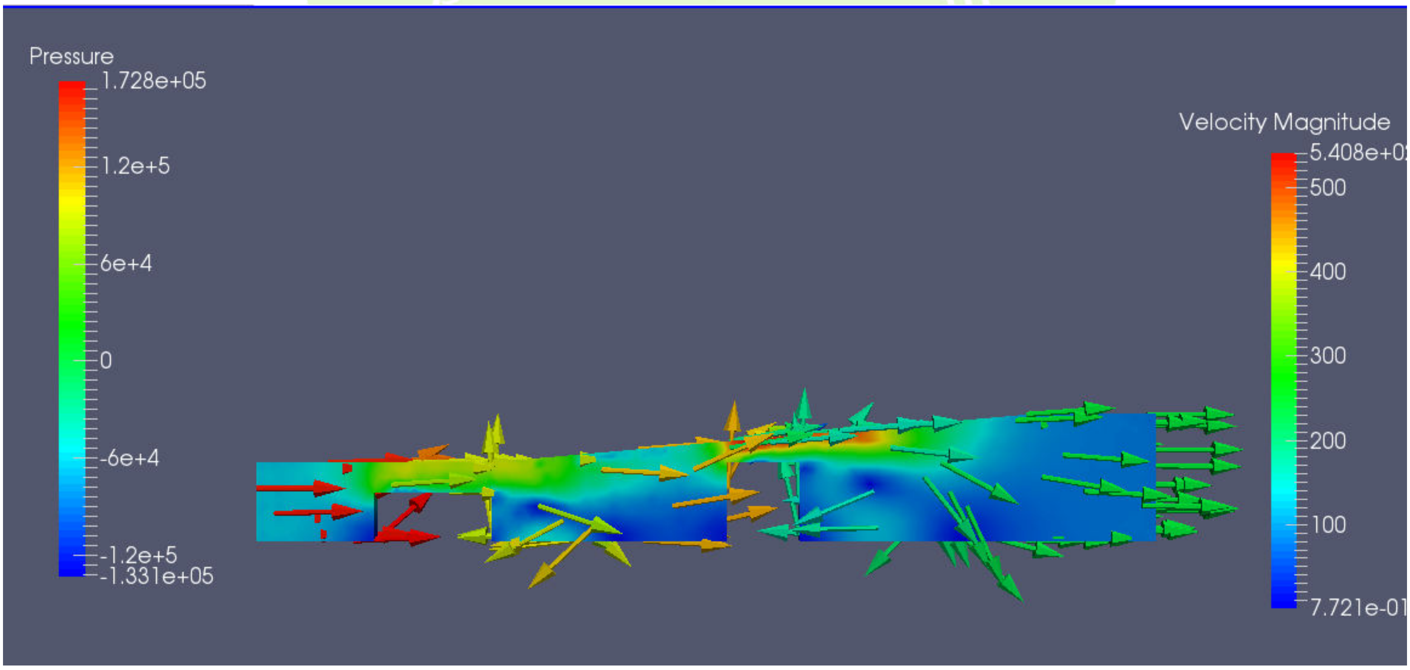


Fig. 4(b): Flow path for 13° casing angle with strut and velocity at 120m/s

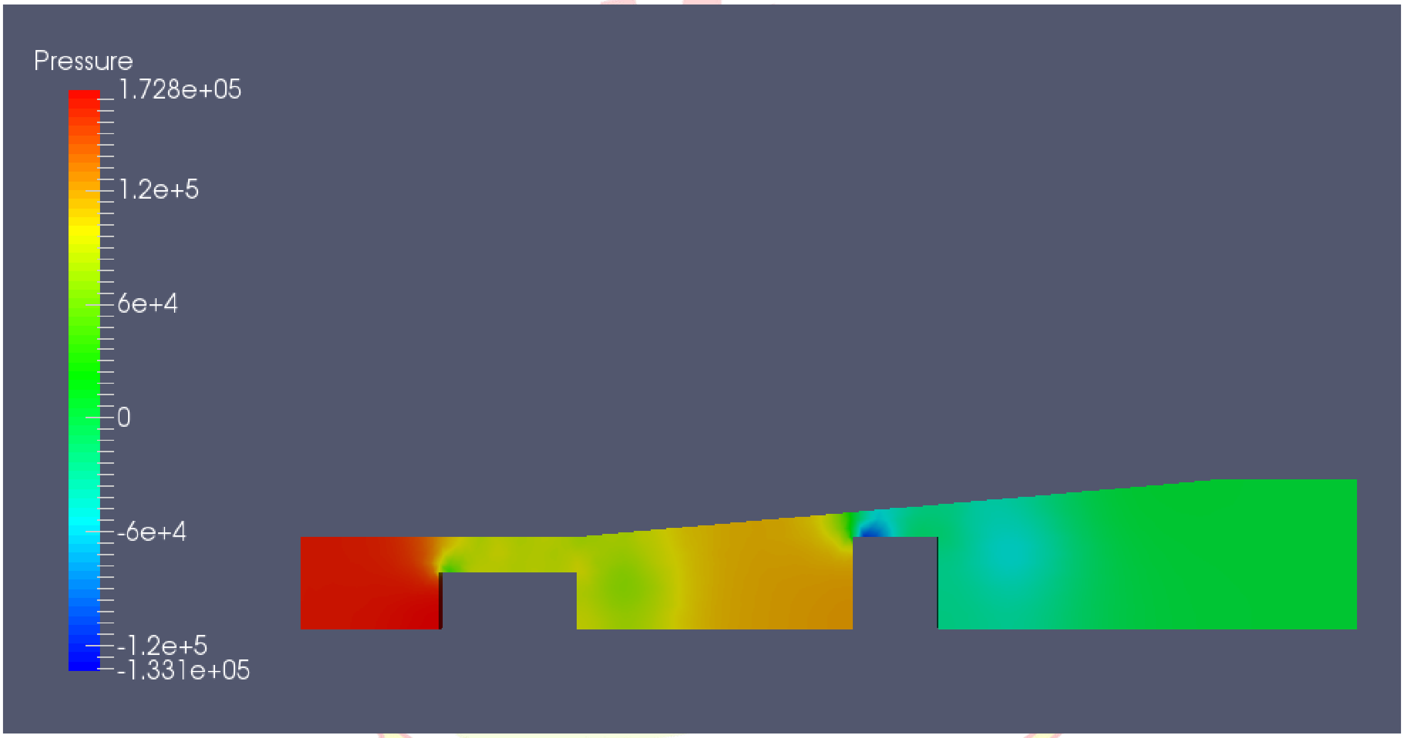
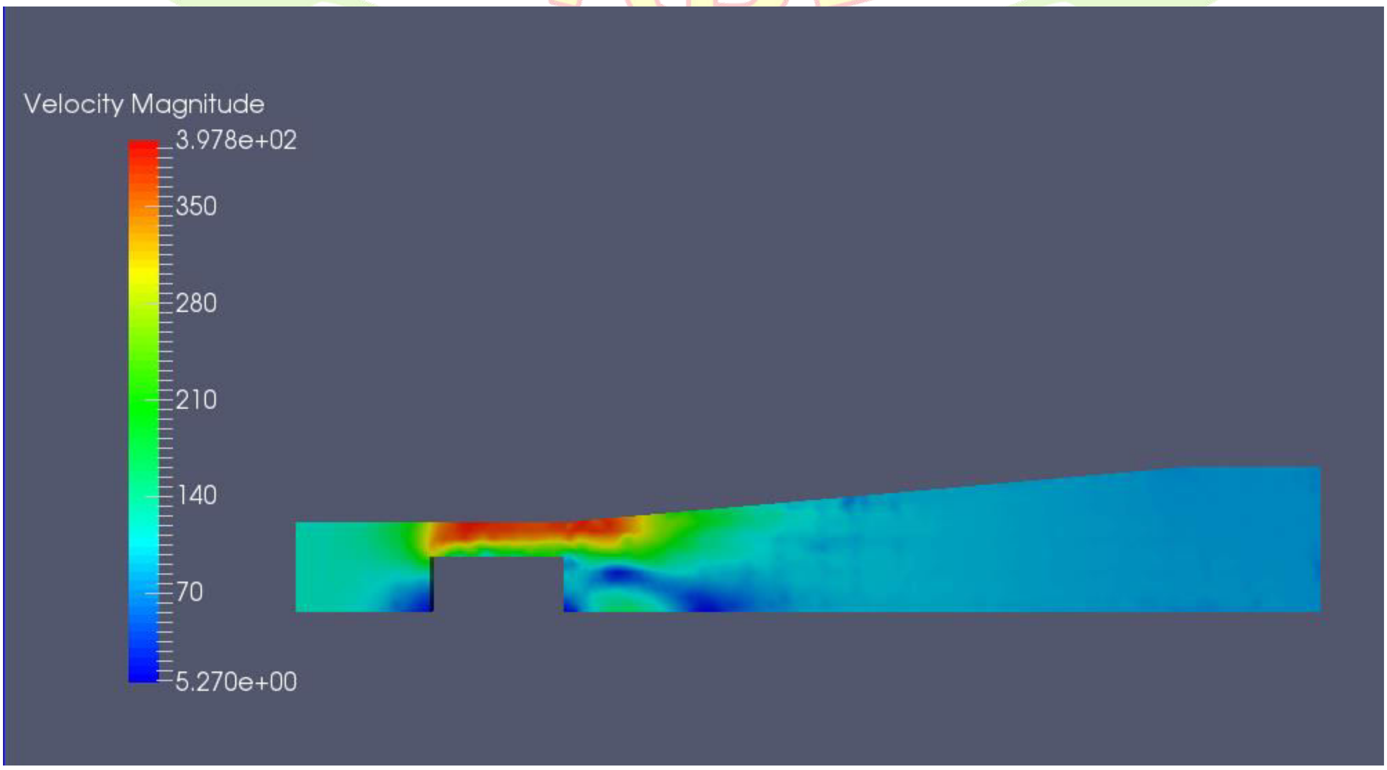


