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Design and Analysis of Snorkel Intake System for an LCV

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Abstract - *The purpose of an air intake is to make air available to an engine's intake manifold, where it can be sucked during the intake stroke of piston into the combustion chamber. Fuel economy is important in today's car and truck owners as the cost of transportation more or less decides the final cost of the delivered product. Also many of truck travel in conditions where the roads are not proper and the dust from the surroundings may easily enter the turbocharger assembly affecting overall performance of the truck and increase maintenance. This led to the development of Snorkel assembly in LCV. A 3.5 L 4 stroke diesel engine was considered for calculations. A comprehensive analysis was done on the intake snorkel of an LCV by first doing the modal analysis followed by flow analysis using computational fluid dynamics and different models of snorkel were then developed. The results of these models were compared and an optimum design was chosen based on parameters such as pressure drop and streamline flow. The scope for future studies and design validation is also discussed in this paper.*

Key Words: *Snorkel, Computational Fluid Dynamics, Pressure Drop, Modal Analysis, Optimization, LCV (Light Commercial Vehicle).*

1. INTRODUCTION

Air intake system with filter plays important role in getting desired quality air into engine. Clean air causes better combustion efficiency and less air pollution. The air filters remove foreign particles such as dust, dirt and soot from the intake air, thereby maintaining the performance of the engine and protecting it from damage. Proper maintenance can help vehicles perform as designed. Thereby improving fuel economy, emissions, and overall drivability. Nowadays engines are being downsized to meet high efficiency demands. And the engine is combined with a turbocharger. However, the turbocharged engine produces suction in the intake system, thus increases the chances of dust entry in the system. Also, airborne dust particles are very coarse in nature, which makes the life of air filters very short. Optimized air filtration is essential to protect the engine from various contaminants such as dust which can prominently cause engine wear and performance. The air filter should be designed to adequately protect the engine for the severe conditions which are going to en-counter during its service life. Quartz (Silica) is a major component of dust. Silica is harder than steel, and quickly wears steel components inside engines, compressors, and blowers. Abnormal wear is associated with contamination levels found inside the engine, which increases oil consumption, engine overheating, loss of power, exhaust emission failure etc.

To decrease the load on air filter and to increase its life there is a need for a device which can allow entry of dry and somewhat clean air beforehand. This objective is achieved by a device called Snorkel. It is a hollow tube shape device which allows entry of air and prevents rain or water entry. It is usually made of HDPE (High Density Polyethylene) which transports the air from atmosphere to main filter without any leakage of air. The snorkel used in our case is made of two parts, the part consisting of the inlet blades which are positioned at an angle of 45 degrees. HDPE is known for its large strength-to-density ratio. Although the density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. Computational Fluid Dynamics (CFD) is considered to be the most cost effective solution for flow analysis of intake system along with filter media. Unsteady intake wave dynamics have a first order influence on an engine's performance and fuel economy. [1]Zehra Şahin discusses the effects of water injection into intake air on the engine performance and exhaust emissions were investigated. It was determined that, WI into intake air at specified ratios decreases significantly smoke index K and NOx emission and improves somewhat the engine performance. [2] 3D viscous CFD analysis was carried to understand the flow behavior through the intake system, air filter geometry and filter media. CFD simulation shows 7-10% variation with experimental results using k-ε turbulence model. [3] A higher air intake pressure is required to increase air density in allowing for better combustion within a limited time to improve fuel economy, power output and exhaust emissions. [4] (CFD) analysis was performed in four different 90 degree elbows with air-water two-phase flows. The inside diameters of the elbows were 6.35mm and 12.7mm with radius to diameter ratios (*r/D*) of 1.5 to 3. [5] Modal analysis was performed on the engine bracket and it was found that higher the resonant frequency, higher is the level of noise disturbances.

2. CALCULATION

The engine specifications are considered as follows:

a)Engine capacity – 3500 cc

b) Rated RPM – 2400

c) Volumetric Efficiency – 1.3

d) Correction factor – 2

Formula used for mass flow rate is given below:

$$\text{Mass Flow Rate in CFM} = \frac{\text{Swept Volume(CID) X Speed(in rpm) x VE}}{\text{1728 X CF}}$$

Different values of mass flow rate are as follows :-

1) In CFM = 262.5506

2) In m3/hr = 262.5506*1.699=446.07

3) In Kg/hr = 446.07*1.22=544.209

Q = A*v (Air velocity, v =3m/s)

A=262.5506/(3600*3)= 0.0421m2

Width was assumed to be 100mm due to space constraints. This gives, the length of the entry of snorkel to be 412mm.

