Design and Development of Air Intake System for Commercial Vehicles

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Abstract- Air intake system of any vehicle is the most important part of the vehicle which should play a major role to enhance the engine performance. Any vehicle has to pass certain regulatory over the air intake system performance and design laid down by government bodies. Air intake system consists of some sub level (ducts and hoses) as well as proprietary performance parts (air cleaner assembly). In order to design an air intake system that satisfies engine's air requirement for getting enhanced performance, the effect of the characteristics of each part on the entire system has to be considered. The research objective for the current abstract is to design and develop a highly efficient air cleaner system for a particular 4 cylinder Engine based on its filtration accuracy (as assumption 99.9% approx.) and to be validate on requirements of high filtration and volumetric efficiency, Low pressure drop, low noise, Easy Serviceability, Accessibility and Maintainability etc.

Keywords: Air cleaner assembly, CFD, counter flow measurement module, service and maintainability

I. INTRODUCTION

During earlier days the naturally aspirated type engines are used for the vehicles, but with the developed era of new inventions and improvement in technology sector the turbocharged engines are process for the better efficiency and performance requirements. As per the demand increment of air flow rate in IC engines the improvement of air quality and the flow system is a must needed factor for the air intake system development. The major factor of the challenging zone to develop the air intake systems are;

- Less restriction to the flow
- Better cleaning of air
- Durable design of ducts and mountings
- Efficient engine performance enhancement with better fuel economy

The intake system provides the internal combustion engine with fresh air and it has a major effect on engine performance and emissions. Therefore great attention has to be focused on the design of the intake system. Many investigations are related to the improvement of the breathing capacity of the engine, to the minimization of pressure losses along the pipes and to the distribution uniformity of air among the cylinders of the engine.

II. OBJECTIVES AND MODELLING

In order to determine the best air cleaner system for a particular engine and vehicle application the intake airflow and restriction limit of the engine to be identify based on power rating required for the vehicle. Also the level of dust or contaminants in the environment in which the vehicle is used must be defined with respect to desired service interval for the air cleaner system. Also the boundary conditions to determine the best design considerations for air intake system based on system requirements for an IC engine should be:

- Max. temperature rise between ambient air and turbo air inlet: 15°
- Maximum intake restriction with dry type air cleaner, with clean filter
  - For medium duty engines: mm H_2O: 381 (i.e. 15"of H_2O)
  - For Heavy Duty: mm H_2O: 432 (i.e. 17"of H_2O)
- Maximum intake restriction with dirty filter, mm H_2O: 635

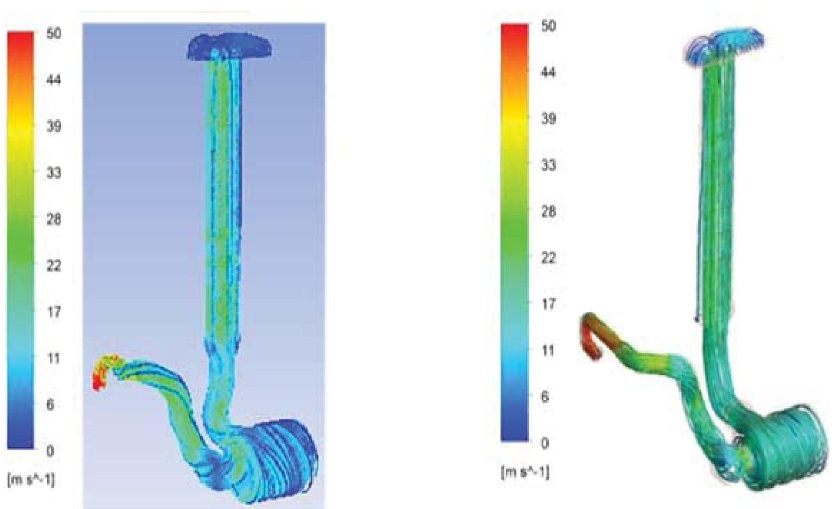
III. DESIGN RECOMMENDATION AND STANDARDS

The general recommendations for air intake system design are based on mentioned guidelines;

