Flow Analysis Of Engine Intake Manifold & Flexible Rubber Hose Pipe Used In Air Intake System Based On Computational Fluid Dynamics

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Abstract : Air intake system and filter play major role in getting good quality air into automobile engine. It improves the combustion efficiency and also reduces air pollution. Geometrical design of intake manifold is very important feature for obtaining for the good performance of an I.C. engine. During suction stroke high vacuum pressure is generated which causes flow in the air intake system. Air flow starts from hood to engine intake manifold. Flexible hose is used as a inlet of air in the Air Intake System of the engine which has corrugated structure. Due to high vacuum and fluctuation in air supply, flexible hose lead to cyclic stresses causing fatigue failure. To avoid failure of flexible hose the magnitude of cyclic stresses should be decresed. Aim behind this research work is to find that what type of Geometrical changes are possible in Intake Manifold to overcome the problems associated with it. Guide vanes will be provided in Air Intake pipe of AIS to reduce the pressure drop which occurs in rubber hose. Pressure drop analysis will be compared between conventional geometry of IM and New modified geometry of IM So we can conclude that which geometry is better and provides better flow inside it.

***Keywords:-* CFD, Intake Manifold, AIS, Air Intake Hose, Guide Vane**

1. INTRODUCTION

1.1 INTRODUCTION ABOUT AIR INTAKE SYSTEM

The main function of an air intake system is to provide the clean air to engine with correct amount for the required air to burn in the manifold chamber. The intake system of an engine has three main workings. Its first and usually most important function is to provide a method of filtering the air to ensure that the engine receives clean air free of trash particles. The flow efficiency of the intake system has a direct impact on the power of the engine able to deliver. The air must be "filtered" before it enters to the combustion chamber. The system that filters the air and give direction into the cylinders is called an Air Intake System (AIS). The AIS can be divided into main three parts: an inlet and intake section in which the incoming "dirty" air is guided into, a filter-box section where a filter is located that cleans the polluted air and separate the dirty particles from entering the cylinders, and an inlet to the engine where the clean air is guided to the cylinders. Air enters the filter through dirty pipe and inlet side plenum, which guides the flow through the filter media. Optimum utilization of filter can reduce the cost of filter replacements and keep the filter in use for longer time.

1.2 ELEMENTS OF AIS

Modern naturally-aspirated intakes consist of at least four basic elements:

- Intake Manifold
- Air Filter
- Mass Air Flow Sensor
- Throttle Body

1.3 INTRODUCTION ABOUT INTAKE MANIFOLD

In automotive engineering an inlet manifold or intake manifold is the part of an engine that supplies the fuel/air mixture to the cylinders. In other side, an exhaust manifold collects the exhaust gases from multiple cylinders into a smaller number of pipes, often down to one pipe. The primary function of the intake manifold is to uniformly distribute the combustion mixture (or just air in a direct injection engine) to each intake port in the cylinder head(s). Equal distribution is important to optimize the efficiency and performance of the engine. IM provides Air motion to the chamber.

1.4 IM CONSTRUCTION

It consists two main parts, in combination with the throttle body, which include the plenum and the cylinder runners. Air enters in to plenum due to vacuum created by engine, plenum stores the combustion air as basin and then transport the combustion air to engine through the cylinder runner.

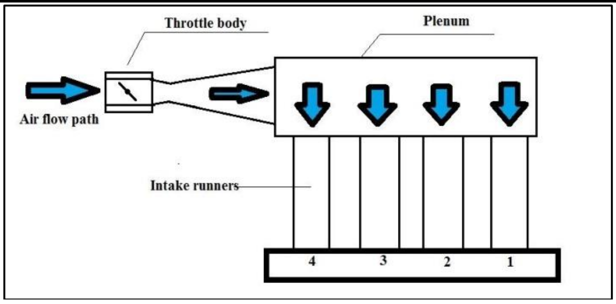


Fig 1 - Body of Intake Manifold[2]

The general terminologies of intake system, which can be used for enhancement in performance of the engine are:

(1) Plenum:

It is storage device which placed between throttle valve and cylinder runner. The function of the plenum is to equalize pressure for more even distribution air-fuel mixture in side combustion chamber. There are two types of intake manifold on the basis of manifold dimension, fixed length intake manifold and variable length intake manifold.