Fig. 4(c): Pressure contour for 13° casing angle with strut and velocity at 120m/s



ISSN 2395-695X (Print)
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Vol. 2, Special Issue 13, April 2016

Fig. 5(a): Velocity contour for 13° casing angle without strut and velocity at 120m/s

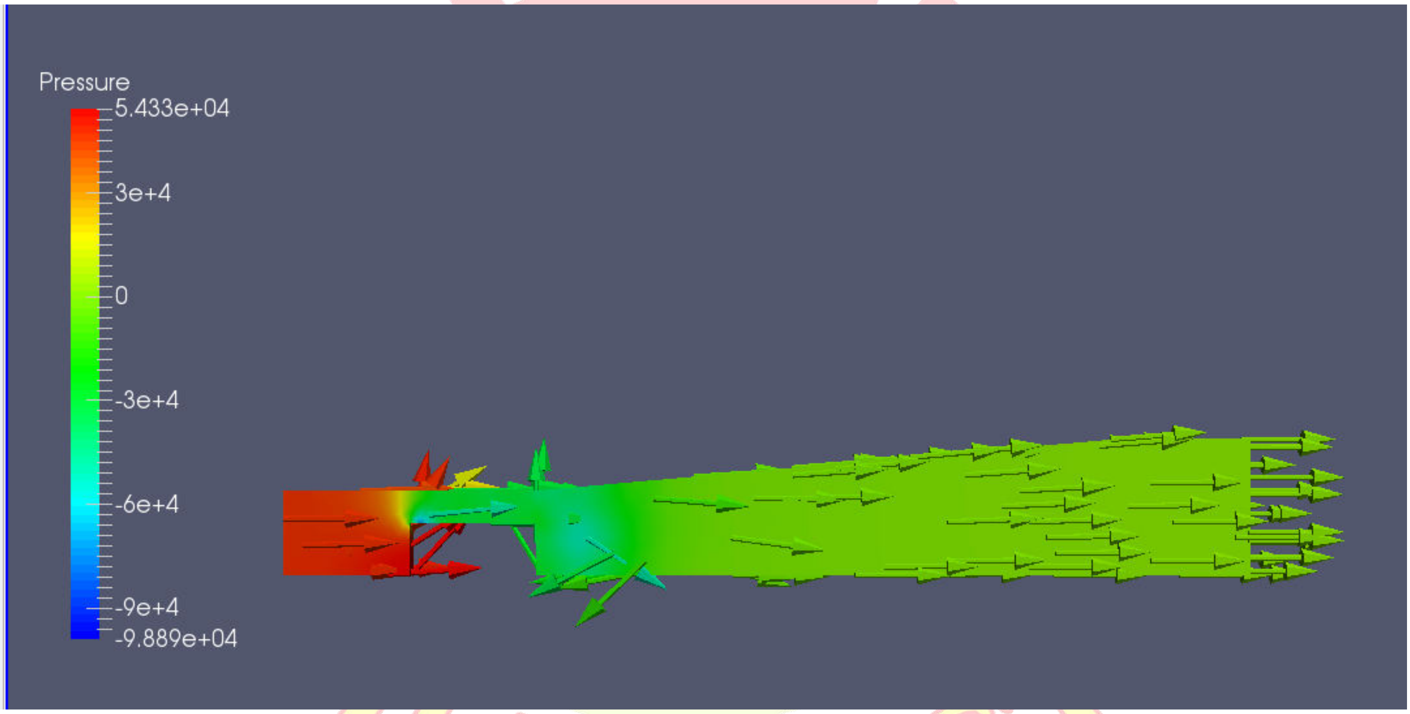
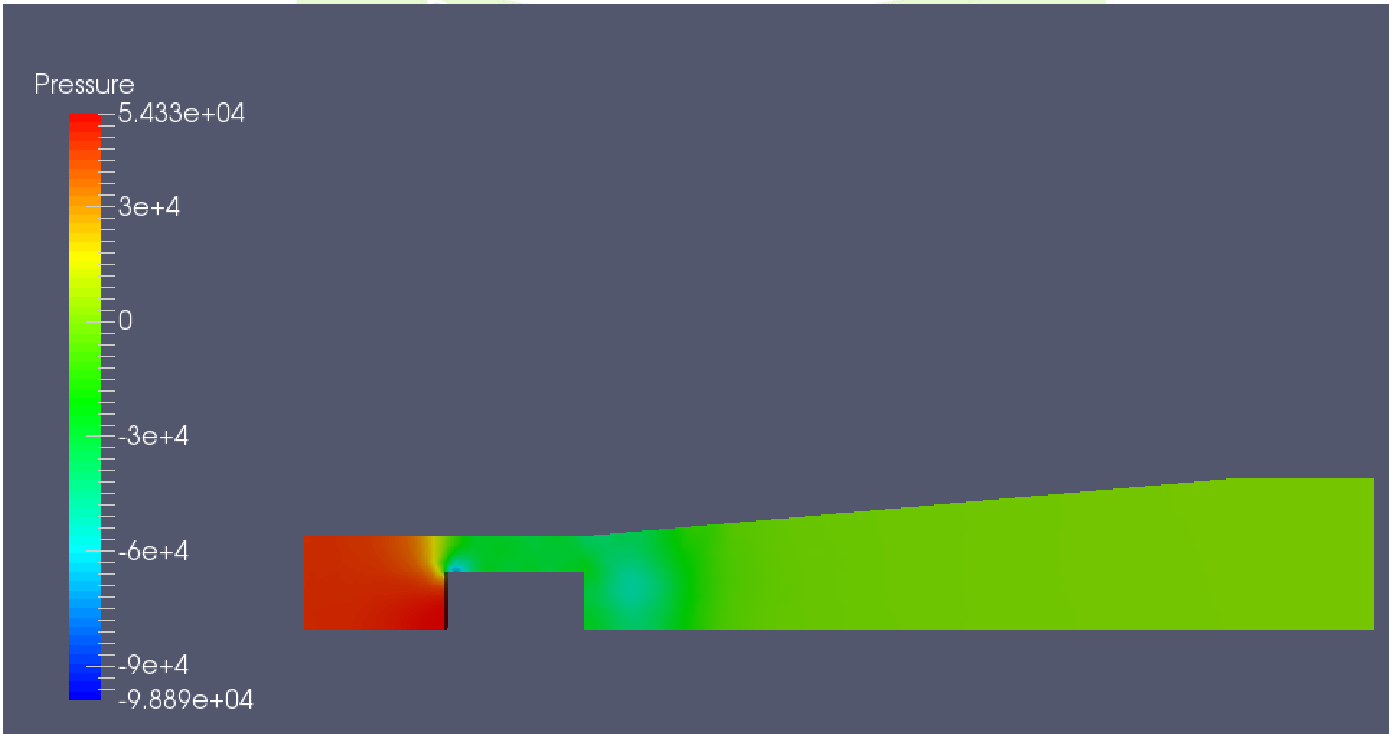