1. The air cleaner must be at least 99.9% effective at removing airborne dirt particles when tested according to SAE STD.
2. The air cleaner design must provide adequate filter element service life in the environment in which the vehicle will be operated.
3. The restriction of the installed intake system with a clean filter element must not exceed the Maximum Inlet Restriction with Clean Filter on the Engine Data Sheet.
4. The system must include a restriction indication device, connected to the intake system with a filtered fitting, set to indicate when the Maximum Inlet Restriction with Dirty Filter on the Engine Data Sheet is reached.
5. The air inlet location on the vehicle must prevent the ingestion of hot engine compartment air, Prevent the direct ingestion of rain and road spray, Prevent the ingestion of exhaust soot.
6. The heating of intake air as it passes through the intake system must not exceed the maximum temperature rise between ambient and engine air inlet.
7. The intake system must remove at least 80% of ingested moisture when tested per SAE STD.
8. The air intake piping from the filter to TC inlet must be made of non-corrodible material.
9. Clamps used on the clean side of the intake system must be T-bolt or high quality screw type design, to provide a consistent 360 degree seal throughout the life of the vehicle.
10. Any break-away joints used in the intake system (such as the hood to air cleaner housing joint) must be upstream of the air cleaner.
11. The intake system must allow routine engine servicing without opening any part of the intake system between the air cleaner and turbocharger.
12. The air intake system must include a shutdown device if the vehicle will be operated in the presence of combustible fumes.

IV. MODELING AND SIMULATION OF "AIR INTAKE SYSTEM" BY USING PRO-E/ANSYS

In consideration of requirement some of the basic CAD data for air intake system prepared by using CAD tool Pro-Engineer and Simulation boundaries with ANSYS CFD. The system consists of Primary and secondary ducts, snorkel assembly, air cleaner assembly, route hose, turbocharger pipe assembly. Here the flow resistance (1500 Pa) as a factor of safety consider for air cleaner assembly only. As the other parts are belongs to the route path the iteration wise data prepared for the flow path restriction verification by using CFD analysis. Also here with the resistance factor for the air cleaner assembly consider to verify the pressure drop during the air flow within the air intake system.



Iteration 1 Iteration 2

Figure 1. Air flow path line colored by velocity magnitude (m/s)

V. POST PROCESSING BY USING ANSYS

The air flow counters are the fluid simulation code on finite volume method for simulating the performance of air intake system with requires air flow as per engine's rated power. Tools using this three dimensional approach accurately predict all engine breathing characteristics. This enables engineers to Consider air system and air intake effects during analysis. The post processing for fluid simulation (CFD) has to be use following boundary conditions to finding out the require results: (elaborate the figure 1 and 2 and explain it in all places)

1. Air flow; 650Kg/Hr.
2. Filtration restriction boundary; 1500 MPA.
3. Maximum pressure drop; 381 mmH_2O (15" of H_2O).

As per the post processing result shown (Refer figure 2 and figure 3), both the figures are highlighted the pressure drop zone from snorkel top to turbo inlet end. Based on color rating scale the effects on air flow within the system showing the restriction in Pascal as shown. It shows the change in routing of air flow area will leads for increment or decrement of restriction.

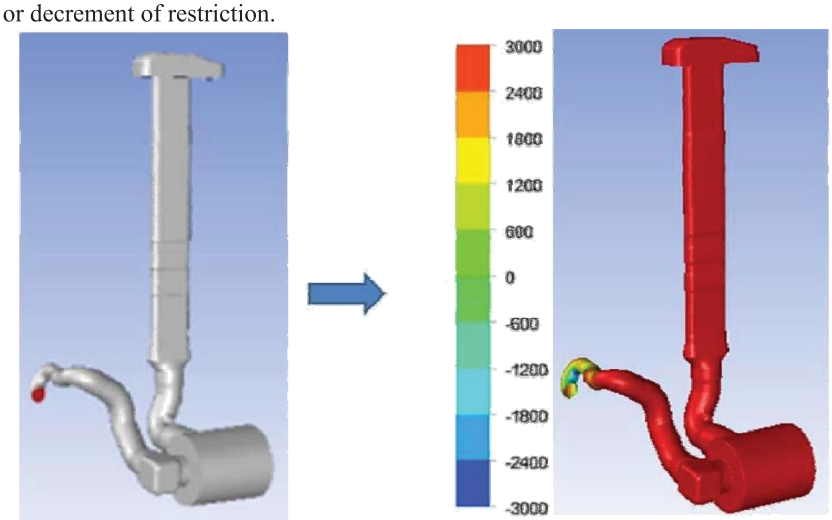


Figure 2. Air flow pressure drop contours for iteration 1 (Total Pressure Contours in pa)