3. PRE-PROCESSING

3.1 Cad Modelling

Initial design of the model were done using previous design considerations by researching from the past models used in similar kind of vehicles. Design improvement were then done by smoothing out the flow near the entry to the snorkel models. The next question that was to be addressed was choosing the number of passages needed for a streamline flow. The models were so developed such that the number of passages differed in each one of them. Model 1 was developed where in there was no compartments to guide the flow. Subsequently other models were developed with 2, 3 and 4 passages.

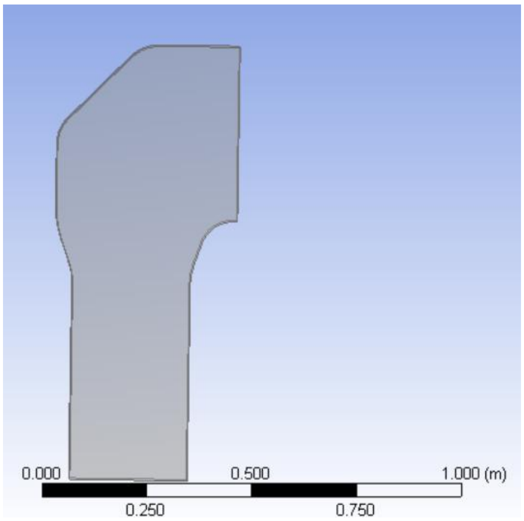

Fig 1. Model 0

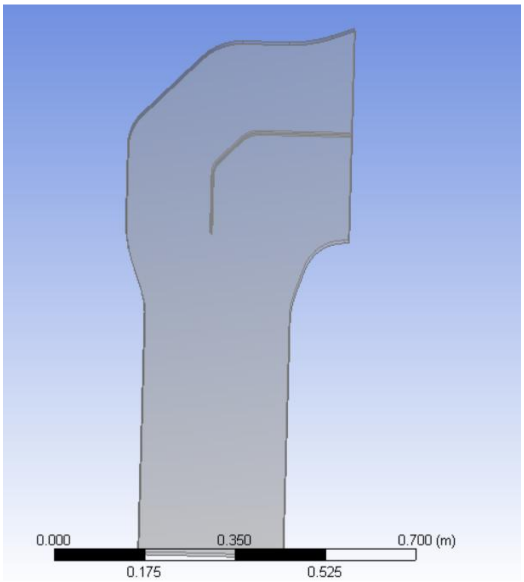

Fig 2. Model 2

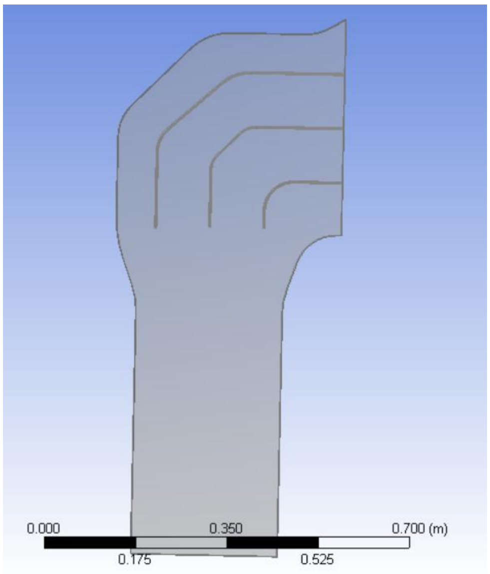

Fig 3. Model 3

3.2 Meshing

Meshing plays an important role in doing any kind of analysis as a good mesh will result in accurate results. Structural and Fine 3 D Mesh was chosen as it is more accurate compared to other types of meshes. The use of inflation was taken into consideration while meshing to take into account the effect of boundary layer formation.