(2) Cylinder Runner:

The cylinder runners are the parts of the air intake system which delivers air from plenum to the combustion chamber. As the purpose of the cylinder runner is distribution of air, performance to transport the maximum amount of air, and in the case of the engine, the successive enhancement in volumetric efficiency.

1.5 Rubber Hose used in AIS

Vehicle's air intake system needs to be airtight in order to function properly. In addition to the air intake system, every component, no matter how large or small, must be in proper working condition in order for the entire system to work to its fullest extent. When the air intake hose, which is the rubber tube piece that connects the air filter box and the intake manifold, becomes old or possibly even cracks, it won't function appropriately. The air intake hose's primary function is to filter the air that goes into the intake manifold. Without the hose, trash could get into intake manifold, which could then travel to the vehicle's engine. Over time, this could cause the engine's injectors to stop up, which would then result in vehicle not running efficiently and wouldn't get nearly as good mileage.During suction stroke high vacuum pressure is generated which causes flow in the air intake system. Air flow starts from hood to engine inlet manifold. Flexible hose has corrugated structure. Due to high vacuum and fluctuation in air supply, flexible hose lead to cyclic stresses causing fatigue failure. To avoid failure of flexible hose the magnitude of cyclic stresses should be reduced. This can be achieved by finding the region of maximum stress. In case of flexible hose, the maximum stress occurs in the region where the deformation of rubber is maximum.

1.6 Objectives

Following are the objectives of this research work:

- Minimize the pressure drop which is occurred in Flexible rubber hose pipe used in AIS
- Reduction in pressure drop within Intake Manifold Body with constant mass flow rate
- Provide better flow Uniformity of air within the Intake Manifold

Problem Definition

The rational design of the intake manifold not only can reduce the inlet pressure loss and increase the intake air quantity, but also can ensure the intake uniformity of each cylinder. Therefore, designing the intake manifold is one of the key technologies of ensuring the engine power, economy, and reliability and emission quality. Pressure drop reduction is necessary to improve the performance of the engine and increase the life of the rubber hose by reducing fatigue failure.

Proposed Methodology

With the help of Literature Review and previous years research analysis it will be found that what type of Geometrical changes are possible in Intake Manifold to overcome the problems associated with it. After referring these analysis somewhat geometrical modifications will be applied Intake Manifold and with the help of Design Software (SOLID WORKS) this new modified geometry will be imported in ANSYS FLUENT and its flow analysis will be analyzed that what changes are occurred. Guide vanes will be provided in Air Intake pipe of AIS to reduce the pressure drop which occurs in rubber hose. Pressure drop analysis will be compared between conventional geometry of IM and New modified geometry of IM So we can conclude that which geometry is better and provides better flow inside it.

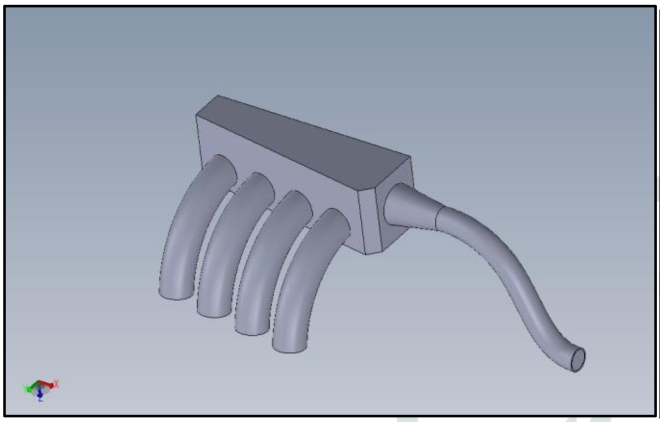
Proposed Work [CFD Analysis]

There are two Geometries which are constructed in Solid Works for the Analysis in ANSYS Fluent.

- Conventionally used Geometry of IM
- New Modified Geometry

Material used in these both the models is "319F Aluminium" which has better advantages compare to other alloys Specifications for both the models are described in below Table:

	Model 1 (Conventional Geometry) (mm)	**Model 2** (New Modified Geometry) (mm)
Material	319F Aluminum	319F Aluminum
Plenum Length	240	230
Plenum Width	Larger Section - 83 Smaller Section - 40	60
Runner Diameter	36.2	36
Runner Length	218.82	227.28
Intake Hose Diameter	26.1	26.1
Intake Hose Length	164	164
Thickness	1	1



