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Effect Of OEM Style And Aftermarket Performance Air Filters On Vehicle Parameters.

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Abstract

The importance of the engine air induction system has recently increased because of governmental engine exhaust particulate and evaporative emission regulations. This has created a renewed interest in optimizing the existing parameters of the air induction mechanism like the air filter, filter box, piping etc for better performance. Air filter provided on the engine intake is subjected to increased levels of abuse due to the diverse driving conditions. The OEM air filter in modern vehicles is usually a paper type air filter. Due to the increased presence of counterfeit air filter in the market, there is a possibility that filter may be of poorer quality resulting in get premature clogging. The presence of increased number of aftermarket performance filters has prompted automotive enthusiasts to replace their OEM filters with these performance filters for better performance. This study addresses the issue of whether OEM air filter replacement with aftermarket air filter (oiled media filter from K&N) improves fuel economy. The increasing air filter pressure drop in diesel-engine-powered vehicles due to clogging was measured, with primary focus on changes in vehicle fuel economy but also including acceleration and engine temperature. The performance of both types of filters in new and clogged condition in terms of pressure drop, air discharge and filtering efficiency are also studied.

Keywords: air induction system; air filter; OEM and Aftermarket airfilter; pressure drop ; fuel economy; acceleration; filtering efficiency.

1. Introduction.

The stringent engine exhaust particulate and evaporative emission regulations imposed by various governments around the world have prompted the automobile manufacturers to conduct extensive research in to vehicle air induction systems. Major progress in engine air filtration in recent years has been made by introducing inline; flow-

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through fluted and pleated filters, and nanofiber filter media. The fluted and pleated in-line, reduced-volume filters provide high filtration performance while occupying less space. In these designs, almost the entire volume of the filter housing accommodates the filter media. The engine air filter market is driven by the performance requirements for engine air induction systems such as; low flow restriction, high dust-holding capacity long life or service-free designs, high gravimetric and fractional efficiency, small, compact components, integrated air intake & silencing system, permanent air intake systems with zero evaporative emissions, exclusive designs, volumetrically efficient filters to fit into available space. According to Schilling [11], 30% of contaminants penetrating the air induction system and entering the engine passes out the exhaust. Engine operation, lifetime, engine emissions, and fuel consumption depend on the air induction system design and its performance. One of the most overlooked and least serviced components in vehicle is the engine air filter. One of the possible reasons for this is the increased service life of air filters as they are replaced at every 40,000-50,000kms. It is critical to clean the engine air filter of removable debris lodged in the filter at every oil service to ensure that it completes its service life. Past studies have indicated that replacing a clogged or dirty air filter may significantly improve vehicle fuel economy, but these studies examined only gasoline vehicles using carburettors and the open loop control typical of the 1970s [3,4,5]. General trends in automobile maintenance records will show that people tend to service vehicle components which will affect the performance (fuel economy etc) of the vehicle in time and neglect those which are not thought as affecting it. In the study we determine the effect of air filter condition on the performance of the vehicle. The study conducted by Jaroszczyk, Wake, and Connor [3] reported in 1993 that proper filtration systems make engines more fuel efficient; however, they gave no data or reference information to support this claim. The OECD claimed in a 1981 report [4] based on earlier research by the Thornton Research Centre that "excessive pressure across a dirty air filter" can cause a 1–15% increase in fuel consumption. In the Thornton study, six 1970–73 model year vehicles were tested using the Economic Commission for Europe hot-start driving cycle (ECE 15) to explore the fuel economy variation due to "deliberate malfunctions," defined as maintenance problems such as damaged spark plugs, poor idle mixture, improper idle speed, and "restricted air filters." Of the six vehicles, only five were tested with restricted air filters, accomplished by "masking the cross-sectional area of the air cleaner element." No further description of how the amount of restriction was quantified was given, but the vehicles showed a variable response to the testing. Two of the vehicles showed less than a 1% decrease in fuel economy, two others showed 11% and 15% decreases in fuel economy, and the fifth vehicle showed a decrease in fuel economy of more than 30% due to the restricted air cleaner. The Thornton researchers believed that the large change was due to the style of carburettor used in this 1971 Vauxhall Viva, which used a fixed-jet atmospherically vented carburettor, which is very sensitive to a throttled air intake. The wide variability in the effect of restricted air intake from a simulated clogged air filter was attributed to the different styles of carburettors, which varied among the tested vehicles.