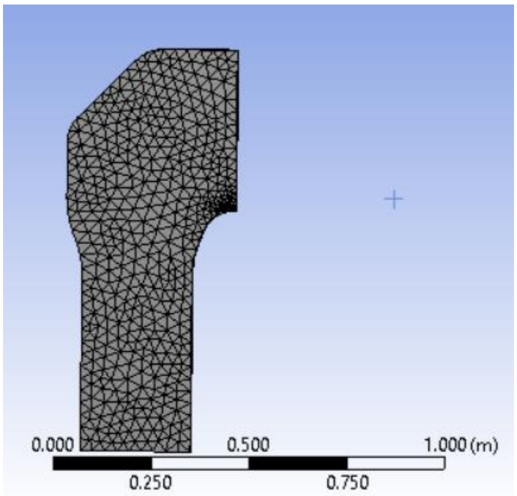

Fig 4. Model 0 Meshing

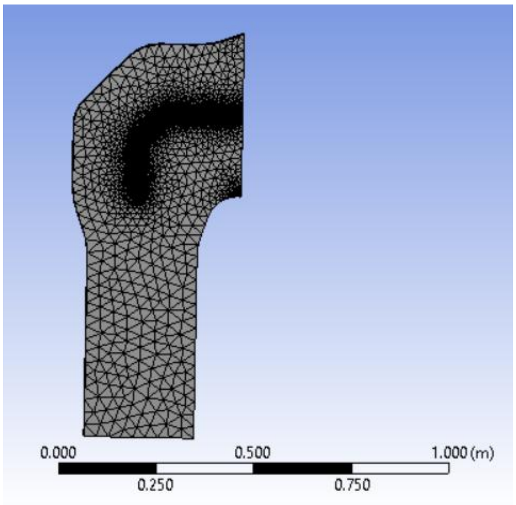

Fig 5. Model 2 Meshing

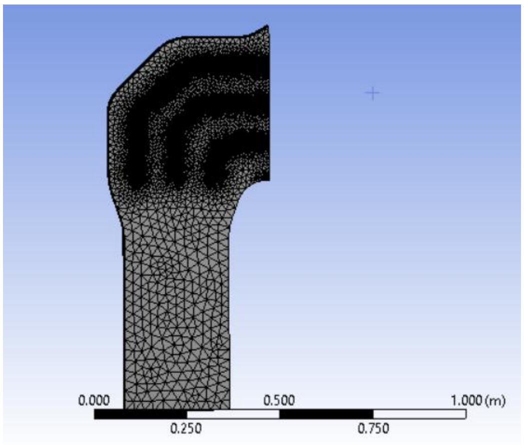

Fig 6. Model 4 Meshing

4. RESULTS

4.1 Cfd Results

4.1.1 Model 0

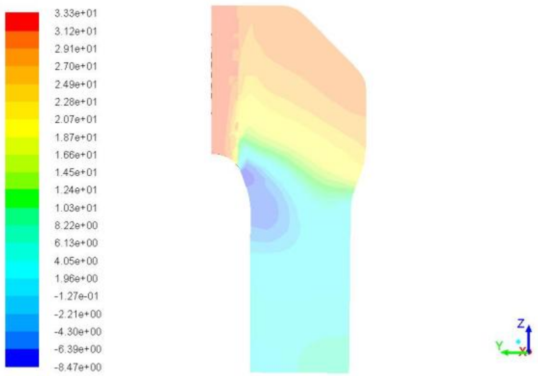

Fig.7. Pressure Contour

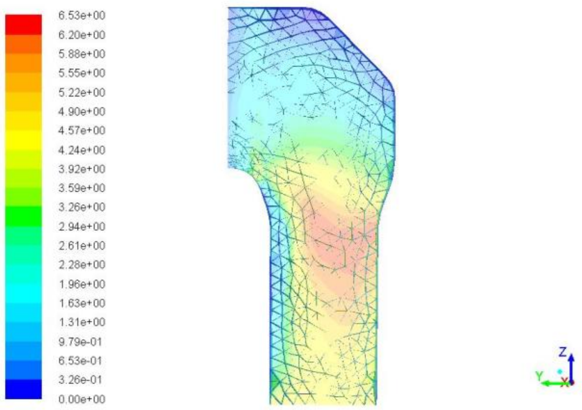

Fig 8. Velocity Contour

Static Pressures

Outlet: 5.8676633 Pa

Inlet: 31.184816 Pa

Pressure Difference: 25.3171 Pa

In case of Model 0, the Delta P is very large as the flow is forced to flow through sudden bends inside the snorkel which leads to a sharp increase in Pressure Drop. This Sharp increase is undesirable for us. Also there is seen a vortex creation which leads to reversal of flow. Thus, the engine is not able to suck the air at the desired rate. This leads to Optimization of design where certain curvature were given to the model to decrease the sharp bends thus resulting in the decrease of Pressure Drop.