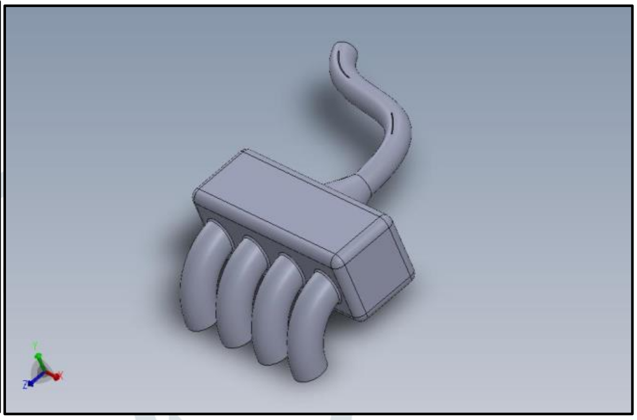


Figure 2 - Conventional Model of IM Figure 3 - New Modified Model of IM

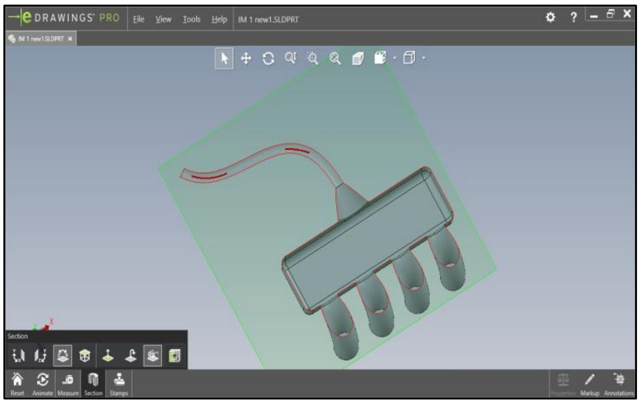
Guide Vane Placed in Air Intake Rubber Hose

Specifications for the guide vane placed in Air Intake Hose are given in below Table:

	Guide vane 1 (Placed at start of Hose From Plenum) (mm)	**Guide vane 2 (Placed at End of Hose) (mm)**
Arc Length	34.847	51.967
Chord Length	34.719	50.999
Thickness	1	1
Diameter	234.974	155
Angle	16.994 degree	38.419 degree

Table 1 – Specifications for Guide Vanes

Two guide vanes are placed in Air Intake Rubber Hose to reduce the pressure drop and provide better flow of air within the pipe. Both guide vanes are shown in below figure in the sectional view of Intake Manifold.



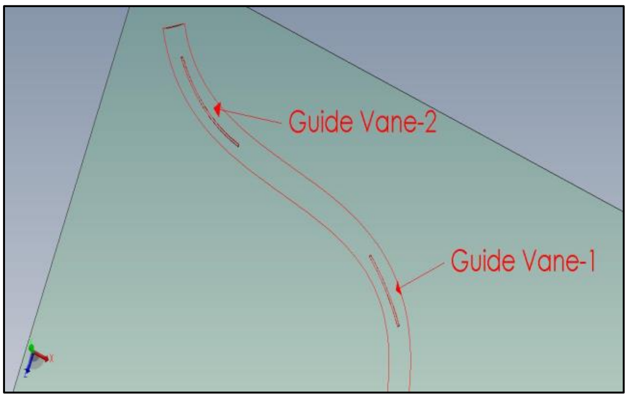
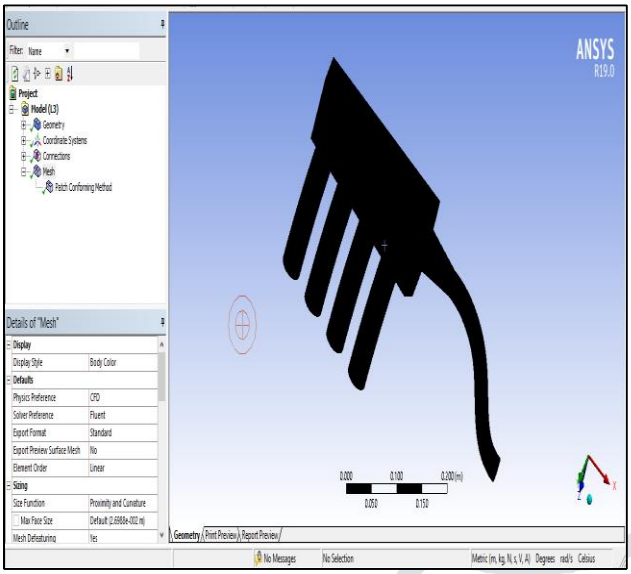