Fig. 5(b): Flow path for 13° casing angle without strut and velocity at 120m/s



ISSN 2395-695X (Print)
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Vol. 2, Special Issue 13, April 2016

Fig. 5(c): Pressure contour for 13° casing angle without strut and velocity at 120m/s

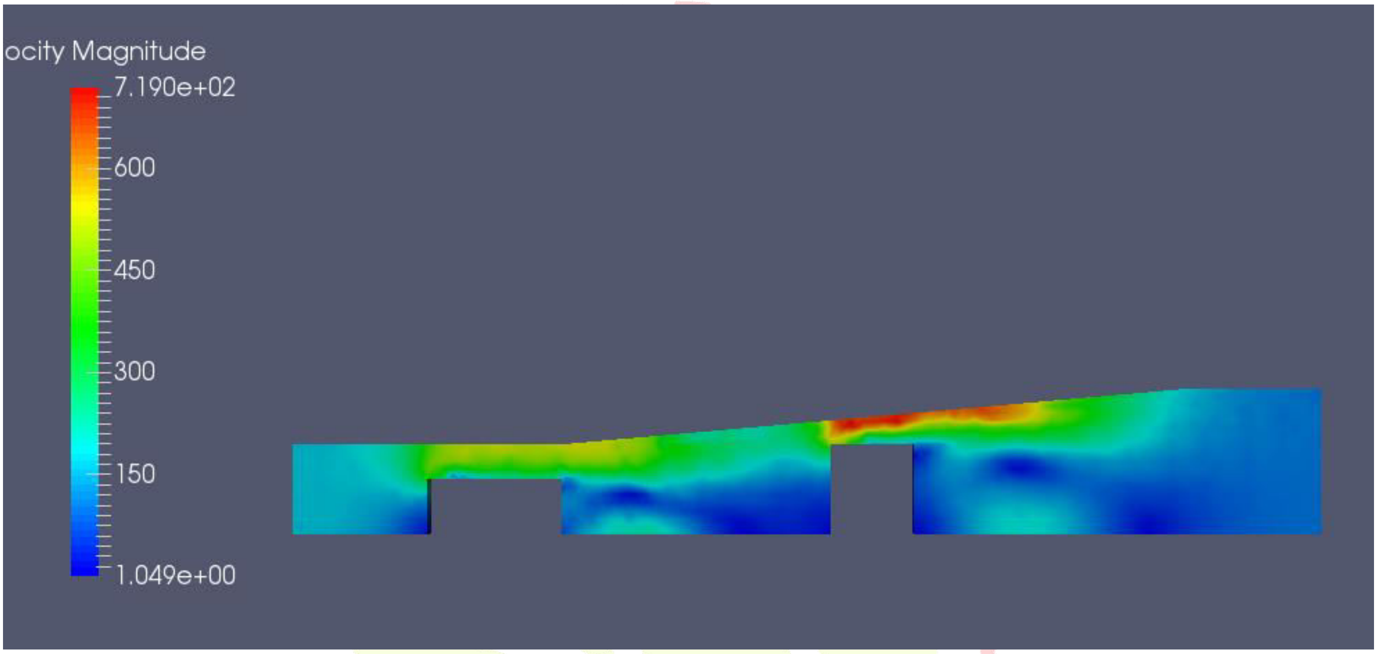

Fig. 6(a): Velocity contour for 13° casing angle with strut and velocity at 160m/s

