Effect of Geometric Change on Performance of an Air Filter

Sudarshan T A[1#], Rajesh A[2*]

[1,2]*Assistant Professor, Department of Mechanical Engineering,*
New Horizon College of Engineering, Bangalore-560103.
Email address:sudarshan88ta@gmail.com[#], rajesh.inspiring@gmail.com[*]

***Abstract*: The paper focuses mainly on pressure drop of a car air intake manifold. This is analyzed through CFD software to increase the combustion efficiency of the engine. An initial design of air filter has been taken from the reference vehicle where the efficiency of the air filter data is below the optimum level. Therefore the geometry of the air intake manifold design is altered and the analysis is done by applying suitable boundary conditions. i.e. pressure, temperature and velocity of the air which flows through the air intake manifold. The altered design has been done through CAD software and further it is meshed by using ANSA software and the post processing is performed through CFD analysis for the above boundary conditions and the results are obtained by using STAR CCM+ software also these obtained results are compared with experimental data.**

***Keywords*-Air filter, intake manifold, combustion efficiency and cavitations**

I. INTRODUCTION

In an automobile, engine is one of the main components where power is extracted to the sub components to drive the vehicle. The engine of a car needs air for the combustion process in the cylinders. 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. In this paper the air intake system has been chosen to analyze. The main function of an air intake system is to supply the engine with clean air and correct amount for the required air to burn in the manifold chamber. Air enters the filter through inlet pipe and inlet side plenum, which guides the flow uniformly through the filter media. Optimum utilization of filter can significantly reduce the cost of filter replacements frequently and keep the filter in use for longer time. To optimize intake system and filter, thorough understanding of flows and pressure drop through the system is essential. Computational Fluid Dynamics (CFD) is considered to be the most cost effective solution for flow analysis of intake system along with filter media. Air intake Systems employ specially-shaped intake tubes designed to straighten airflow as much as possible while looking great in engine compartment.

An air filter is an important part of a car's intake system, because it is through the air filter that the engine "breathes." An engine needs an exact mixture of fuel and air in order to run, and all of the air enters the system first through the air filter. The air filter's purpose is to filter out dirt and other foreign particles in the air, preventing them from entering the system and possibly damaging the engine.

II.TYPICAL AIR INTAKE SYSTEM

Main components of air intakes system

- Air inlet duct
- Air filter
- Clean side duct
- Compressor inlet.

A typical air intake system is displayed in the fig.1 The air from the atmosphere enters through the inlet, as the air is coming from the environment it will contain the dust particles. There is a bellow in between the air inlet and the air filter which reduces the suspended dust particles because of its geometry. Then this air enters into the filter, which consists of filter element usually made up of paper which will be a porous. As the air passes through the filter element it will be more clean without the dust and suspended particles. This air now passes through the clean side duct and is compressed in order to feed to the combustion.

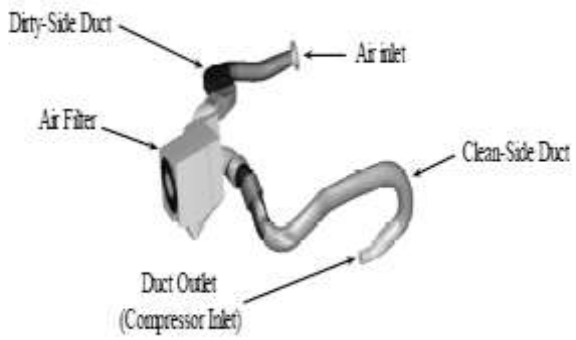

Fig 1 Air intake system

For an engine equipped with a carburetor, Air comes in the air filter housing, passes through the air filter, into the carburetor where. The fuel is mixed with it. Then it passes through the intake manifold and is drawn into the cylinders. The most advanced part of the system was an Air Temperature Sensor in the air intake. It was used to measure the air temperature and, by opening and closing a flap, allow cool air in through the air horn or heated air piped in from around an exhaust manifold. This was to prevent carburetor icing that would cause the car to stall and die out. It also facilitated vaporization of the fuel into the air stream. In a fuel-injected car it's a whole different ball game. Air is drawn in through the air intake. This is usually a long plastic tube going into the air filter housing. The reason the intake tube is long is to get the air moving in a fairly steady, coherent stream. It then passes through the air filter and then through an Air Flow Meter. The intake system of an engine has three main functions. Its first and usually most identifiable function is to provide a method of filtering the air to ensure that the engine receives clean air free without debris. Two other characteristics that are of importance to the engineers designing the intake system are its flow and acoustic performance. The flow efficiency of the intake system has a direct impact on the power the engine is able to deliver. The acoustic performance is important because government regulations dictate the maximum noise level that vehicles can make during a pass-by test. The speed of air generated by the intake system can be a significant contributor to this pass-by noise and separated flow . It may be noted that since the loss pressure from the intake duct towards atmosphere, this paper assumes the inlet is at the intake manifold where as the air filter duct and the outlet is at atmosphere. The fundamentals of installing a performance air intake system i.e, air filters on vehicle not only increase the performance of air intake which is also one of the most essential upgrades to vehicle.