Figure 4 - Sectional View of IMFigure 5 – Guide Vanes Placed in Air Intake Hose

Mesh Generation and Creation of Name Sections

Tetrahedral meshing is performed for both the models. There is one Inlet and four Outlets which are described in below figures:



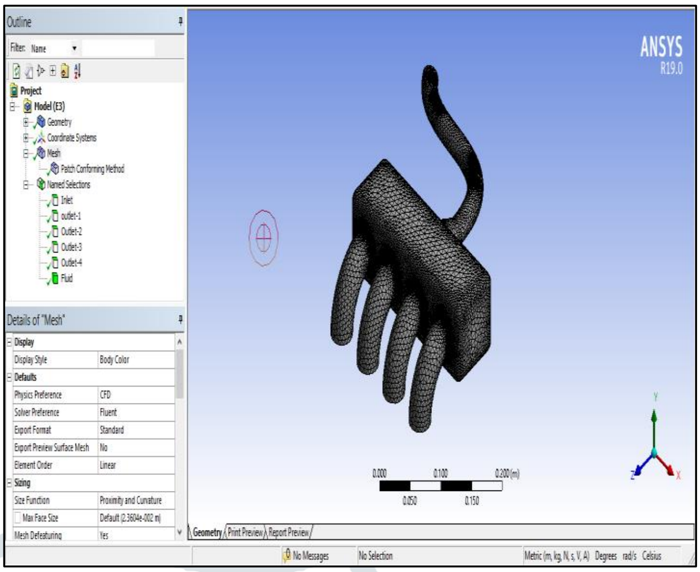
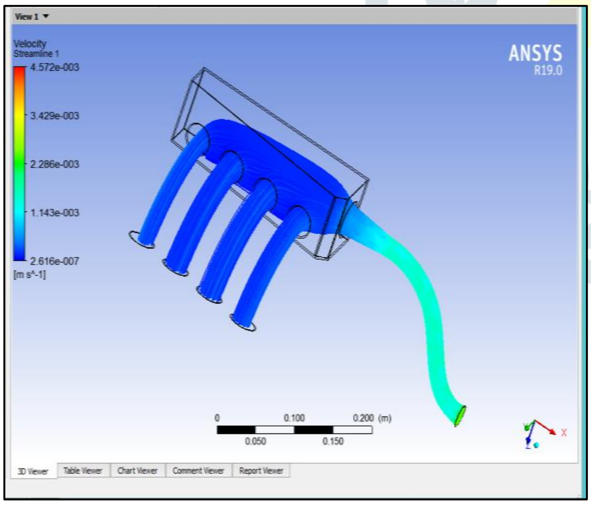


Figure 6– Meshing of Model 1Figure 7 - Meshing of Model 2

Set up for the Analysis

Velocity inlet is taken as a inlet boundary condition and Pressure outlet is considered as Outlet boundary condition. Inlet Velocity to the air intake pipe is given as 2.5 mm/s to achieve the results. K-epsilon standard model with standard wall functions is considered as a viscous model. Air is taken for Inlet Flow to the cylinder with standard properties. Turbulent Intensity and Turbulent Viscosity Ratio are considered as default values in ANSYS as 5% and 10.

After performing the Iterations we have got following results. Both the models are described with velocity stream lines in below figures:



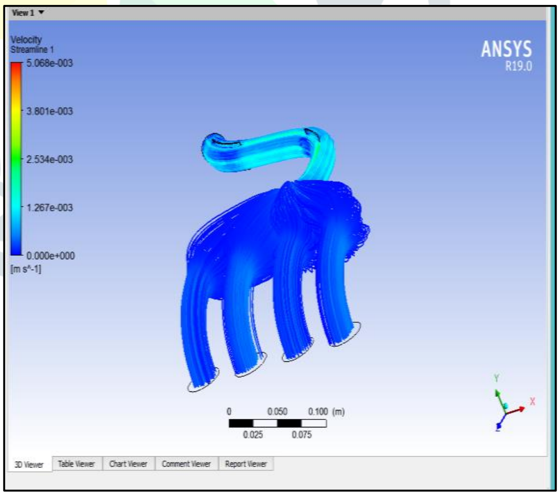


Figure 8– Velocity Streamlines for Model 1Figure 9 - Velocity Streamlines for Model 2