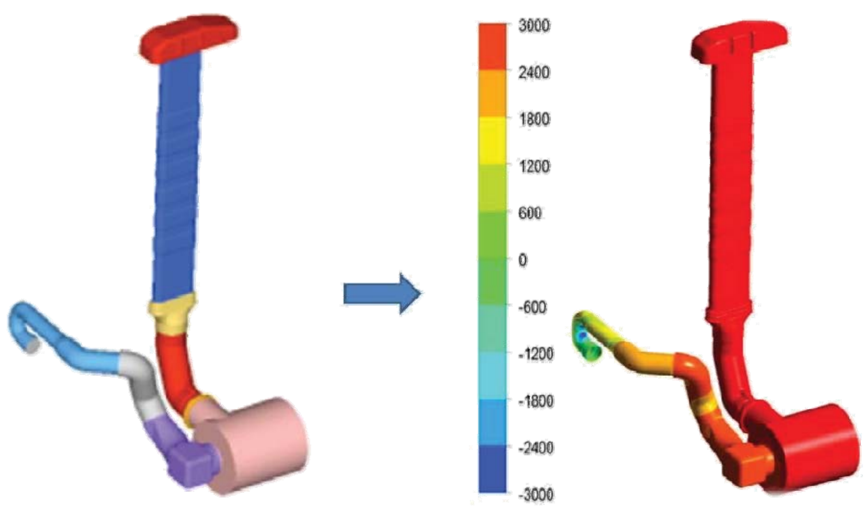


Figure 3. Air flow pressure drop contours for iteration 2 (Total Pressure Contours in pa)

Table 1: CFD results for pressure drop contours

	System Components	Snorkel Head (S1)	Housing System 1 (S2)	Air cleaner (S3)	Housing System 2 (S4)	Total System
Total Pressure Drop (Pa)	Iteration 1	130	340	1500 (Filter Resistance)	1868	3838 (15.6"H_2O)
	Iteration 2	137	351	1500 (Filter Resistance)	1614	3602 (14.4"H_2O)

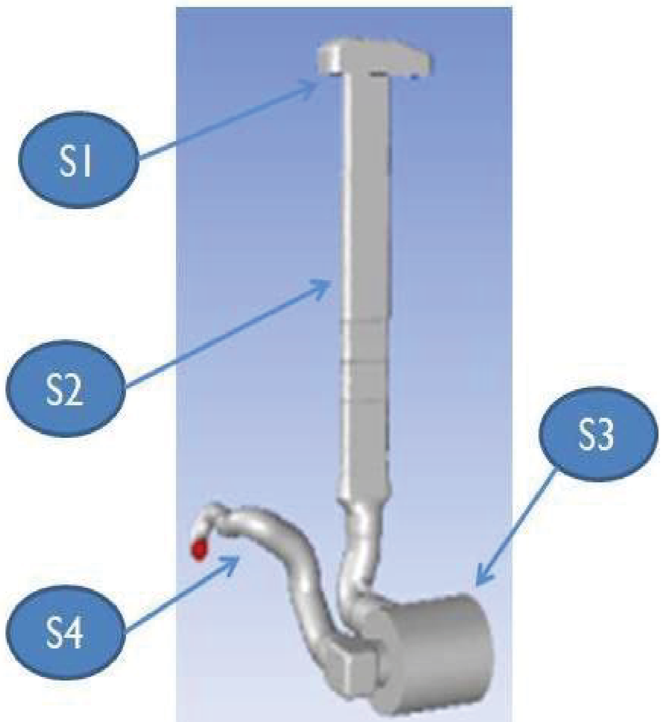


Figure 4. AIS system components

VI. MODELLING AND CALCULATION OF AIR INTAKE SYSTEM RESISTANCE

Based on the simulation results the manual calculations and modeling will be done with following structural requirements;

For smooth pipes (for air ducts)

$$R = 0.000502 \times F^2 / D^2 \quad \text{.......... (i)}$$

Where, F=air flow (CFM)
D= diameter of smooth pipes in inches
R = flow resistances in inches of water per feet

For clean filter D=102mm and F=386CFM
So for our current design let we have 2 ducts each of 500mm length

Then,
R= 0.24132203” of H_2O/Feet

And the restriction in the air cleaner at 443.2624 CFM is 6” (152.4mm)
And for pre cleaner at 443.2624 CFM is 3” (76.2mm)

Also for 90 degree elbow between ducts of 250 mm length,

$$R = 0.0008367 \times F^2 / D^2 \quad \text{………..(ii)}$$

Result for R is,
R=1.266833” of H_2O/Feet
So total restriction for clean filter is = 287.24mm of H_2O (i.e.11.3” of H_2O/Feet)

VII. RESULTS AND DISCUSSION

This research work shows that the requirement of air intake system’s design and development has been considered based on its basis calculations and recommendation as per the SAE standard. The result based on the CAD and CFD virtual systems may be vary with respect to the manual and practical conditions of an air intake system for commercial vehicle. The summarized result over the analysis (manual or simulated) will provide a beneficial air intake system as per the mentioned requirements;

- The limit of pressure drop is found to be less than 380mm which is under permissible limit hence the pressure drop due to restriction in the entire routing of air intake system design is safe.
- The less pressure drop leads to the better cleaning and filtration efficiency to be achieved as per the system requirement.
- Better dust holding capacity and filter life increase with respect to the change in pressure drop will leads a good serviceable & durable filtration system
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