II. OBJECTIVE

- There is an existing air filter, which needs replacement of filter element after a period of time, reduce the pressure drop and increase the life span of the entire filter system.
- Steady state analysis of the air filter has to be carried out using porous media.
- The pressure drop in the existing filter is 683.817pa which need to be reduced by 25% as per the optimum design requirement for the engine to fit filter. In order to achieve this design, modify the existing geometry
- Avoid the low pressure zones to increase the life of the filter.
- Steady state analysis of the air intake system, measure the pressure drop, temperature and velocity distribution.
- Comparing the pressure drop with the experimental data and the revised design.

III. PROCESS FLOW CHART

The air intake manifold steady state analysis starts with extraction of fluid core from the given intake manifold the optimization process is as shown in fig.1

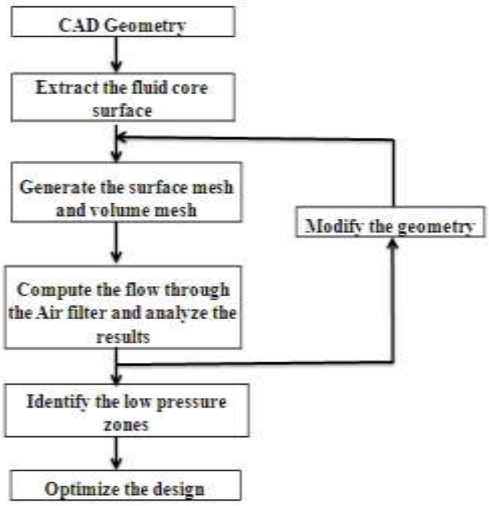

Fig.1 Process flow chart for optimizing the design

IV. METHODOLOGIES

- A thorough review of literature for different types of air filter and design techniques are studied.
- Modify the geometry focusing on reducing the pressure drop, locate the zones of low pressure, so that cavitations can be reduced.
- Generate the surface mesh for existing air filter using ANSA software, apply the boundary conditions for the given material properties and calculate the solution using STAR CCM+ software.
- plot the results for the obtained values, locate the low pressure zone and calculate the pressure drop correlate with test results.
- Repeat the above procedure for the revised geometry until the requirements are met

V. MODEL DISCRIPTION

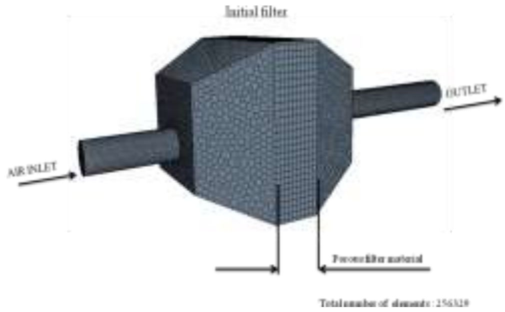

Fig.2.1 Mesh model of air filter

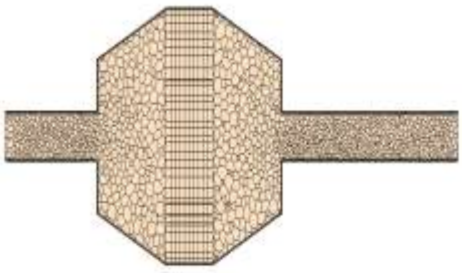

Fig 2.2 Cross section of mesh model

Fig.2.1 and Fig.2.2 shows the meshed model isometric view of air filter geometry where the fluid enters into the engine cylinder through the air intake manifold. A mesh analysis is performed to obtain optimum mesh and the total number of quad and tri elements is 256348 in number.

VI. FLUID PROPERTIES AND BOUNDARY CONDITIONS

- Inlet velocity : 40m/s
- Turbulence Intensity : 1%
- Turbulence length scale : 4mm
- Outlet : atmospheric pressure(101.325kPa)
- Porosity : 21 kg/m^4
- The Walls are considered as Adiabatic walls
- Fluid used : Air
- Density : 1.225 Kg/m^3

VII. RESULTS AND DISCUSSION

In the initial design the upstream and the downstream runner are not co-axial. The results of initial design indicates the existences of low pressure zone i.e, pressure of 683.817 Pa leads to erosion and cavitations, which reduces the life span of the air filter system.

In the revised design it is observed that the low pressure zone does not exist because of fillet feature is introduced and the Low pressure zone at the downstream is reduced i.e, pressure drop is 510.086 Pa.