Results and Discussion

Pressure readings are taken at different locations within the Intake Manifold body, Graphical Analysis comparing both the models is shown in below graphs:

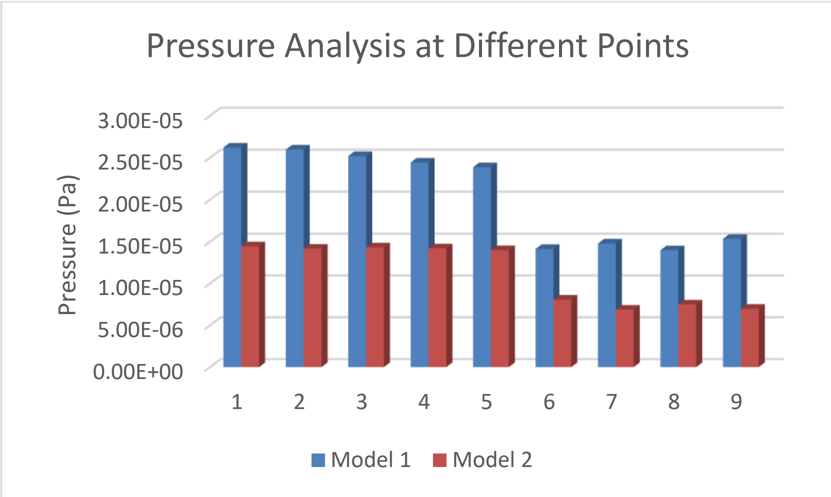


Figure 10 – Pressure Analysis

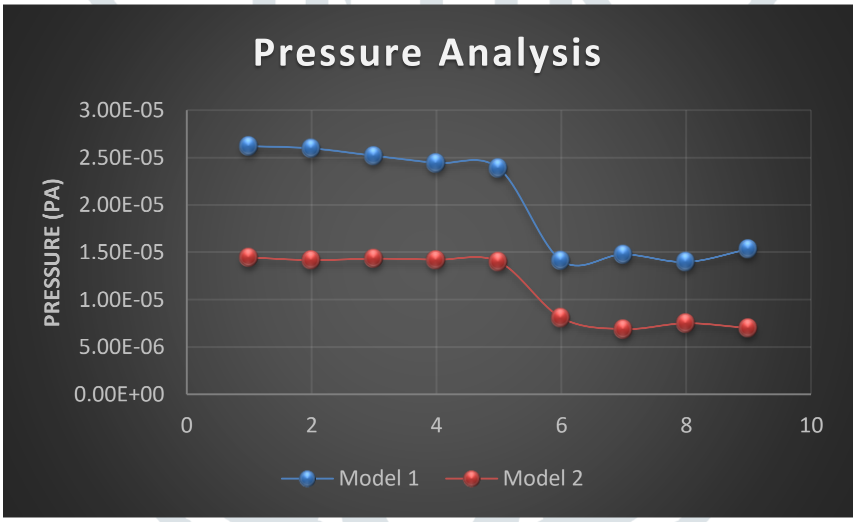
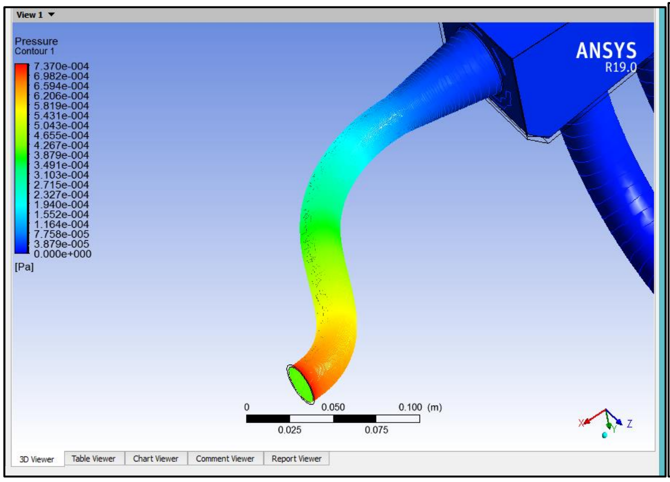


Figure 11 – Pressure Analysis Graph

Pressure Counters for Air Intake Rubber Hose

- Pressure Counters for Air Intake Rubber Hose without Guide vanes [Model 1]



