Automatic Air Filter Cleaning for Commercial Vehicles Using Exhaust Gas Suction

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Abstract: Since the automotive industry came into existence there has been a large amount of technology development. Due to these developments automotive industry has been able to produce products at low operational cost and it is also a benefit to the customer since they are getting the products at right price. But now sometimes there is a need to modify the existing technology rather than creating new ones because they involve a lot of research and development plus more finances. Air filters are an important part of the air intake system since it removes dust, mould, pollen and other impurities from the air. It sometimes has the ability to removes particles in range of microns. The concept of automatic air filter cleaning is to increase the life of the air filter and generate cost saving from the customer point. While in case of using exhaust gas for suction effect certain changes are to be made in the exhaust system routing so that a connection can be made to vacuator valve and the suction effect can be created.

IndexTerms **-** Cubic flow per metre (CFM), MERV Rating, HEPA Class, Suction Pressure;

I. INTRODUCTION

In case of an air filter the life span is decided on the basis of the number of kilometers they travel or in some cases like a heavy commercial tipper truck it may be on the hours of operation. But the question which arises parallel to the above-mentioned statement is "when should we change the air filter?" The answer to the question is when the air filter reaches a restriction or pressure drop a turbocharger cannot sustain to work efficiently. In this case the filter gets completely choked up due to the dust and the engine does not get enough amount of air to complete the combustion. This situation generates negative effect on the engine performance such as air starvation, reduction in fuel economy, carbon deposits on the cylinder surface, low transient response and damage to engine parts such as pipes, valves and the exhaust system. The intention is to create a system or a mechanism which will get activated once the filter is chocked. It will be something to clean the air filter automatically once the filter is choked and the service indicator glows up. Thus, with the help of this project the life of the air filter increases and at the same time cost saving from the side of the customer takes place. The main important factor to be kept in mind while creating the mechanism has to be that it should not damage the air filter. The air filter contains a folded paper element media pleats which will easily get damaged once an external force is applied on the surface.

II. AIR INTAKE SYSTEM

The main purpose of air intake system is to make sure that it removes all moisture, dust and chaff from the air before it reaches the engine cylinder. If dust enters the air intake system and somehow if it manages to reach the engine cylinder then rapid wear of the cylinder and piston ring occurs which will directly affect the engine performance and reduce the overall efficiency [5].

And also if the required amount of air is not given to the engine cylinders then there incomplete combustion will take place and due to these problems such as carbon deposit on the valves, rings and piston which will cause engine wear and oil consumption problem.

2.1 Assembly:

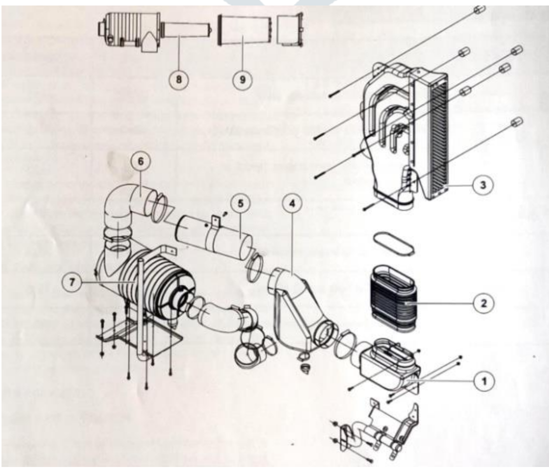

Fig 1 Assembly of an Air Intake System

The air intake system mainly consists of the following parts:
1.Snorkel Lower Half, 2. Bellow Assembly, 3. Snorkel Assembly, 4. Assembly duct – Air cleaner to pre cleaner, 5. Pipe Duct to Hose, 6. Hose Air Filter to Pre-Cleaner, 7. Air Filter Assembly, 8. Safety Element, 9. Primary Element

2.2 Air filter assembly:

The air filter mainly consists of two parts. The primary filter and the secondary filter [1].

Fig 2 Air filter assembly

The outer or primary filter element is made to take out impurities on the air flow coming into the absorption process, the inner or secondary filter act as or represent an optionally available filtration during servicing of the main filter, generally it fits inside the outer element as shown in the above figure. It protects even if the main filter is damaged or replaced.

2.3 MERV Rating & HEPA Class:

The efficiency or effectiveness of the air filter is rated on the basis of MERV (Minimum efficiency reporting value) which is generally known as MERV rating. It was designed and brought into implementation by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). The purpose of this rating is to give an idea regarding the consistent improvements which are made in improving the precision and accuracy of the air filter ratings. The MERV ratings are available from the range of 1 – 20, in which air filters with rating 1 are the least efficient and those with 20 are the highly efficient ones. The MERV ratings with respect to particle size can be explained as follows [2].