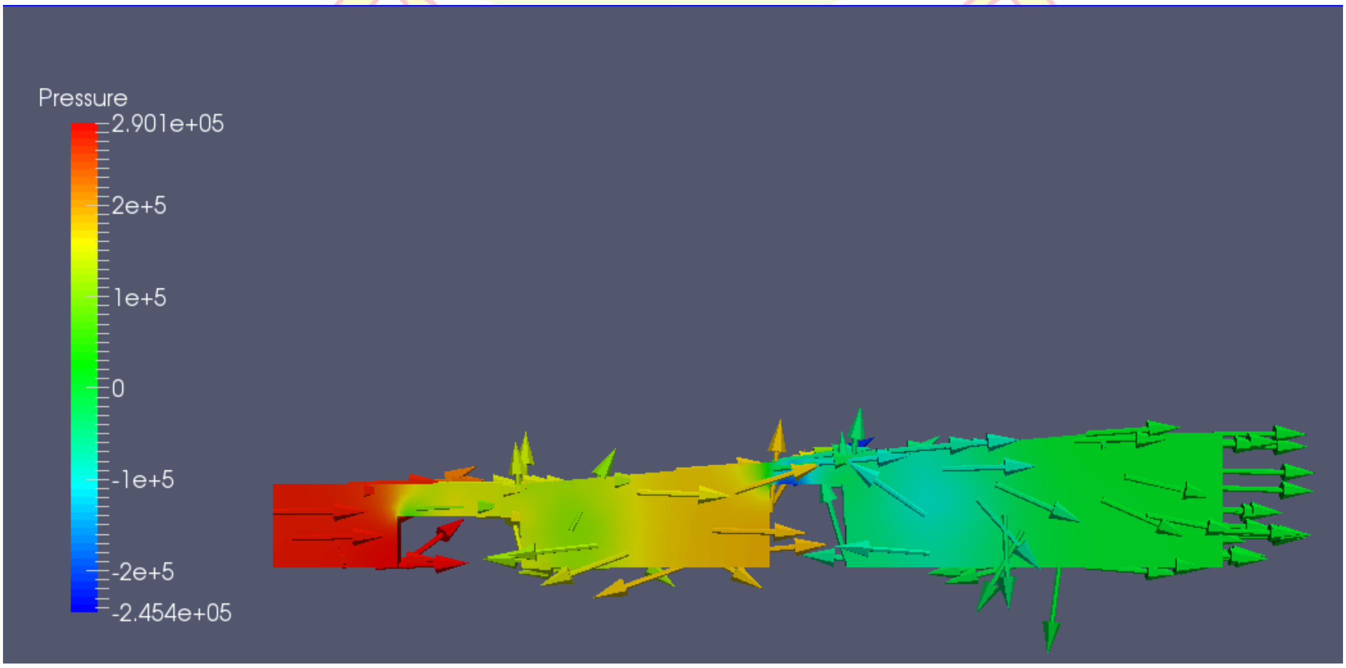

Fig. 6(b): Flow path for 13° casing angle with strut and velocity at 160m/s

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International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 13, April 2016

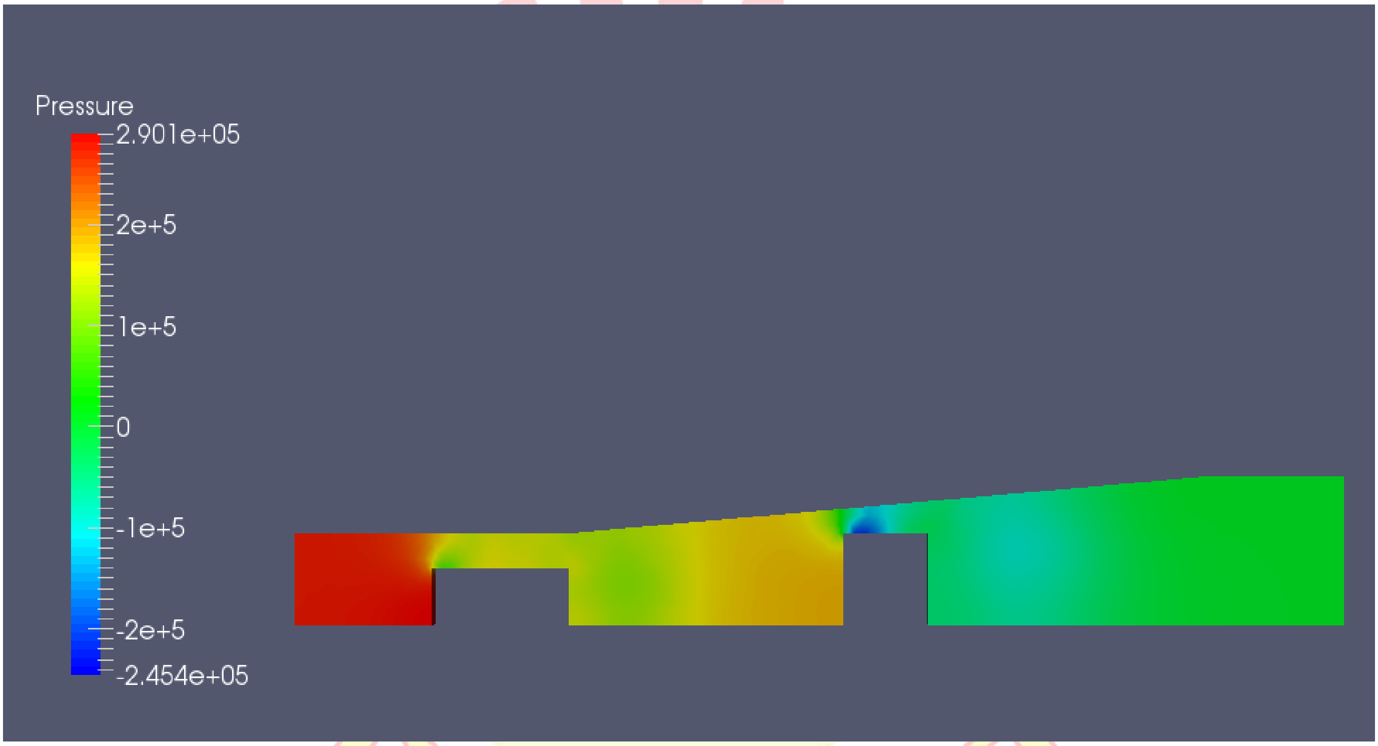
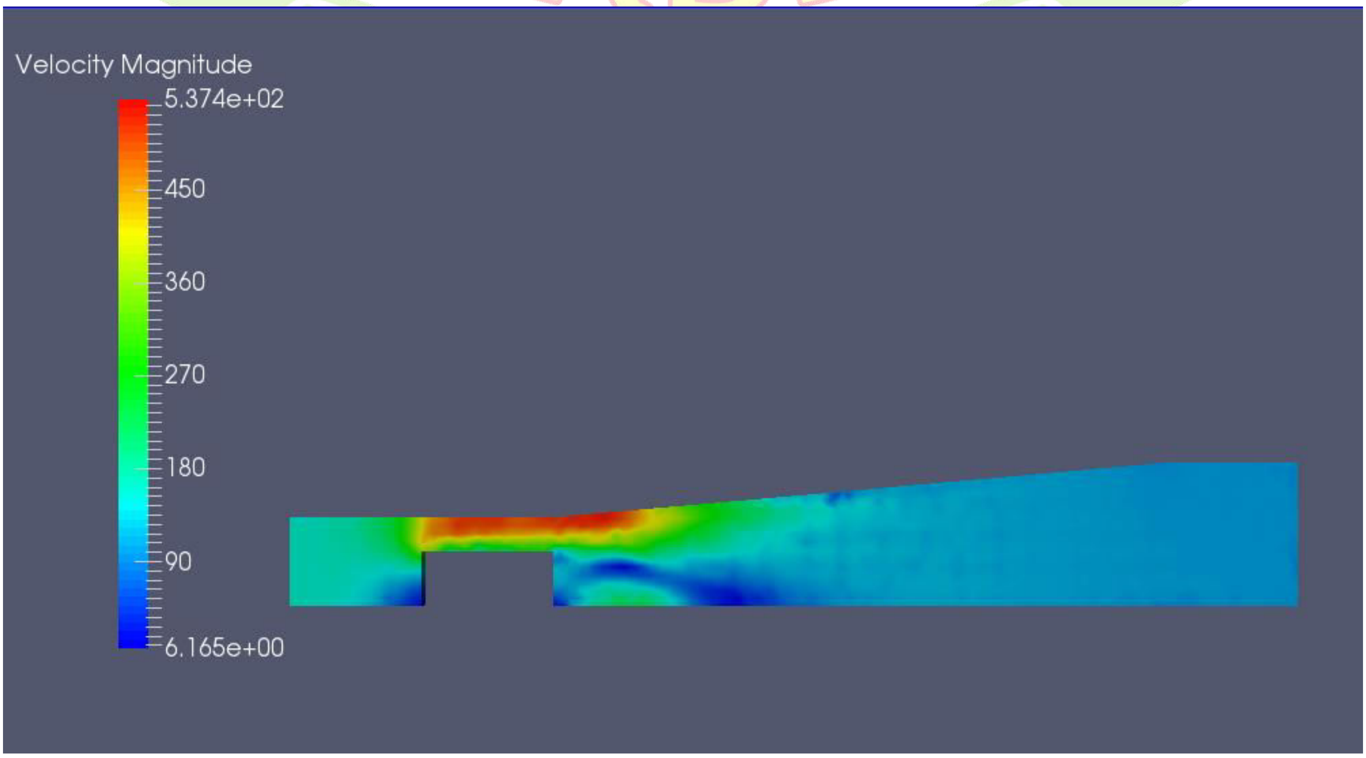