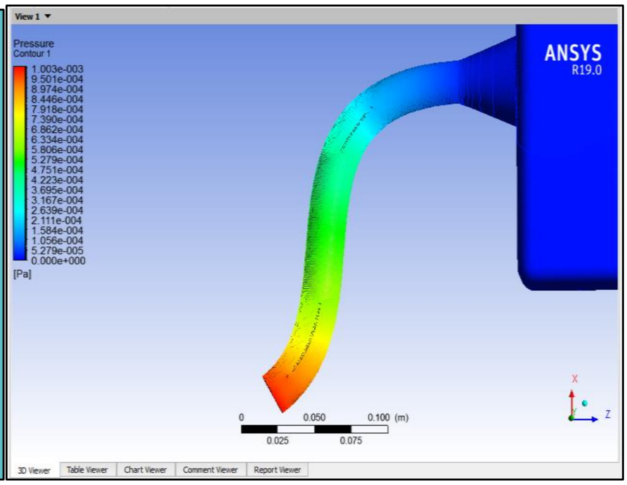


Figure 12 – Pressure Counters For Model 1 Figure 13– Pressure Counters for Model 2

Pressure counters are plotted for the models to analyse the pressure drop within the air intake pipe of the Intake Manifold. Pressure counters for both the Models are shown in above Figure:

Graphical result achieved from the pressure counters is as follow:

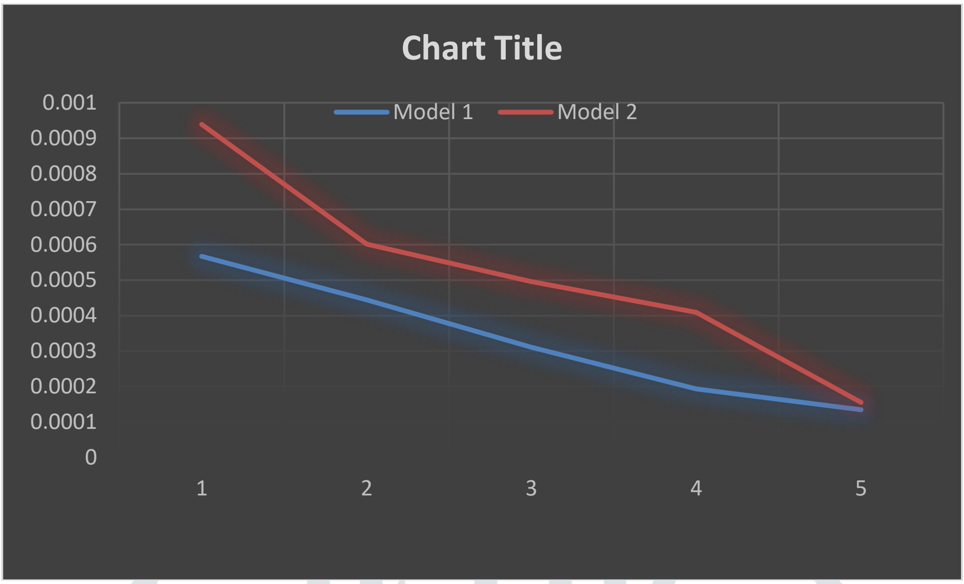


Figure 14 - Pressure Analysis Graph for Air Intake Pipe

CONCLUSION

- As per the analysis achieved with using ANSYS FLUENT New modified geometry of IM (Model 2) has better flow uniformity with comparing to Conventional Geometry (Model 1).
- Velocity stream lines shows that air flow is equally distributed among all cylinder runners in Model 2 due to applying modifications in plenum length-width and geometry of IM. While as showing velocity streamlines for Model 1, Air flow is not equally distributed in all the cylinder runners.
- Pressure Analysis Graphs shows that there is a reduction in pressure drop within IM for Model 2 with comparing to Model 1.As per the analysis results, we can conclude that Pressure drop within IM body can be reduced by 17-19 % with doing modification in the geometry of the Intake Manifold.
- Pressure Counter Analysis of Air Intake Pipe shows that there is a quite reduction in high vacuum pressure generation (Points – 2, 5 in Figure 14) due to placement of two guide vanes within the air intake pipe. So improvement in the life of the hose is possible by reducing the fatigue failure of the hose.

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➢ **Useful Links:**

[10] Understanding of car AIS file:///D:/DATA/CFD/Understanding%20a%20car%20air%20intake%20system.html

[11] www.cfd-online.com

[12] https://nptel.ac.in/courses/112105045