4.1.2 Model 2

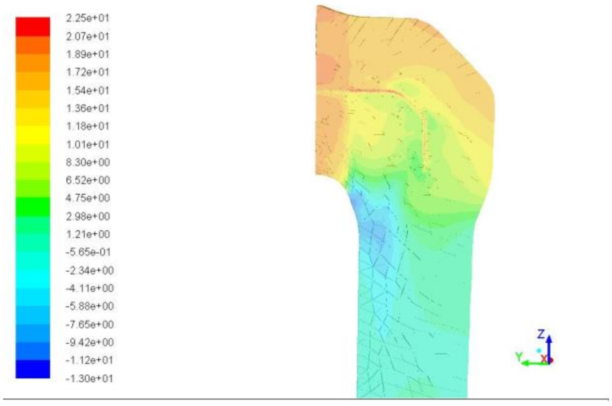

Fig. 9 Pressure Contour

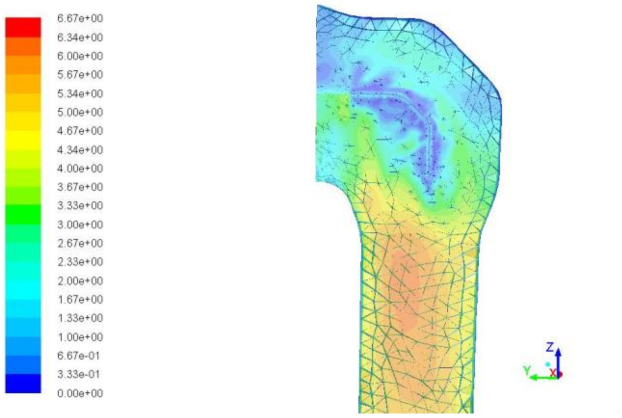

Fig. 10 Velocity Contour

Static Pressures:

Outlet: 0.75687941 Pa

Intake: 16.869594 Pa

Pressure Difference: 17.6264 Pa

As we can see, the Pressure drop is greatly reduced when we give a partition to our model. This is because the fluid is given a pathway to follow, thus reducing any sharp bends and thus decreasing the pressure drop.

4.1.3. Model 4

Static Pressures:

Outlet: -2.0425714 Pa

Intake: 20.182678 Pa

Pressure Difference: 22.2252 Pa

As the number of partitions go on increasing, boundary layer thickness also increases across the layers of the partition. As these layers increasing the velocity becomes more and more stagnant at that region. This in turn increases the pressure drop.