Fig. 6(c): Pressure contour for 13° casing angle with strut and velocity at 160m/s



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Vol. 2, Special Issue 13, April 2016

Fig. 7(a): Velocity contour for 13° casing angle without strut and velocity at 160m/s

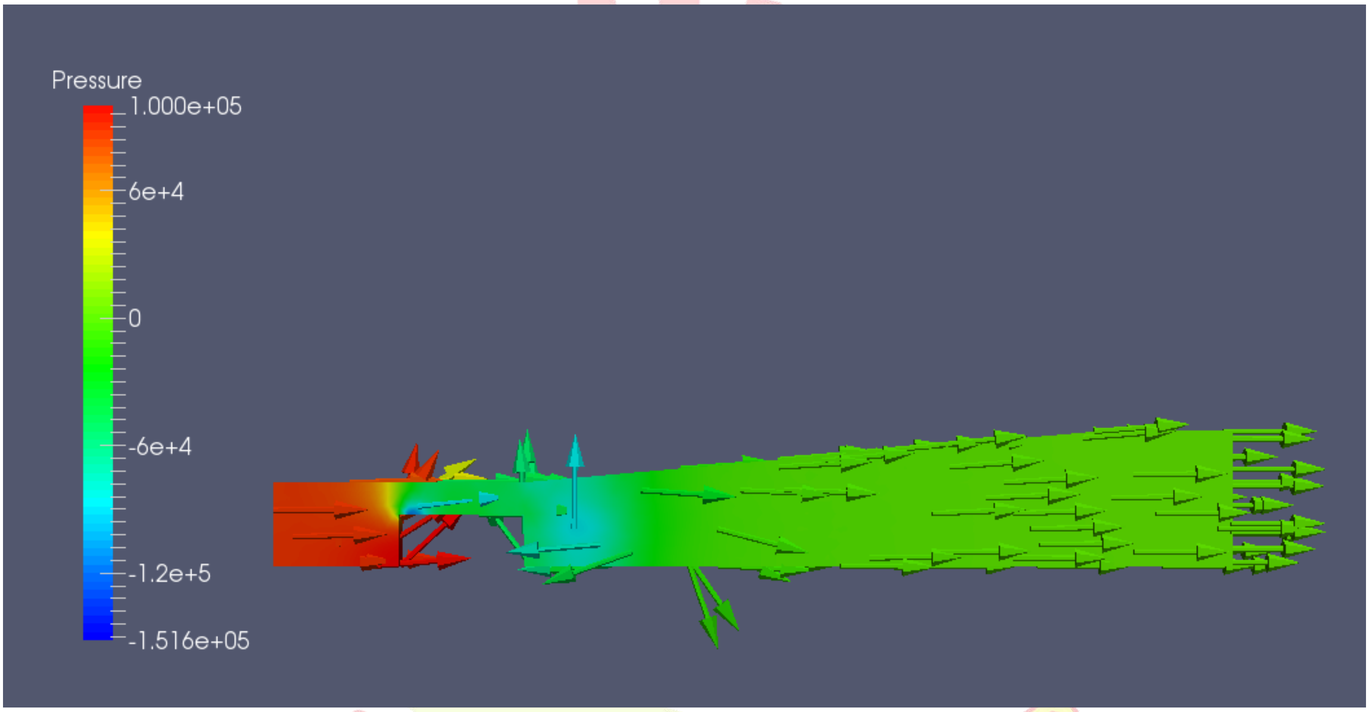