The results of the Thornton Research Centre tests [5] are of limited use to consumers today because the vehicle engine technology has evolved significantly since those tests were conducted. As of the early 1980s, some form of closed-loop fuel control had been implemented on most light-duty vehicles to enable them to meet the emissions standards. Recent work done by John Thomas, Brian West and Shean Huff [2] has shown that modern gasoline engines with closed loop feedback systems are not sensitive to the state of the air filter, given that the engine power is controlled by throttling the intake air. Because of this control approach, any additional throttling from a clogged air filter is offset by further opening the throttle (to achieve the same desired manifold pressure); however, maximum engine power and acceleration is affected by the intake air restriction imposed by a clogged filter. The vehicles were tested on the chassis dynamometer for the study [2].

The study conducted by Golebiewski [12] on Fiat multi jet engine showed that engine adaptability under varying loads were better no filter conditions compared to when new filter was installed. It was also found that increased air filter clogging correspondingly increased the air flow resistance and in turn decreased the flexibility to varying loads and fuel economy of the engine, and best to replace the filter frequently according to manufacturer's recommendations.

The study conducted by John Thomas, Brian West and Shean Huff [1] in 2013 on diesel vehicles shows that the effect of air filter condition on fuel economy was small and was less than the sensitivity of standard dynamometer vehicle testing. The study also showed a reduction in performance and acceleration of the engine under clogging of air filter. Both the studies on diesel [1] and gasoline [2] vehicles show decreased power and acceleration of the engine when filter was clogged. In real life the decreased performance of the engine due to a clogged filter will result in lower fuel economy due to the driver depressing the accelerator pedal more to compensate for the decreased performance.

For automotive enthusiasts looking to increase the performance of their vehicles, one of the first modifications done on the vehicle is the replacing of stock air filter with an aftermarket performance filter. There are a wide variety of aftermarket performance filters to choose from. They vary in their brand name, filter area, filter medium, price, service life and method of install. Almost all of the aftermarket performance filters promise an increase in performance, fuel economy and increased service life compared to OEM style filters. But most of the claims made by the companies are not backed up by solid experimental proof. Hence the effect of aftermarket performance filter on vehicle performance is also brought under the field of study.

2. Experimental Study.

The methodology and experimental procedure used in the present study are explained in this section.

2.1 Air Service Filter Indicator Test.

The air filter indicator provided on the air filter box was first tested to identify the pressure drop required to set the air service filter indicator. This was done by using a vacuum cleaner to generate adequate vacuum and a u-tube manometer to determine the pressure drop created.

2.2 Pressure Drop Test.

The pressure drop test was conducted on the vehicle engine to determine the pressure drop created by the air filter element along the RPM range of the engine. The test was conducted by installing the required the filter in the filter box and measuring the pressure drop created by filter element across the engine rpm range by means of a manometer. One end on the manometer is connected to the hole provided for air filter service indicator on filter box. And other end was open to atmosphere. The readings were taken for new OEM Filter and K&N filter; clogged OEM and K&N filter and no filter conditions. To replicate filter clogging in a similar manner kitchen tissue paper rolls were wound on the outer surface of the cylindrical air filter. The number of tissue papers used was ten which caused a partial service indication the OEM type air filter. This type of clogging was used to consistently replicate and simulate the clogging event over the entire study of filters.

2.3 Air Discharge Test.

Air discharge test was conducted to measure the resistance offered by the given air filter element to the air flow. The test was conducted utilizing a commercially available household blower to generate the air stream. The discharge was measured using Pitot tube in pipe arrangement and u-tube manometer.

2.4 Load Test.

The load test was conducted on a stationary engine under various air filter conditions to determine the effect of air filter condition on the various performance parameters of the engine. The load test was conducted for no filter; new OEM and K&N filter; clogged OEM and K&N filter. The variation in brake thermal efficiency and mechanical efficiency for various air filter conditions over the load range was studied.

Table 1. Kirloskar Diesel Engine Specifications.