MERV Rating	Minimum Particle Size
1-4	>10.0 µm
5-8	10.0 - 3.0 µm
9-12	3.0 – 1.0 µm
13-16	1.0 – 0.3 µm

Table 1 MERV Rating

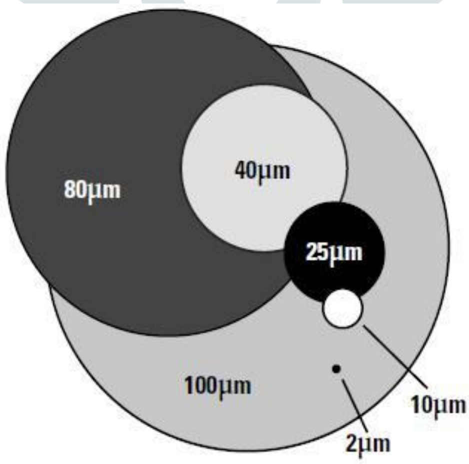

Fig 3 Micron Size Comparison

Even though the filters mentioned in the above rating are not able to clean the particle size which are of the lowest value, they should be able to clean the particles of the largest value in order to maintain the position in that particular MERV rating. In case of commercial vehicles filters with MERV rating of 17 – 20 are used because of the higher dust removing capacity of the particles of smallest size.

The other name which is used for high efficiency air filters which can remove dust up to the range of 0.3 µm is High Efficiency Particulate Arrestance (HEPA). In order to qualify as HEPA a filter must be able to clean 99.97% of dust particles which are in the range of 0.3 µm [3]. The norms are finalised by the United States Department of Energy. The efficiency of a particular class of air filter can be shown with the help of the following table.

Table 2.1 HEPA Class chart

HEPA Class	Total Retention
E10	>85%
E11	>95%
E12	>99.5%
H13	>99.95%
H14	>99.995%
U15	>99.9995%
U16	>99.99995%
U17	>99.99999%

Filters which can be seen in the HEPA class of E12 and H13 can be seen in commercial vehicles.

2.4 Air filter cleaning using Exhaust Gas Suction:

The idea was conceived after going completely through the work of a vacuum cleaner. The purpose of the vacuum cleaner is to clean the dust from the surface of the floors with the help of vacuum. The dust particles which are situated on the floors are heavier in size compared to the dust particles which are placed on the surface or interior of the air filter. The vacuum cleaner performance depends upon the following factors.

1. Air speed – The speed at which the air enters the system. It can be measured either in metres per second (m/s) or miles per hour (mph).
2. Airflow rate – It can be measured in Cubic Feet per metre (CFM).
3. Weight – The quantity of dust and the capacity with which it can perform.

It all basically depends upon the suction power of the system. The unit in which the efficiency of an instrument or machinery which generates vacuum is called Airwatt. It depends upon the amount of airflow generated with reference to the power used by the system. The suction can be defined as the maximum pressure difference which can be created. In general case a household model of vacuum cleaner can generate a suction of about 20 kPa in negative. More suction rating means that the cleaner is more powerful. Since higher dust particles on floor require 20 kPa, the particles in air which are placed on the filter require less pressure.

Now since a vacuum effect had to be created on the air filter a place where it can be implemented had to be found. After many areas and consideration it was decided that the suction will be made through the vacuator valve. The reason behind the selection of vacuator valve is,

1. That there is no need to create an extra portal in order to create the suction.
2. Maximum amount of dust in an air filter will be near the vacuator valve only because the air filter dust is discarded from that particular portion only.
3. The vacuator valve has an optimum diameter of 51.25 mm which is neither too much small nor large for suction to take place.

The suction needs the dislodge the dust from the extreme corner of the air filter without damaging it. The suction can be created by rerouting the exhaust pipes. The exhaust pipe has a standard diameter of 101.59 mm. The idea is to connect the vacuator valve by extending it to the exhaust pipe. Before applying this concept in actual, a stimulation was created with the help of ANSYS. The following considerations were made in the stimulation

- The diameter of the exhaust pipe was taken as 101.59 mm.
- The diameter of the vacuator valve was taken as 51.25 mm.
- The airflow rate in the exhaust system was taken as 550 CFM.

Three angles were taken at which the vacuator valve was connected with the system. The angles are

1. 30º,
2. 60º
3. 90º.