Fig. 7(b): Flow path for 13° casing angle without strut and velocity at 160m/s

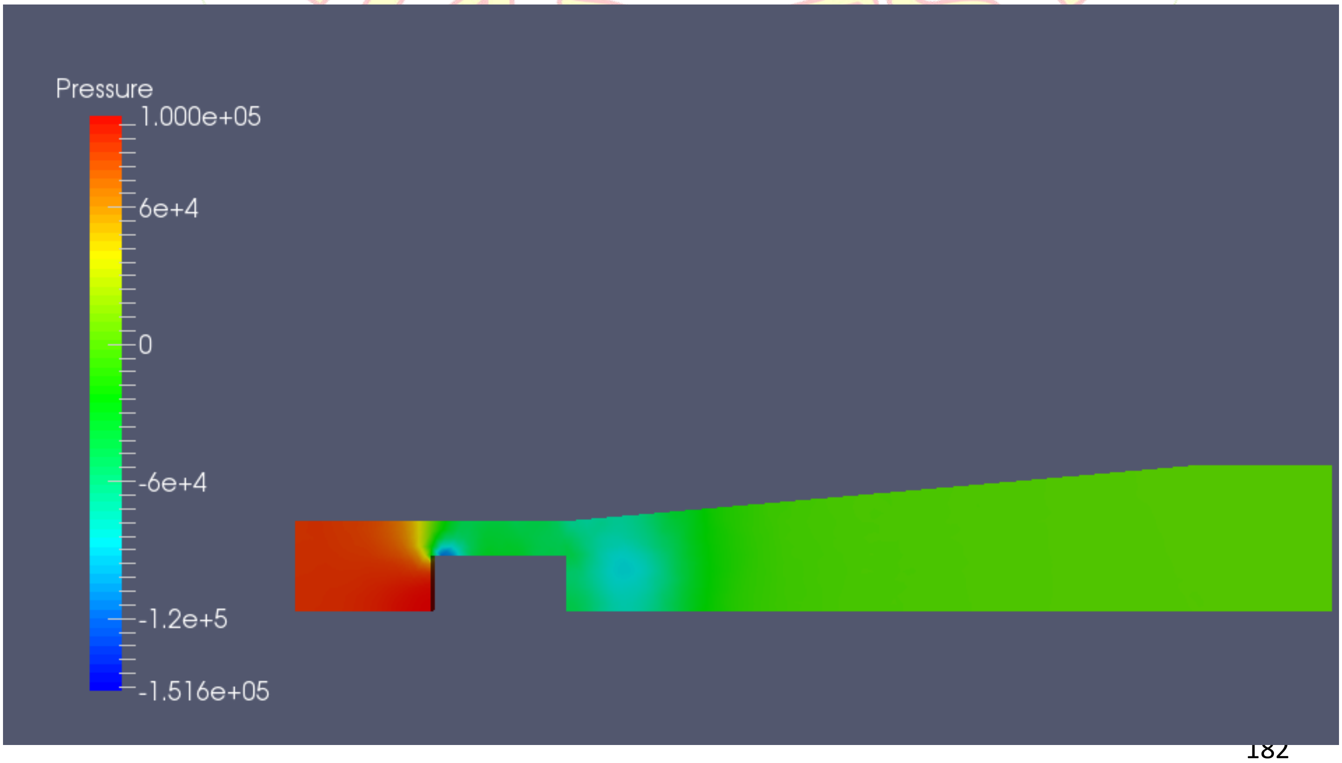


Fig. 7(c): Pressure contour for 13° casing angle without strut and velocity at 160m/s

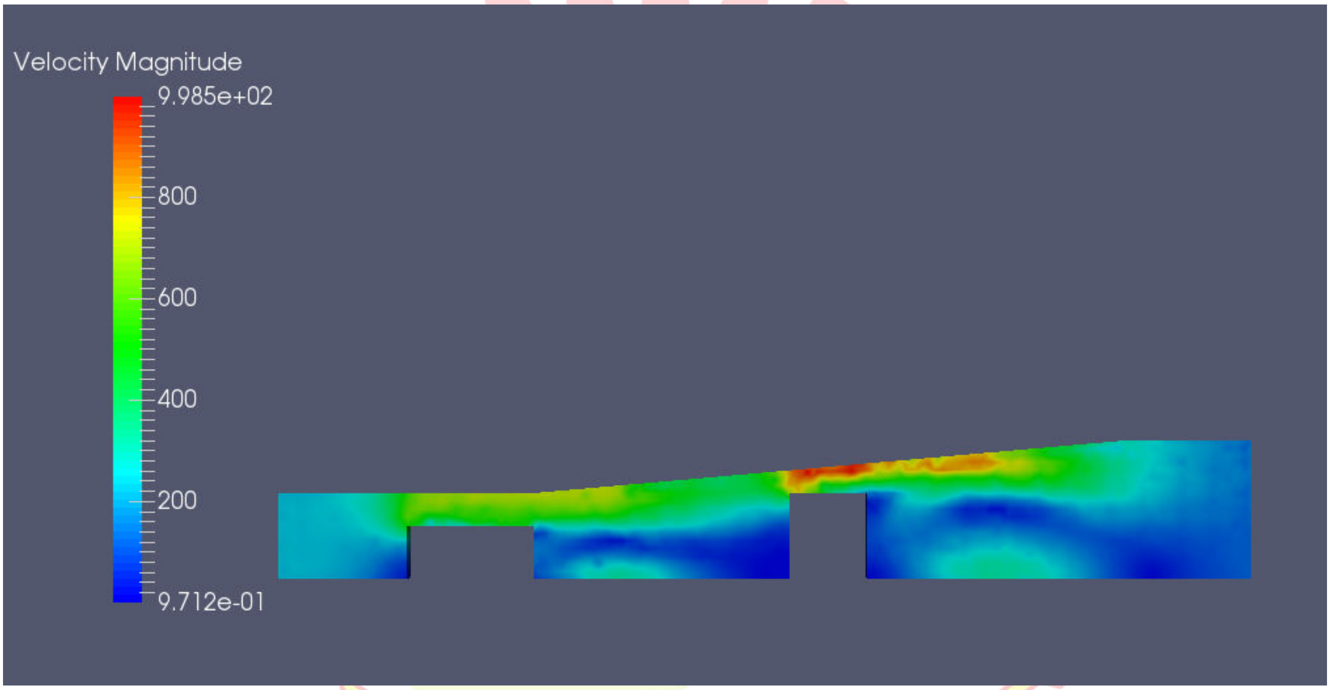
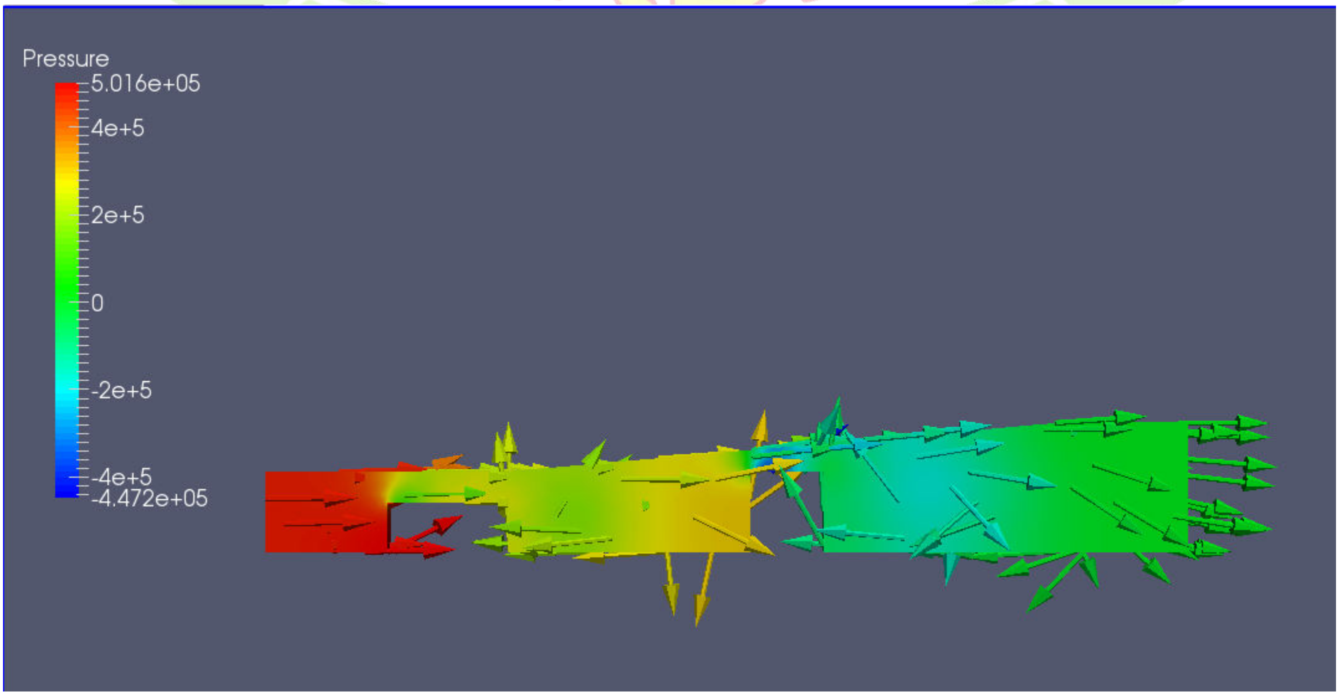