ENGINE	KIRLOSKAR DIESEL
POWER	5 BHP@1500RPM
MAX LOAD	14.5 kgf
BORE/STROKE	80mm/110mm
BRAKEDRUM DIA	330mm

2.5 Fuel Economy Test.

The fuel economy test was conducted on a vehicle subjected to a specified driving cycle to determine the effect of different air filter conditions on the mileage of the vehicle. The fuel economy test was conducted on a 2003 model TATA SUMO. Procedures for the fuel economy tests were based on SAE Standard J1082, "Fuel Economy Measurement Road Test Procedure."[9]

The fuel economy tests were conducted on a nearly 14 km circuit which include both urban (9.7km) and highway roads (4.2km). During the test runs vehicle weight was kept constant, the windows were wound up , the air conditioning was turned off, the blower was turned on to second speed, the headlight was turned on to low beam, all other switchable electrical equipment was turned off and between each run the tyre pressure was also monitored. During each run the odometer readings and time required to complete each run was noted and the vehicle speed was attempted to maintain at 60kmph as far as possible. A total of four different mileage runs were made for a single type of air filter condition. Of the four mileage runs two runs were completed in the opposite direction to counter the gradient effects.

2.6 Acceleration Test.

The acceleration test was conducted on a vehicle subjected to a specified driving cycle to determine the effect of different air filter conditions on the acceleration of the vehicle. Procedures for the acceleration tests were based on the Society of Automotive Engineers (SAE) Recommended Practice J1491, "Vehicle Acceleration Measurement"[10]. The acceleration test was conducted on a 2003 model TATA SUMO. During the test runs vehicle weight was kept constant, the windows were wound up , the air conditioning was turned off, the blower was turned on to second speed, all other switchable electrical equipment was turned off and between each run the tyre pressure was also monitored. For the acceleration test the measurement taken is the time elapsed for increasing the speed from 30 to 50 kmph under WOT conditions with vehicle in 3rd gear. Six runs were made for each measurement until three in each direction were completed.

2.7 Engine Exhaust Temperature Measurement.

The engine exhaust temperature was monitored to determine the effect of air filter condition on the temperature of the exhaust gases coming from the end of the exhaust pipe. The temperature measurement was done using the LM35DZ Temperature sensor.

2.8 Filtering Efficiency Test.

Filtering efficiency test measures the overall ability of the air filter to capture dust. The air filter was reduced to smaller (80x80mm) elements for testing. To replicate dust cement used (2μm to 90μm) whereas the average pore size of paper filter is taken to be25μm. The filter element and cement dust were weighed on scale accurate to 10mg capable of measuring maximum 300g. The required pre-weighed air filter element was mounted on the suction side of the air blower with the help of a zip tie. Next a weighed quantity of cement dust [about 1g] was introduced slowly on the suction side of the blower. The filter element was weighed again to obtain the amount of dust accumulated on the filter element.

3. Results and Discussions.

3.1 Air Service Filter Indicator Test.

The service indicator shows full service indication at around 6.51kPa, which lies in the prescribed range for service indication by the indicator. The partial pressure service indication was found to determine the amount of tissue paper required to generate the clogging event on the air filter.

3.2 *Pressure Drop Test.*

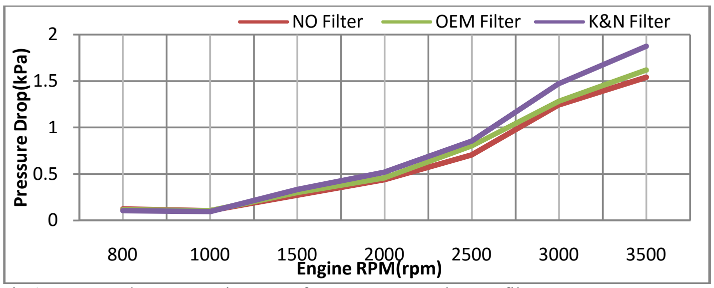

Fig 1. Pressure drop vs. Engine RPM for New OEM and K&N filter.

From the Fig 1 we see that at lower engine rpm both K&N and OEM filter show similar pressure drop. As the rpm increases the deviation in pressure created by both the filters also increases, with K&N showing higher pressure drop compared to the OEM filter. The increasing pressure drop seen in no filter condition as engine rpm increases is due to the resistance created by the air filter box and piping towards air flow.

From Fig 2 below we see that the pressure drop created by K&N filter was found to be significantly increasing compared to that of the OEM filter. At about 3500rpm we see that K&N filter was showing full service indication compared to that of OEM filter which was showing only partial service condition. The results obtained from the Fig. 1.&2.are contradictory to the claims put forth by the K&N filter that it offers lower resistance to air flow compared to OEM filter. Since the pressure tapping for the U-tube manometer was taken at the bend of the air filter box outlet, there is a possibility of turbulence affecting the pressure drop readings.