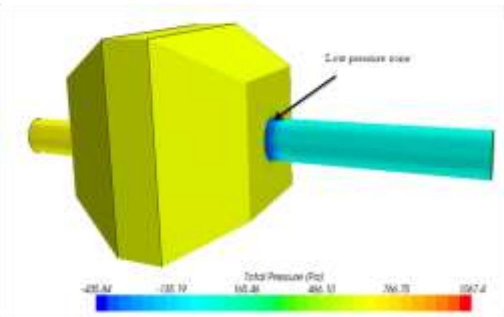

Fig 3.1a Iso view contour plot of initial design model

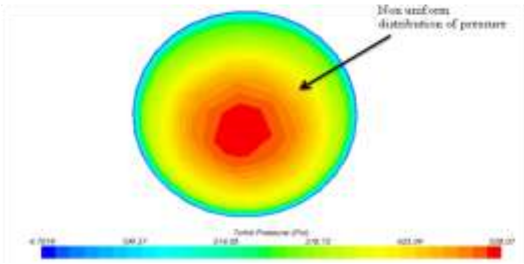

Fig 3.1b Side view contour plot of initial design pressure distribution.

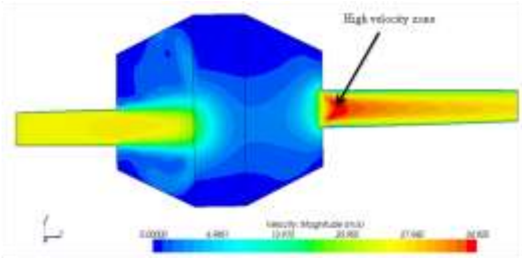

Fig 3.1c Cross sectional view contour plot of velocity distribution.

The fig 3.1a, fig 3.2b and fig 3.2c shows the analysis result of reference design of an air filter, where the air enters in to the air intake manifold at pressure of $1.064*10^3$ Pa and exits at a pressure and velocity of $3.8019*10^2$ Pa and 34.925 m/s respectively. Therefore the total pressure drop in the intial design is 683.818 Pa. In the contour plot the low pressure zone is indentified where the pressure distribution is not uniform and modification of the geometry is necessary to obtain the required pressure drop.

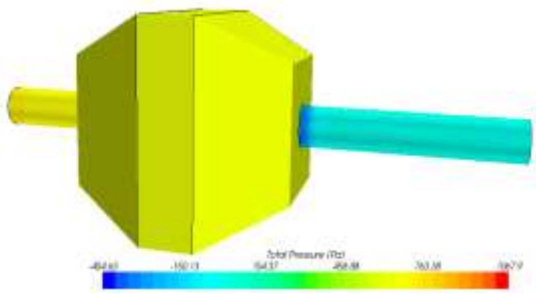

Fig 3.2a Iso view contour plot of Intermediate design model

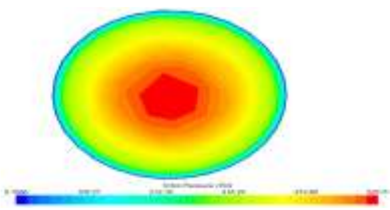

Fig 3.2b Side view contour plot of intermediate design pressure distribution.

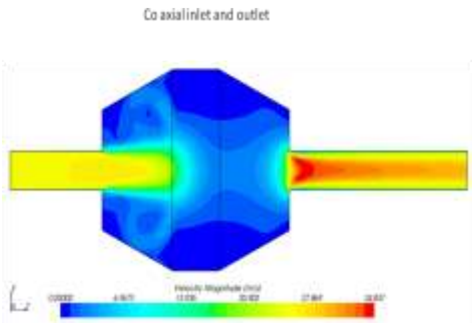

Fig 3.2c Cross sectional view contour plot of velocity distribution.

The intermediate revised design is as shown in fig 3.2a,fig 3.2b and fig 3.2c where the pressure drop and velocity distribution obtained is not optimum and further the geometry has to be revised to obtain the required pressure.

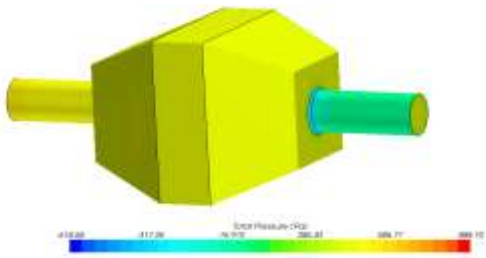

Fig 3.3a Iso view contour plot of final design model

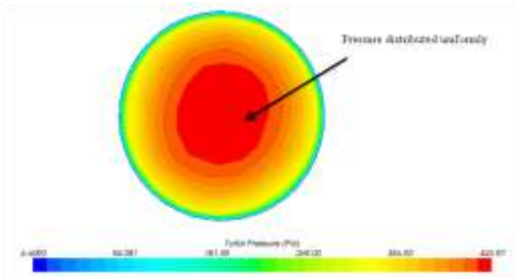

Fig 3.3b Side view contour plot of pressure distribution in final design.