Fig. 8(a): Velocity contour for 13° casing angle with strut and velocity at 200m/s



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Vol. 2, Special Issue 13, April 2016

Fig. 8(b): Flow path for 13° casing angle with strut and velocity at 200m/s

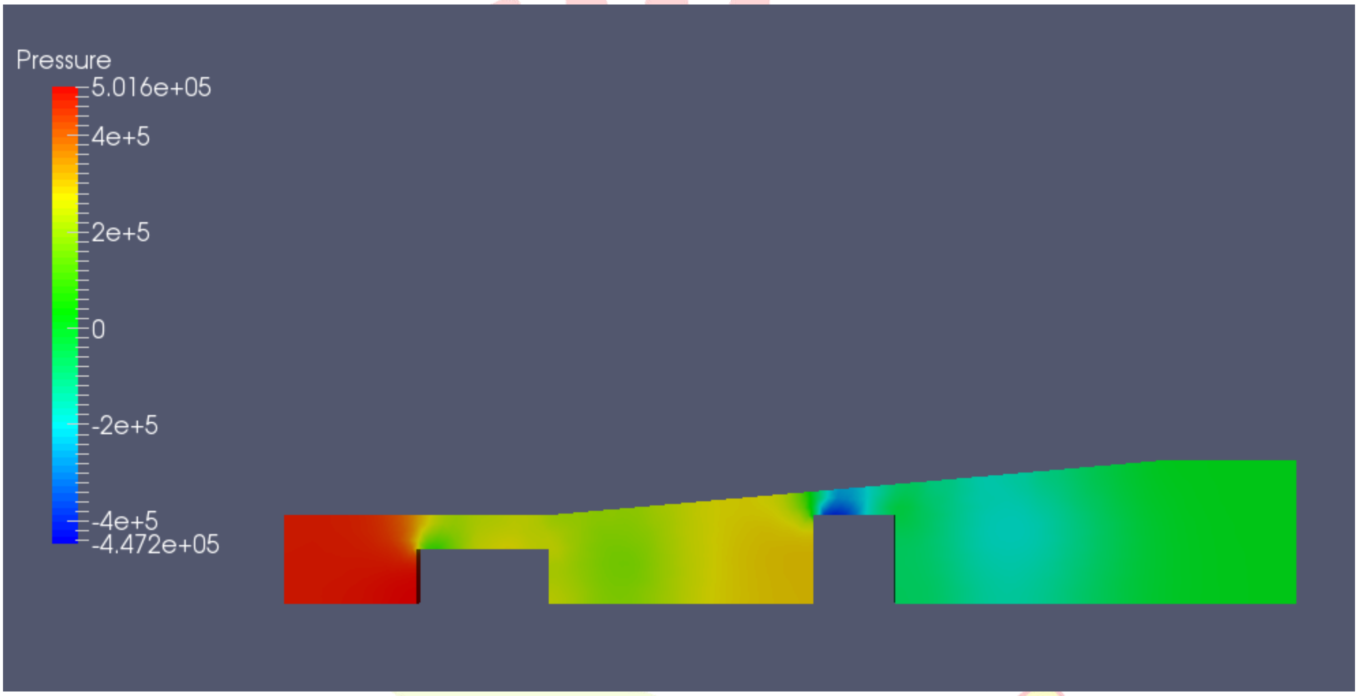
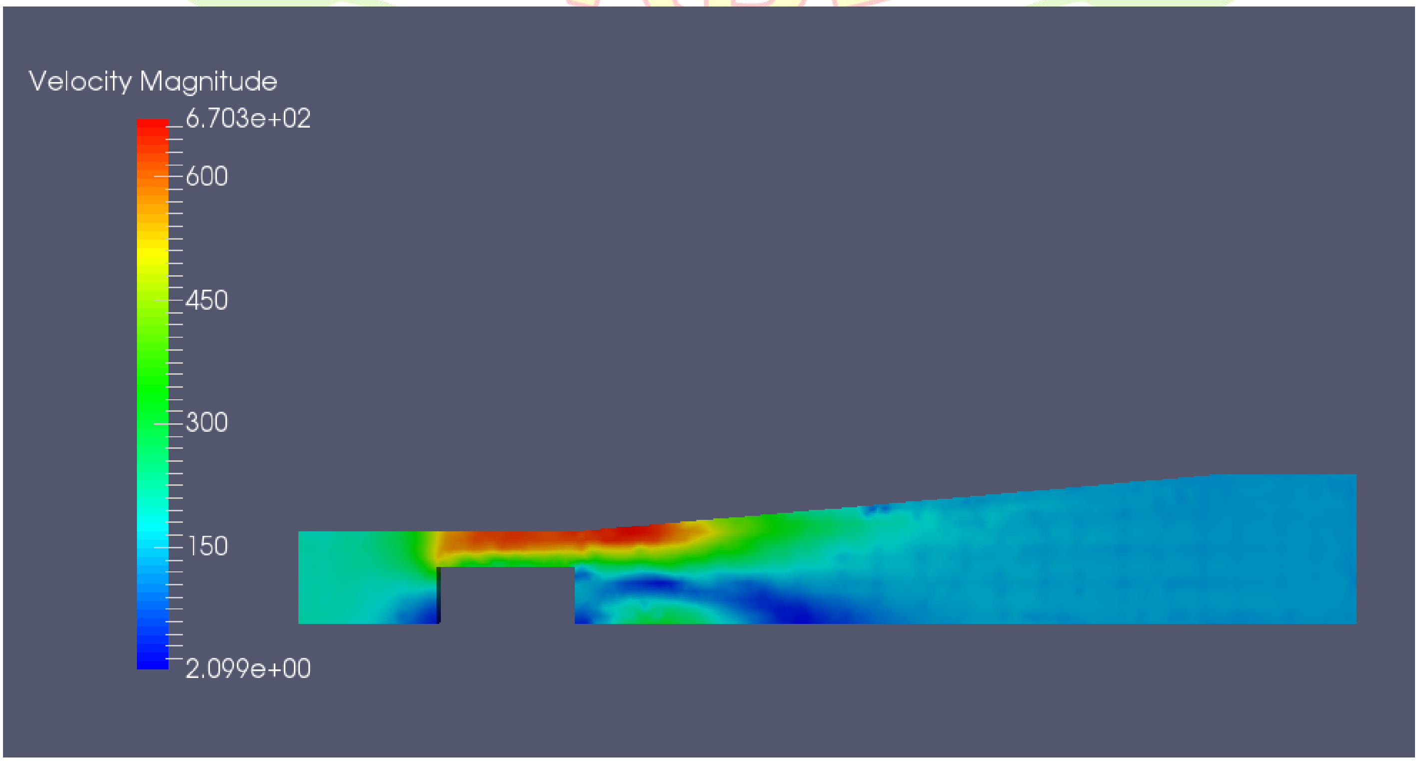


Fig. 8(c): Pressure contour for 13° casing angle with strut and velocity at 200m/s



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Vol. 2, Special Issue 13, April 2016