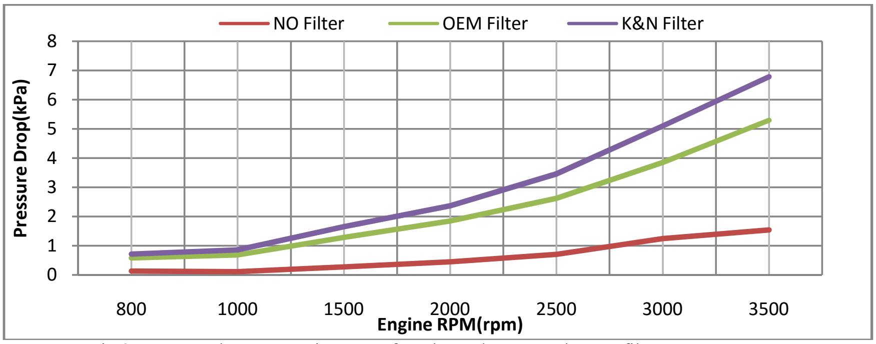

Fig 2. Pressure drop vs. Engine RPM for Clogged OEM and K&N filter.

3.3 Air Discharge Test.

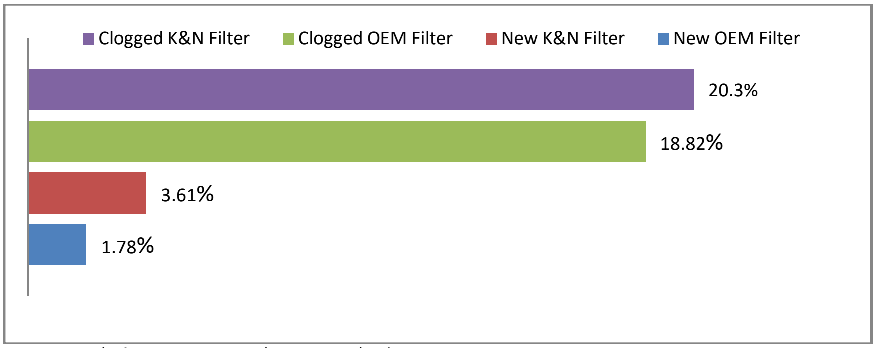

Fig 3. Percentage Resistance to Air Flow.

Fig 3 shows that K&N filter exhibits higher resistance to air flow compared to OEM filter in both new and clogged condition. Here the air flow resistance offered by air filter box in no filter condition is taken as the reference, the resistance offered by remaining filter conditions are calculated with respect to that of no filter condition.

3.4 Load Test.

From fig 4 shown below we see that the difference in brake thermal efficiency (BTE) is more or less negligible at lower loads for various air filter conditions, but deviates significantly at higher loads. The BTE was found to be the highest for no filter condition followed by new K&N, new OEM, clogged K&N and Clogged OEM in the decreasing order over the load range.

From fig 5 shown below the difference in mechanical efficiency between the new OEM & K&N and clogged OEM &K&N filters were negligible. The mechanical efficiency was found to be the highest for no filter condition followed by the new and clogged filter conditions respectively.

While the differences in efficiencies between the various air filter conditions were found to be of little practical significance, it must be taken in to notice the fact that the tests were conducted on the engine at 1500rpm where the air requirement is much smaller compared to that of a vehicle engine which operates at over a wide range of rpm. Hence it can be seen be seen that as far as a vehicle engine is concerned the differences in efficiencies between the various air filter conditions will increase with increasing engine rpm.