2.5 ANSYS Analysis:

The analysis was done at three different angles and the results are as follows:

1. At 30º

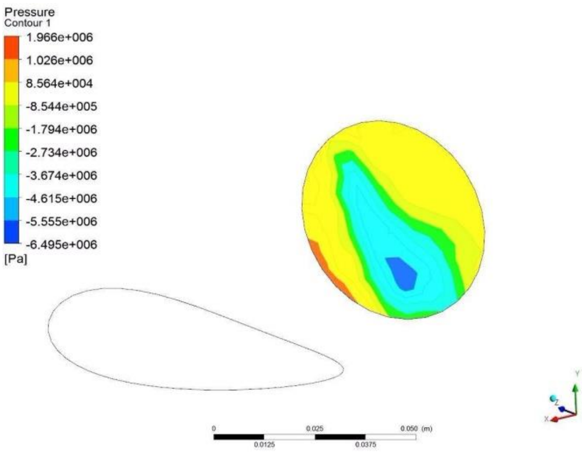

Fig 4 Suction effect at 30º

The results obtained at 30º can be written as follows:
Force which is generated towards the inner side of the air filter = 1.966e + 006 = 1.966 ×10^6 Pa
Suction effect created near vacuator valve towards the direction of exhaust = -6.495e + 006 = 6.495×10^6 Pa

2. At 60º

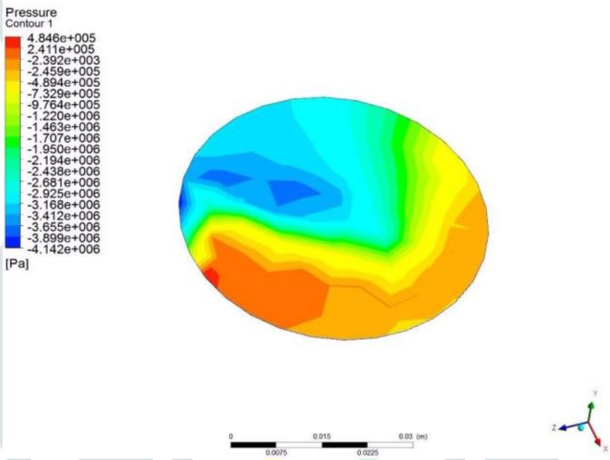

Fig 5 Suction effect at 60º

The results obtained at 60º can be written as follows:
Force which is generated towards the inner side of the air filter = 4.846e + 005 = 4.846 ×10^5 Pa
Suction effect created near vacuator valve towards the direction of exhaust -4.142e + 006 = 4.142×10^6 Pa

3. At 90º

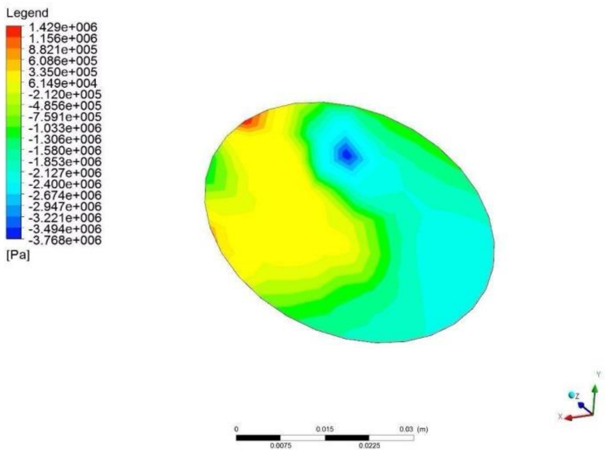

Fig 6 Suction effect at 90º

The results obtained at 90º can be written as follows:
Force which is generated towards the inner side of the air filter= 1.429e + 006 = 1.429×10^6 Pa
Suction effect created near vacuator valve towards the direction of exhaust = -3.768e + 006 = 3.768×10^6 Pa

The suction and inlet pressure in all the above cases can be shown as follows:

Table 2.2 Suction Pressure at different angles

Angle	Suction Pressure	Inlet Pressure
30º	6.495 ×10^6 Pa	1.966×10^6 Pa
60º	4.142 ×10^6 Pa	4.846×10^5 Pa
90º	3.768 ×10^6 Pa	1.429×10^6 Pa

III. CONCLUSION

Here, it can seen that the maximum suction pressure is generated at 30º of 6.495 ×10^6 Pa. Since the area near the vacuator valve contains good concentration of dust particles, this mechanism will be able to remove atleast 500 – 600 gms of dust particles improving the life span of an air filter by almost 6000 kms.

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