Fig. 9(b): Velocity contour for 13° casing angle without strut and velocity at 200m/s

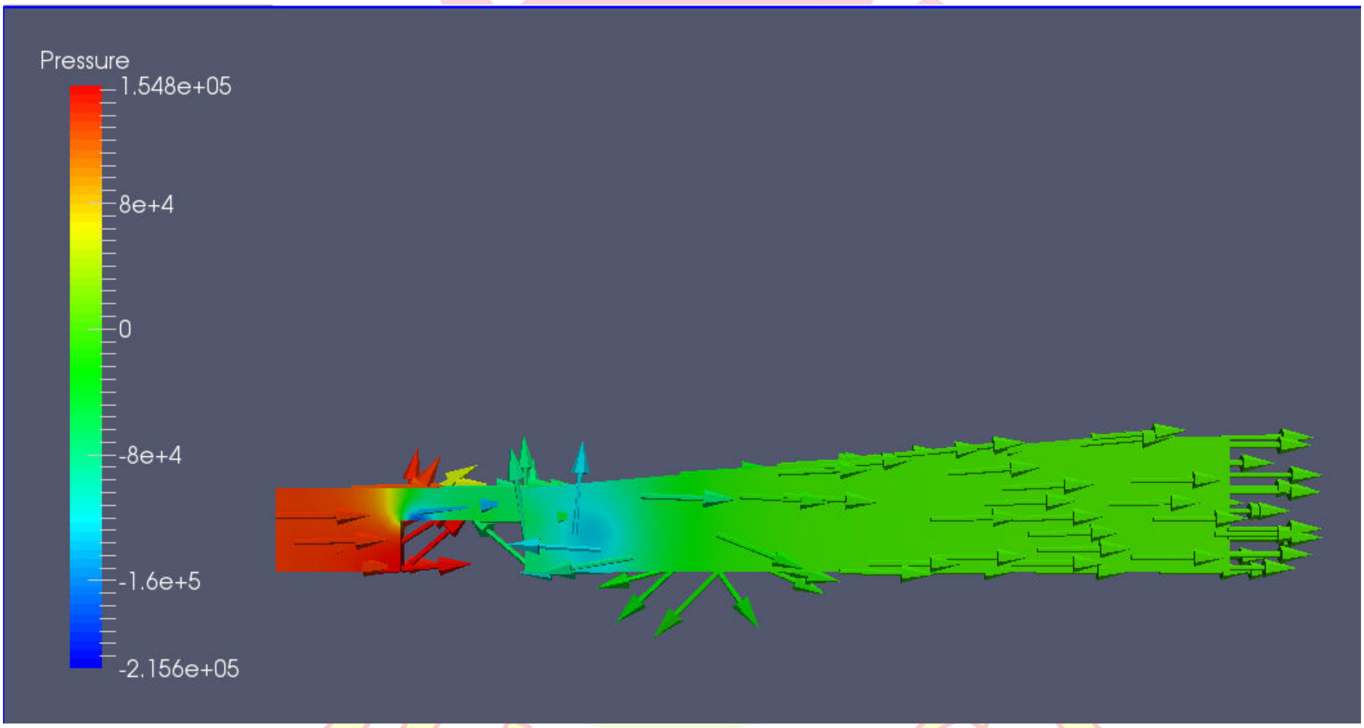

Fig. 9(b): Flow path for 13° casing angle without strut and velocity at 200m/s

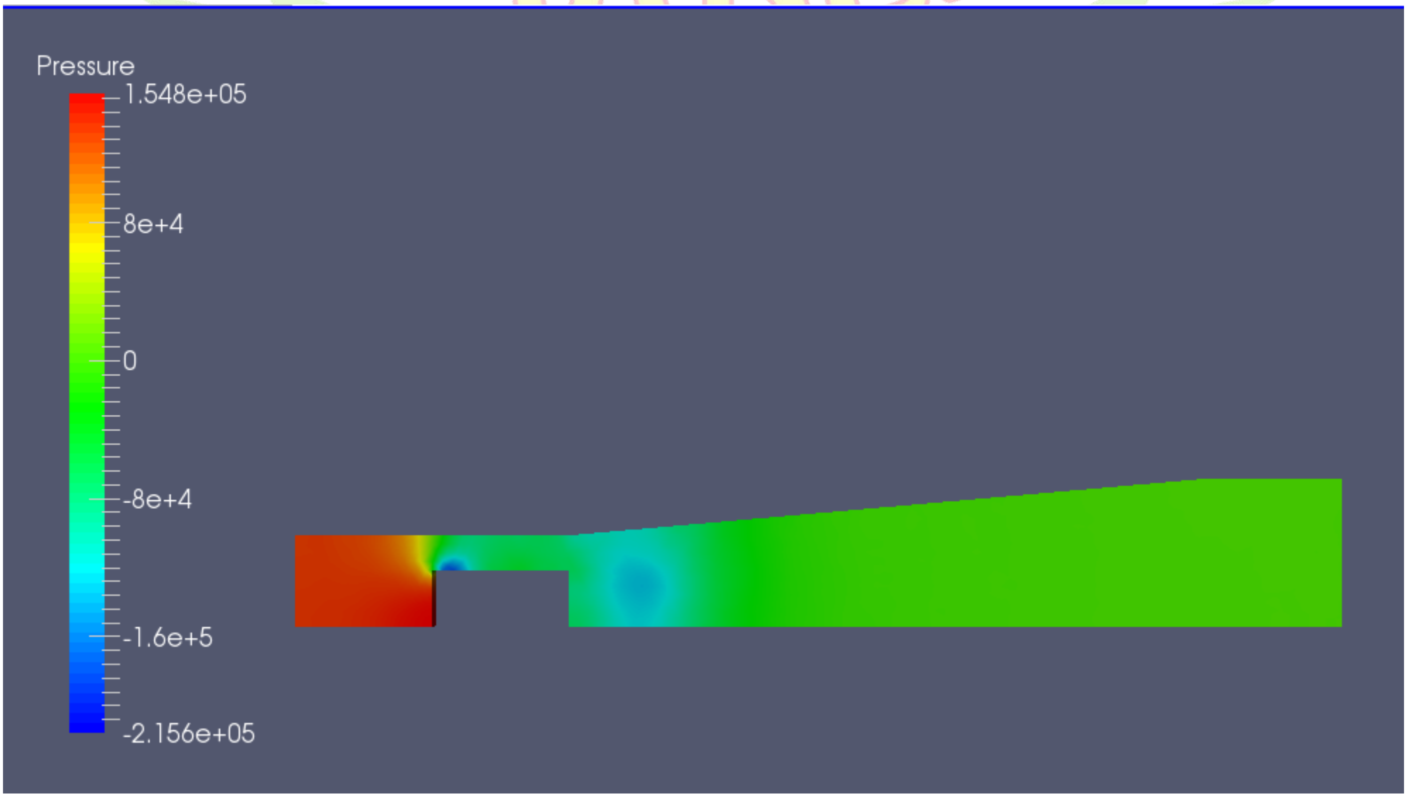

Fig. 9(c): Pressure contour for 13° casing angle without strut and velocity at 200m/s

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