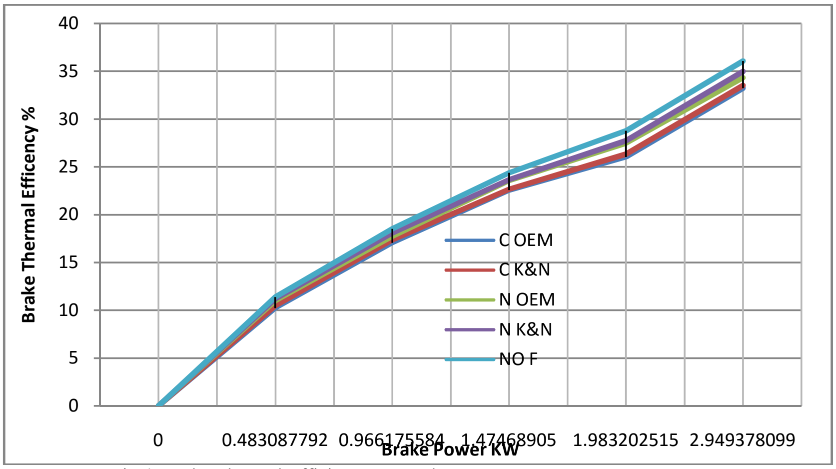

Fig 4. Brake Thermal Efficiency vs. Brake Power.

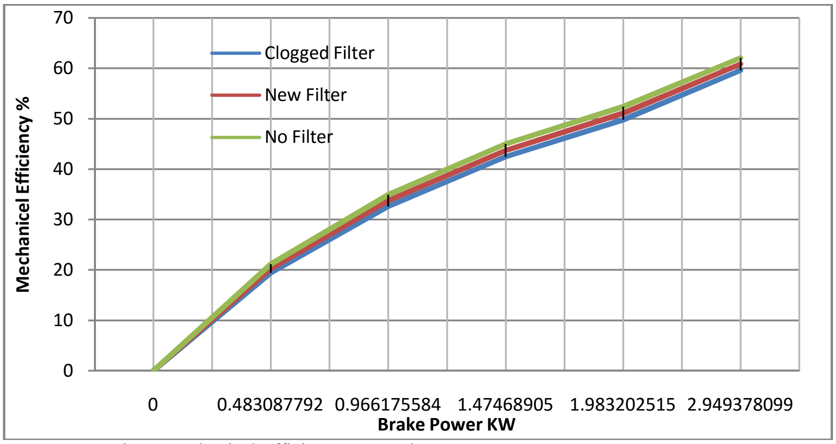

Fig 5. Mechanical Efficiency vs. Brake Power.

3.5 Fuel Economy Test.

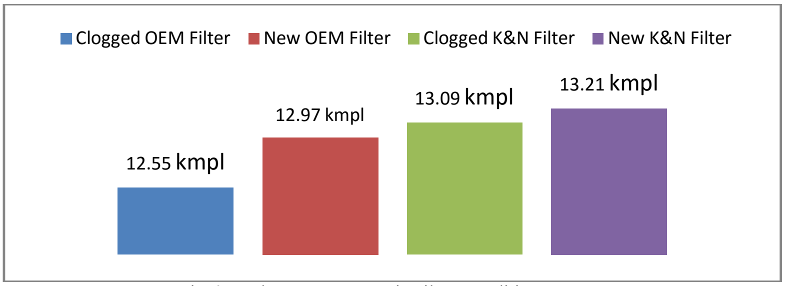

Fig 6. Fuel economy vs. Air Filter Condition.

From fig 6 we see that the K&N filter was performing better compared to OEM filter in terms of fuel economy. The fuel economy of the engine equipped with K&N filter was found to vary only slightly at new and clogged filter conditions. Whereas when equipped with OEM filter the fuel economy of the engine dropped by about 0.5kmpl when compared between new and clogged filter conditions. It was also observed that there was an slight increase in vibration from the engine which can be felt at the accelerator pedal when driving the vehicle installed with a K&N filter. This indirectly made the vehicle less comfortable drive for long distances.

3.6 Acceleration Test.

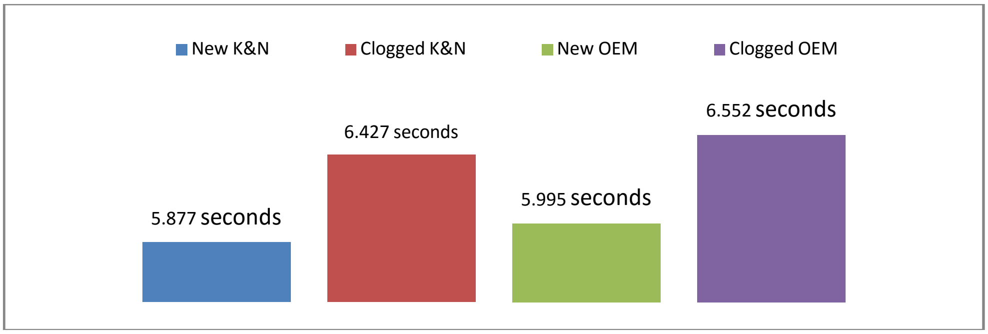

Fig 7. Acceleration Time vs. Air Filter Condition.