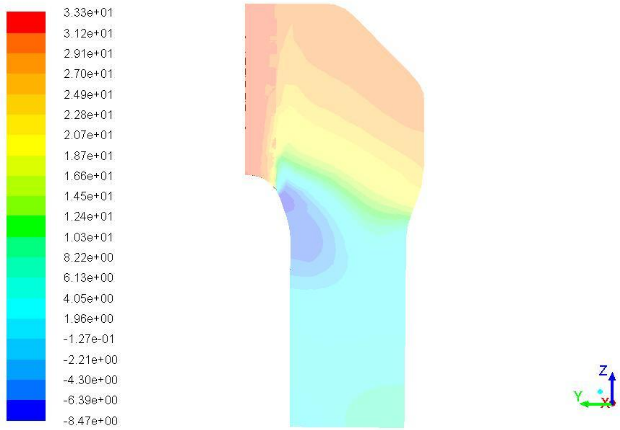

Fig. 11 Pressure Contour

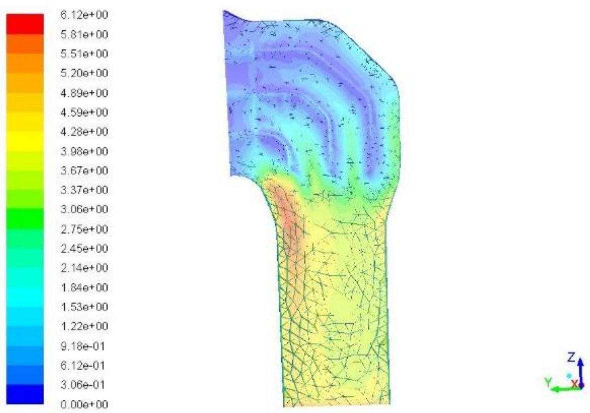

Fig. 12 Velocity Contour

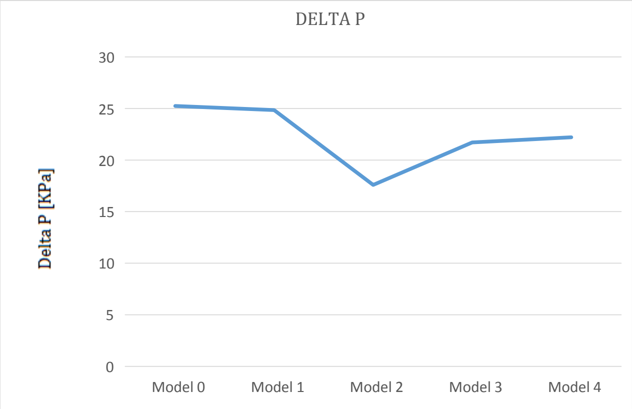

Fig.13 Delta P v Models

Thus, we find that there is a certain limitation in keeping the number of passages for the fluid to flow through. The Results of these discussions is studied ranging from Model 0 to Model 4 and their Pressure Drops are tabulated as above.

4.2 Modal Analysis

Modal analysis is used to determine the response to externally applied transient vibrations. Modal analysis gives natural frequencies and mode shapes of a structure or a particular component. This analysis can be used to conduct more detailed dynamic analysis like transient dynamic analysis, harmonic analysis or spectrum analysis.

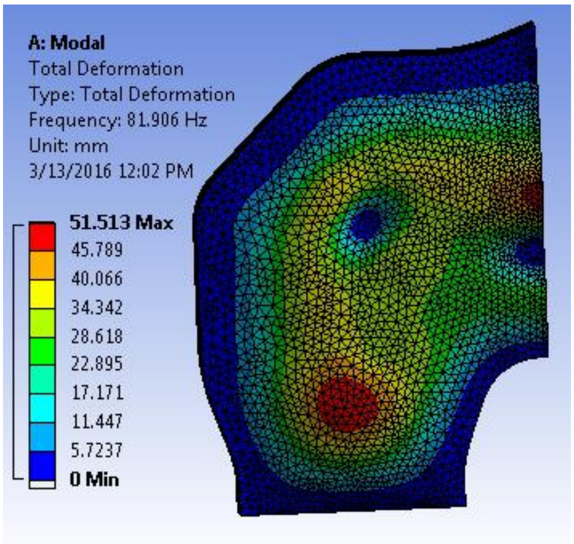

Fig. 14 Total deformation plot for first frequency

Natural frequency and mode shapes of the model are tabulated as follows:

Table 1. Mode Shapes (1-10) of Snorkel

Frequency	Optimized Snorkel(Hz)
1st	81.906
2nd	100.51
3rd	108.07
4th	111.87
5th	150.97
6th	160.05
7th	168.15
8th	176.09
9th	218.78
10th	224.09

From the table, the first six frequencies shown are called as the natural frequencies. Hence, if the external disturbance frequency matches these, resonance takes place. The 4th natural frequency lies in the operating frequency range.

5. CONCLUSION

We find that the Pressure drop across the intake system can be reduced by giving certain number of passages across the snorkel for heavy duty applications. The model taken in this paper requires 2 passages for ensuring minimum pressure drop thereby providing the basis of any future study done on different models of the snorkel. The Pressure drop was found to be 25.31 Pa on a snorkel without any Partitions but it reduced by 30.36% to 17.624 Pa when the snorkel was provided with 2 passages for the fluid to flow through. As the partitions i.e. passages were increased, it was found that due to the large thickness of the boundary layer formation the pressure drop was found to increase again. Thus, Model 2 was chosen as the optimum model. The Modal analysis was also conducted to ensure the product does not fail in Resonance as the frequency does not match the external natural frequency.

6. FUTURE SCOPE

Next study lies in conducting a detailed study of the cost and effect analysis of adding a partition and if the addition of partition is justified financially for any company. Different Parts of this Snorkel assembly can be produced with different Manufacturing techniques using High Density Polyethylene (HDPE). The structural analysis can be carried out further on such models and be ensured to check its durability. Also, further study lies in checking the effects of the addition of Filter assembly to make sure the flow rate is proper to the Turbo Charger without any losses.

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