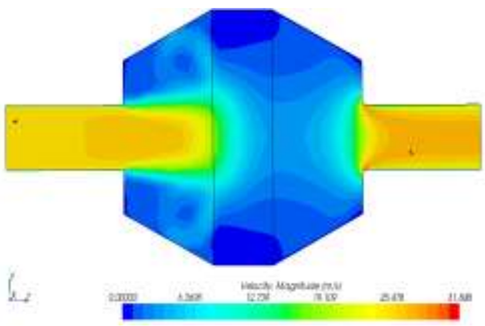

Fig 3.3c Cross sectional view contour plot of velocity distribution.

The fig 3.3a, fig 3.3b and fig 3.3c shows the analysis result of optimum design of an air filter, where the air enters in to the air intake manifold at atmospheric pressure i.e, $8.858{*}10^2$ Pa and exits at a pressure and velocity of $3.757{*}10^2$ Pa and 31.648 m/s respectively. Therefore the difference between the inlet and exit pressure is around 510.086 Pa.and the pressure distribution inside the air filter manifold is uniform.

IV. COMPARISION OF INITIAL AND REVISED GEOMETRY

In order to show the difference between the initial design and the revised design both the geometries are overlapped.

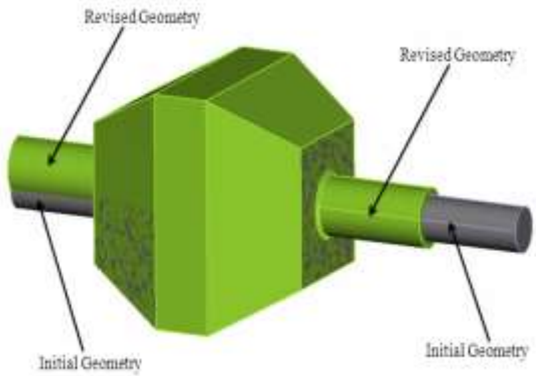

Fig 8.13 Comparison of Initial and final geometry

The initial design is analyzed using the boundary conditions results are plotted. Then the design is changed by keeping the upstream and downstream co-axial, the diameter is increased, and a fillet is introduced. Final revised design is arrived after trying 14 different geometrical combinations and solution.

V. CONCLUSION

From the above results we conclude that the Chances of cavitations and erosion are reduced. Instead of high velocity at a single location, a uniform velocity is achieved. Pressure at the outlet is uniformly distributed, which would lead to better distribution of air to different ports. Required pressure drop 510.086pa is achieved, which is 25% lesser than the initial design. The above results clearly indicate that by the usage of the revised design would lead to increased life of air filter.

REFERENCES

[1] M. R. Chopade, A.P.Valavade, S. H. Barhatte. "Performance Enhancement of Air Filters by Design Optimization" International Journal of Advanced Engineering Technology E-ISSN 0976-3945. Department of Mechanical Engineering, MIT College of Engineering, Pune, India

[2]Maria Dybeck "CFD-Procedures For Air Induction Systems" Luleå University of Technology Department of Engineering Sciences and Mathematics. Sweden

[3]. Warren Seeley, Alex Leong "A New Approach to Optimizing The Clean Side Air Duct Using CFD" Ford Dunton, Dunton Research & Engineering Centre, Basildon, Essex, SS15 6EE

[4].Geoff Capon, Tim Morris "The Effect of Air Inlet System Features on Automotive Turbocharger Compressor Performance" Ford Motor Company Limited.USA

[5]. Damien Kennedy, Gerry Woods, Darragh Forrest" Development of a new air intake and exhaust system for a single seat race car" Dublin Institute of Technology, Germany.

[6].Chang Ming Tsang. "Analysis of Pleated Air Filters Using Computational Fluid Dynamics" Graduate Department of Mechanical and Industrial Engineering University of Toronto

[7].D Ramasamy,Zamri, M S Mahendran, S Vijayan "Design Optimization Of Air Intake System"Proceedings of the International multi conference of Engineers and computer scientists 2010 Vol 2. IMECS 2010, March 17 19 2010, Hong kong

[8].Ravinder Yerram, Nagendra Prasad, Prakash Rao Malathkar, Vasudeo Halbe, Shashidhara Murthy K. (2006). Optimization of Intake System and Filter of an Automobile Using CFD Analysis. Quality Engineering & Software Technologies (QuEST), Bangalore, India.

[9].Semin, Abdul Rahim Ismail, Rosli Abu Bakar and Ismail Ali. (2008). Steady-State and Transient Simulation of Gas Flown Temperature of Intake Port Engine. University Malaysia Pahang, Kuantan, Malaysia