From the fig 7 shown below we can see that the difference in time for acceleration between the various air filter conditions is very small. The acceleration time was found to be the least for new K&N filter followed by the new OEM, clogged K&N and clogged OEM filter respectively.

3.7 Engine Exhaust Temperature Measurement.

Table 2. Engine Exhaust Temperatures

Air Filter Condition	Ambient Air Temperature(^{0}C)	Exhaust Temperature(^{0}C)
New OEM	30.3	72.3
New K&N	29.7	70.5
Clogged OEM	30.4	71.6
Clogged K&N	31.6	70.2

3.8 Filtering Efficiency Test.

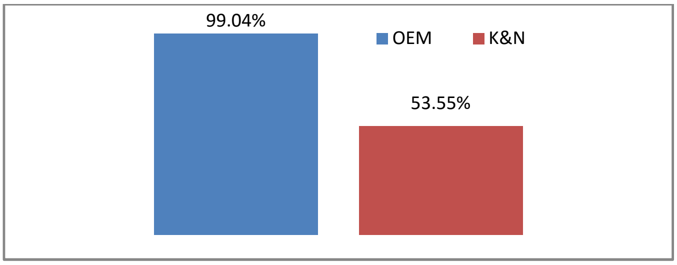

Fig 8. OEM and K&N Filtering Efficiency.

Fig 8 shows that the filtering efficiency of the OEM filter was superior to that of the K&N filter. The decreased filtering efficiency of the K&N filter can be attributed to the increased pore size of the cotton gauze medium used in the filter. The actual filtering efficiency of the K&N filter will be higher in real life scenario due to the increased surface area exposed to the air stream.

4. Conclusions.

As automotive enthusiasts, we are always looking for ways to increase the power output of our motors. One of the first steps taken to achieve the same is by switching the stock air filter with an aftermarket performance air filter.

Many aftermarket companies now manufacture and offer high performance air filters. Almost all claim a power gain through increased airflow and some claim better filtration as well. Some of the major companies manufacturing after market performance air filter are K&N, Pipercross, Green Cotton, Powertec, ITG etc. In the concerned project we evaluate the effect of OEM style paper filter and aftermarket performance filter on vehicle parameters. The expected results are that the K&N filter will provide better breathing capacity to the engine compared to the paper filter as per the company claim. The better breathing capacity over the entire life of the filter ensures better throttle response and increased acceleration etc. The pressure drop test and air discharge test conducted as part of the project provides evidence contrary to the company's claim.

The pressured drop test conducted shows that in the new filter condition, K&N shows slightly higher pressure drop compared to the paper filter. Whereas in the clogged condition K&N shows very high pressure drop at higher rpms compared to paper filter. Similar results were also obtained for the air discharge test wherein new and clogged K&N and paper filter showed nearly similar restriction to air flow, with K&N filter showing slightly higher restriction.

The acceleration and fuel economy tests conducted on the vehicle shows that the vehicle performance will be slightly better when the filter is new compared to that when it is clogged. The fuel economy tests shows that K&N air filter provides a better fuel economy compared to OEM style paper filter in both new and clogged condition. The acceleration tests also shows that acceleration times for K&N was slightly lower than OEM style paper filter in both new and clogged condition. The exhaust temperature readings show that effect of air filter condition on exhaust gas temperature is negligible under the subjected test conditions. The filtering efficiency test conducted on OEM and K&N air filter shows that OEM air filter exhibits superior air filtering qualities compared to K&N filter. It should also be noted that the actual filtering efficiency of K&N air filter will be greater than obtained from the test. This was because in real life condition the actual air filter surface area exposed to dust is higher compared to that exposed during the test.

Though the K&N air filter was found to render slightly better performance compared to OEM style paper air filter, the very high cost of K&N air filter (Rs6500/-) compared to that of the OEM air filter(Rs200/-) is a deterrent. From the tests we also see that clogged filter degrades the performance of the vehicle noticeably. But from a practical point of view the effect in degradation of performance was found to be negligible.

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